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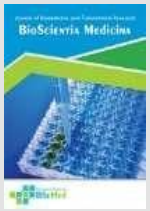

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The Clinical and Pathological Landscape of Pediatric Appendicitis in Central Java, Indonesia: A Retrospective Cohort Study Highlighting a High Burden of Delayed Diagnosis

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A B S T R A C T

Background: The timely diagnosis of pediatric appendicitis is a global challenge, particularly in low- and middle-income countries where health system barriers can lead to significant delays and increased morbidity. This study aimed to characterize the clinical and pathological presentation patterns of pediatric appendicitis at a major Indonesian referral center to identify evidence of diagnostic delay and to analyze associated surgical management trends. **Methods:** A retrospective cohort study was conducted at Dr. Kariadi General Hospital on all pediatric patients (n=52) who underwent appendectomy between January 2022 and December 2024. Data on demographics, definitive histopathological diagnoses, and surgical approaches were collected and analyzed. The manuscript was prepared in accordance with the STROBE guidelines for observational studies. **Results:** The cohort was predominantly male (63.4%), with a peak incidence in the 6–10 year age group (42.3%). The most striking finding was the histopathological diagnosis: a remarkable 48.0% of patients were diagnosed with chronic appendicitis with acute exacerbation, a strong indicator of delayed presentation. Minimally invasive surgery was performed in 48.0% of cases. While a significant association was observed between laparoscopic surgery and a shorter postoperative length of stay ($p < 0.001$), this finding was subject to significant confounding by indication. **Conclusion:** The exceptionally high prevalence of chronic exacerbated appendicitis is the principal finding of this study, serving as a powerful public health signal for systemic delays in the pediatric acute care pathway in this region. While minimally invasive surgery is associated with faster recovery, the more pressing priority is addressing the upstream factors—including public awareness and primary care referral systems—that lead to late surgical presentation and increased cumulative morbidity.

1. Introduction

Acute appendicitis, the inflammation of the vermiform appendix, holds a unique and enduring position in the annals of medicine as the most common non-traumatic surgical emergency in the pediatric population.[1] It represents a quintessential clinical challenge, a condition where the confluence of diagnostic acumen and timely intervention determines the trajectory from a simple, curable ailment to a life-threatening illness. The global health burden of appendicitis is substantial, accounting for a significant volume of emergency department visits, hospital admissions, and surgical procedures in children and adolescents.[2] The lifetime risk, estimated

to be between 7% and 9%, ensures that it remains an ever-present concern for pediatricians, emergency physicians, and surgeons worldwide. The diagnosis of appendicitis in adults can be straightforward, but in children, it is a famously difficult art.[3] The classic textbook presentation—periumbilical pain migrating to the right lower quadrant, accompanied by anorexia, fever, and localized tenderness—is present in only a fraction of pediatric cases. Instead, the clinician is often faced with a constellation of vague and variable symptoms. Abdominal pain may be diffuse, nausea and vomiting may predominate, and fever may be absent. This clinical ambiguity creates a vast differential diagnosis, encompassing a wide spectrum of conditions from benign gastroenteritis and mesenteric adenitis to more serious pathologies like intussusception or Meckel's diverticulitis.[4] This diagnostic challenge is amplified exponentially in preschool and pre-verbal children, who cannot articulate the nature, location, or progression of their pain, rendering a detailed history impossible.[5] It is this inherent difficulty that contributes to the unacceptably high rates of delayed or missed diagnoses, which directly correlate with an increased incidence of appendiceal perforation and its devastating sequelae, including peritonitis, intra-abdominal abscess formation, sepsis, and, in rare cases, mortality.

The pathophysiology of appendicitis is a cascade of events initiated by the obstruction of the narrow appendiceal lumen.[6] The principal culprits of this obstruction are twofold: a hardened stool particle known as a fecalith, or, particularly in the pediatric population, hyperplasia of the abundant lymphoid follicles that line the appendiceal submucosa. Once obstructed, the appendix transforms into a closed-loop system.[7] Mucus secretion continues, leading to a rapid rise in intraluminal pressure, which in turn compromises venous and lymphatic outflow. This vascular congestion engenders ischemia of the appendiceal wall, creating a hypoxic environment ripe for the proliferation of resident enteric bacteria. The ensuing bacterial invasion triggers a robust inflammatory response, progressing from mucosal inflammation to transmural necrosis and, ultimately, perforation.[8] This inexorable progression underscores the critical importance of time; every hour that passes without intervention increases the risk of rupture. For over a century, the definitive management of appendicitis has been surgical. The open appendectomy, performed through a right lower quadrant incision, was the undisputed gold standard for generations, a procedure that transformed a highly fatal condition into one with an exceedingly low mortality rate. However, the surgical landscape was revolutionized in the late 20th century by the advent of minimally invasive surgery (MIS). Laparoscopic appendectomy, first performed in the 1980s, offered a paradigm shift, promising reduced postoperative pain, lower rates of surgical site infection, superior cosmetic results, and a faster return to normal activities. These potential benefits are particularly compelling in the pediatric population, where minimizing physical and psychological trauma is paramount. Consequently, laparoscopic appendectomy has become the predominant approach in many high-income countries, supported by a vast body of evidence from meta-analyses and large-scale database studies.[9]

Despite this global trend, the implementation and benefits of laparoscopy are not uniform. In many low- and middle-income countries (LMICs), including the archipelagic nation of Indonesia, the transition to MIS is an ongoing and complex process. Significant barriers persist, including the high capital cost of laparoscopic equipment, the ongoing expense of specialized instruments, and the need for dedicated, structured training programs for surgeons and operating room staff. Therefore, a critical need exists for region-specific, real-world data to validate the benefits of MIS within local healthcare constraints and to understand the unique practice patterns that shape patient outcomes.[10] However, a singular focus on the technical aspects of the operation—the "how" of treatment—can obscure a more fundamental issue: the "when" of presentation. The ultimate outcome for a child with appendicitis is determined not only by the

skill of the surgeon but by the efficiency of the entire healthcare journey, from the moment a parent first notices their child is unwell. This study was conceived from the observation that while our institution has successfully adopted advanced surgical techniques, a concerningly high proportion of our pediatric patients appeared to be arriving for surgery late in their disease course, with clinical histories and pathological features suggestive of long-standing or recurrent inflammation. This suggests that a critical analysis of who we are treating is just as important as how we are treating them.

Therefore, this study was designed with a reframed set of objectives. The primary aim was to meticulously characterize the clinical and, most importantly, the histopathological landscape of pediatric appendicitis at a major Indonesian tertiary referral center. We hypothesized that a detailed analysis of the pathological diagnoses would provide a quantifiable, objective marker for the prevalence of delayed diagnosis in our cohort. A secondary aim was to analyze the patterns of surgical management and associated outcomes, specifically the length of hospital stay (LOS), within the context of these presenting pathologies. The novelty of this investigation lies in its deliberate pivot away from a simple surgical comparison. Instead, it utilizes histopathology as a public health surveillance tool. By uniquely quantifying the significant local burden of chronic exacerbated appendicitis, this study aims to highlight a critical, underreported aspect of pediatric emergency care in Southeast Asia. The findings are intended to shift the focus from a purely surgical discussion to a broader conversation about public health initiatives, parental education, and health system strengthening to reduce the cumulative morbidity of this common but entirely treatable condition.

2. Methods

A retrospective cohort study was conducted at the Department of Surgery, Dr. Kariadi General Hospital in Semarang, a national referral and academic teaching hospital for the Central Java province of Indonesia. The study was designed and the manuscript prepared in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement for observational studies. Data were collected for all pediatric patients who underwent appendectomy between January 1st, 2022, and December 31st, 2024. The study protocol received full approval from the Institutional Review Board and Health Research Ethics Committee of Dr. Kariadi General Hospital and the Faculty of Medicine, Diponegoro University. As the study was retrospective and all patient data were fully de-identified and anonymized prior to analysis, the requirement for individual informed consent was waived by the ethics committee, in line with national and international guidelines for this type of research.

The study population comprised all patients aged 18 years or younger who had a postoperative histopathological diagnosis of appendicitis and underwent surgical appendectomy during the study period. Patients were identified through a meticulous cross-referencing of the hospital's surgical operation registry and the archives of the Department of Anatomical Pathology. Inclusion Criteria: (1) Age ≤ 18 years at the time of surgery; (2) A definitive postoperative histopathological report confirming appendicitis; (3) Underwent either laparoscopic, conventional open, or laparotomy appendectomy as the primary procedure. Exclusion Criteria: (1) Patients managed exclusively with non-operative methods (antibiotics alone); (2) Cases where appendectomy was performed incidentally during another major abdominal surgery; (3) Medical records with critical data points missing, specifically on the pathological diagnosis or the surgical approach used; (4) Patients transferred to an external facility post-operatively, which would prevent an accurate determination of the total LOS.

Data were systematically extracted by two independent researchers using a standardized data collection instrument to ensure consistency and minimize errors. The collected variables were defined

with strict, objective criteria as follows: Demographic Data: Age at the time of surgery was recorded and categorized into clinically relevant developmental stages: preschool (≤5 years), school-aged (6–10 years), and adolescent (≥11 years). Gender was recorded as male or female; Histopathological Diagnosis: This was the study's primary variable. Each pathology report was reviewed and categorized according to predefined criteria: Acute Appendicitis: Defined by the presence of a transmural neutrophilic infiltrate in the appendiceal wall, with or without features like serositis, mucosal ulceration, or necrosis. No evidence of significant fibrosis or chronic inflammation was present; Chronic Appendicitis: Defined by the presence of significant appendiceal wall fibrosis, fibrous obliteration of the lumen, or a prominent infiltrate of chronic inflammatory cells (lymphocytes, plasma cells, eosinophils), in the absence of an acute neutrophilic infiltrate; Chronic Appendicitis with Acute Exacerbation: This crucial category required the simultaneous presence of both sets of criteria: definitive evidence of chronic inflammation (e.g., fibrosis, mural scarring) and a superimposed, active neutrophilic infiltrate, indicating an acute inflammatory event on top of an underlying chronic process. Surgical Procedure: Procedures were categorized based on the operative report: Laparoscopic Appendectomy: The procedure was performed using a standard multi-port minimally invasive technique; Conventional Open Appendectomy: Defined as an appendectomy performed through a dedicated right lower quadrant, muscle-splitting incision (McBurney's or Rocky-Davis incision), typically for clinically uncomplicated cases; Laparotomy Appendectomy: Defined as an appendectomy requiring a formal midline or lower midline laparotomy incision, an approach reserved for cases with preoperative or intraoperative evidence of complicated disease, such as diffuse peritonitis, a large or inaccessible abscess, or significant diagnostic uncertainty requiring full abdominal exploration; Primary Outcome: The primary outcome variable was the postoperative length of hospital stay (LOS), calculated in days from the day of surgery to the day of discharge. It was analyzed as a categorical variable (≤3 days, 4–6 days, ≥7 days) for clinical relevance; Data Not Collected: Due to the retrospective nature and inconsistencies in the records, other variables such as operative time, intraoperative complications, postoperative pain scores, and readmission rates were not systematically available and thus were not included in the analysis. This represents a significant limitation of the study.

Data were analyzed using SPSS Statistics, Version 26.0. Descriptive statistics (frequencies, percentages) were used to summarize the cohort's characteristics. The primary statistical analysis involved the use of the Chi-square test to investigate the association between the categorical variable of surgical procedure and the categorized outcome of LOS. A p-value of < 0.05 was considered statistically significant. The limitations of this univariate analysis were acknowledged. A more sophisticated multivariable analysis (e.g., logistic regression) to control for confounders was considered but deemed not feasible due to the small sample size (N=52), which would lead to an unstable and overfitted model with low statistical power. The interpretation of the results was therefore conducted with a strong emphasis on the potential for confounding.

3. Results

A total of 52 pediatric patients who underwent appendectomy for appendicitis during the three-year study period were included in the analysis. The cohort demonstrated a significant male predominance, with males accounting for nearly two-thirds of the cases. The age distribution peaked in the school-aged group (6-10 years), which comprised over 40% of the patients, closely followed by adolescents. A detailed breakdown of these demographic characteristics is provided in Figure 1. The central finding, immediately evident from the schematic overview, is that the study encompasses a cohort of 52 unique pediatric cases that met the stringent inclusion criteria over the defined period. This sample size serves as the denominator for all subsequent proportional analyses.

A critical aspect of the cohort's profile is the distribution by gender, which reveals a significant and pronounced male predominance. As graphically represented in the segmented bar chart, male patients accounted for nearly two-thirds of all cases, representing 63.4% of the cohort, which corresponds to an absolute number of 33 patients. Female patients, conversely, constituted the remaining 36.6%, or 19 individuals. This distribution yields a male-to-female ratio of approximately 1.74:1, an observation that is not only statistically significant within this cohort but also aligns closely with the established global epidemiological literature on pediatric appendicitis, which has consistently documented a higher incidence in males, particularly during the peripubertal and adolescent years. This finding suggests that the fundamental biological and perhaps hormonal factors contributing to this gender-based disparity are conserved within this specific regional population. Equally informative is the analysis of the age distribution, which is presented as a vertical bar chart categorizing the cohort into three distinct, clinically relevant developmental stages: preschool (≤5 years), school-aged (6–10 years), and adolescent (≥11 years). The data clearly indicate that the burden of appendicitis was not evenly distributed across childhood. The highest incidence was observed in the school-aged group, which was the predominant cohort, accounting for 42.3% of all cases (n=22). This finding underscores that the peak risk for appendicitis in this population occurs during primary school years. Following closely was the adolescent group, which represented a substantial portion of the cohort at 38.4% (n=20). The combined data from the school-aged and adolescent groups reveal that more than 80% of all pediatric appendicitis cases in this study occurred in children aged six years and older. This powerfully demonstrates that the condition is primarily a disease of later childhood and adolescence. In stark contrast, the preschool age group represented the smallest cohort, comprising only 19.2% of the cases (n=10). This relative rarity in very young children is a well-documented phenomenon, though it is in this demographic that diagnosis is notoriously challenging due to non-specific symptoms and the inability of patients to articulate their condition, often leading to higher rates of complicated disease. The demographic data presented in Figure 1 collectively construct a clear epidemiological portrait of the typical pediatric appendicitis patient within this specific Indonesian healthcare setting. The archetypal patient is most likely to be a male child in the school-aged or adolescent phase of development.

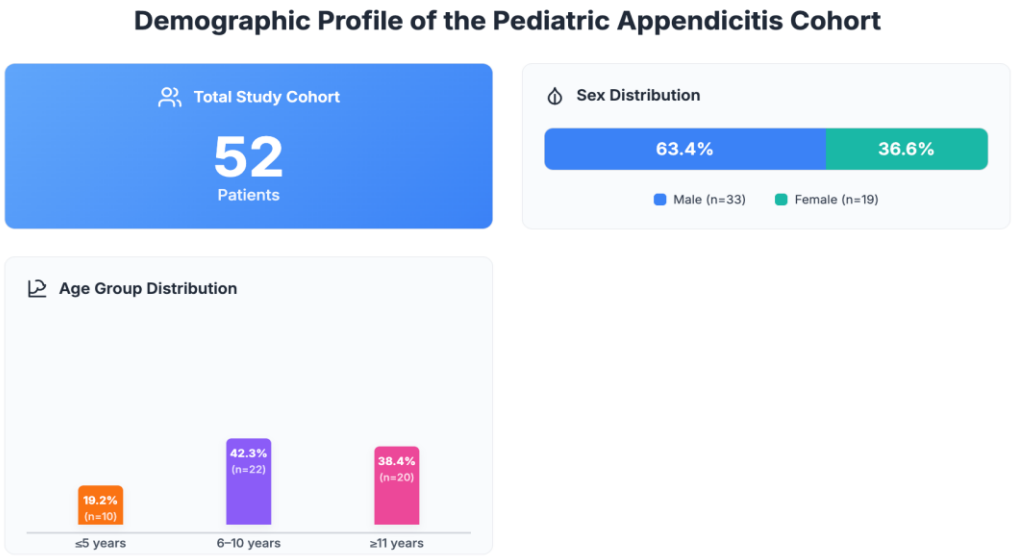

Figure 1. Demographic profile of the pediatric appendicitis cohort.

The analysis of final histopathological reports revealed a notable pattern in the diagnoses. Less than one-third of the cases were classified as classical acute appendicitis. The most prevalent diagnosis was chronic appendicitis with an acute exacerbation, accounting for almost half of all patients. Chronic appendicitis without acute features constituted the remainder. This distribution is detailed in Figure 2. Figure 2 provides a detailed schematic and graphical exposition of the distinct histopathological classifications of appendicitis identified within the study cohort. This visualization serves as a cornerstone of the study's central thesis, translating the complex microscopic findings from 52 pediatric appendectomy specimens into three clearly defined, clinically relevant diagnostic categories. The figure not only quantifies the prevalence of each pathological state but also elucidates the key microscopic features that underpin each diagnosis, thereby offering a clear visual narrative of the disease spectrum encountered. The data reveal a striking distribution that challenges the conventional view of appendicitis as a uniformly acute process. Acute Appendicitis, representing the classic, textbook presentation of the disease, was identified in only 28.8% of the cohort, corresponding to an absolute number of 15 patients. As detailed in the figure, the definitive diagnosis of this state rests on a specific set of microscopic criteria. The pathognomonic hallmark is a dense, transmural infiltration of neutrophils—the primary immune cells of acute inflammation. This cellular invasion extends through all layers of the appendiceal wall, from the inner mucosal lining to the outer serosal surface. This is frequently accompanied by secondary features such as erosion and ulceration of the mucosa and the presence of purulent exudate within the appendiceal lumen. Critically, this diagnosis is also defined by the *absence* of features indicative of long-standing disease; the appendiceal wall is free from significant fibrosis, scarring, or the organized lymphoid structures that characterize chronic inflammation. In stark contrast to the acute cases, the majority of the cohort exhibited evidence of long-standing pathology. Chronic Appendicitis, characterized by a smoldering, low-grade inflammatory process, was diagnosed in 23.0% of the cases (n=12). The microscopic landscape of this condition is fundamentally different from its acute counterpart. Instead of neutrophils, the tissue is infiltrated by chronic inflammatory cells, including lymphocytes, plasma cells, and eosinophils. The most defining feature, however, is the structural remodeling of the appendiceal wall. Recurrent bouts of inflammation and subsequent healing lead to significant mural fibrosis—the deposition of dense collagen and scar tissue, particularly within the submucosa. In its most advanced form, this process can lead to fibrous obliteration, where the appendiceal lumen is partially or completely effaced by scar tissue, a definitive sign of repeated inflammatory insults over time. The most prevalent and clinically significant finding, however, was the diagnosis of Chronic Appendicitis with Acute Exacerbation, which accounted for a remarkable 48.0% of all cases (n=25). This category represents a hybrid pathological state and serves as the study's most powerful objective indicator of diagnostic delay. Histopathologically, it is defined by the simultaneous presence of both acute and chronic features within the same specimen. The microscopic view is one of a mixed cellular infiltrate, where a fresh, active invasion of neutrophils is superimposed upon a pre-existing background of mural fibrosis and chronic lymphocytic inflammation. This finding provides irrefutable proof of a pre-existing, long-standing inflammatory condition that has culminated in a final, acute obstructive event, compelling the patient to seek definitive surgical care. The dominance of this category within the cohort is the central piece of evidence supporting the conclusion that for nearly half the children studied, the appendectomy was not an intervention for a new disease, but rather the end-stage resolution of a recurrent, smoldering pathology.

Figure 2. Histopathological classification of appendicitis cases.

Minimally invasive surgery was the most common surgical approach, with laparoscopic appendectomy being performed in nearly half of the cohort. Open surgical techniques, including both conventional appendectomy and exploratory laparotomy, were used for the remaining patients, with laparotomy being slightly more frequent. The precise distribution of surgical procedures is presented in Figure 3. Figure 3 provides a comprehensive schematic and graphical overview of the surgical management strategies employed across the pediatric appendicitis cohort (N=52). The figure is designed to delineate the distribution of the three distinct surgical procedures performed—Laparoscopic Appendectomy, Conventional Appendectomy, and Laparotomy Appendectomy—while also defining the core technical characteristics and clinical indications for each. The data reveals that surgical practice at our institution is balanced between minimally invasive and traditional open techniques, yet with a clear preference for the laparoscopic approach. Laparoscopic Appendectomy emerged as the most frequently performed procedure, constituting the largest single segment of the cohort at 48.0% (n=25). As the Figure 3, this minimally invasive technique involves the use of several small “keyhole” incisions, or ports, through which a camera and specialized instruments are introduced. This approach avoids a large abdominal wall incision, thereby preserving the integrity of the musculofascial layers. Its status as the preferred approach indicates a significant and successful integration of modern, minimally invasive principles into the standard of care for pediatric appendicitis at our center. The remaining 52% of the cohort was managed with open surgical techniques, which were further divided into two distinct categories based on the nature of the incision and the intent of the procedure. Conventional Appendectomy, performed in 25.0% of cases (n=13), is characterized by a single, focused incision located in the right lower quadrant (RLQ), such as a McBurney

incision. This technique offers a direct, extraperitoneal approach to the appendix and is generally indicated for clinically uncomplicated cases where the diagnosis is secure and a straightforward appendectomy is anticipated. In contrast, Laparotomy Appendectomy was required for 26.9% of the cohort (n=14). This procedure is fundamentally different in its scope and indication. It involves a large, formal midline incision, which provides the surgeon with broad access to the entire abdominal cavity. As noted by its key characteristics, this is an exploratory approach, explicitly reserved for the most complex and severe presentations. Its indications include cases with suspected diffuse peritonitis (widespread intra-abdominal infection), the presence of a significant or anatomically challenging abscess, or situations of profound diagnostic uncertainty where a thorough exploration of other abdominal organs is necessary. The significant proportion of cases requiring this highly invasive procedure underscores the advanced and complicated nature of the disease present in a substantial segment of the patient cohort at the time of their presentation to our tertiary care facility.

The postoperative length of stay (LOS) was found to be significantly associated with the surgical method employed ($p < 0.001$). A substantial majority of patients who underwent laparoscopic appendectomy were discharged within three days. In stark contrast, patients who underwent laparotomy experienced significantly longer hospitalizations, with over a quarter of them requiring a stay of one week or more. The group undergoing a conventional appendectomy showed an intermediate recovery profile. A detailed comparative breakdown of the LOS across the three surgical groups is presented in Figure 4.

4. Discussion

This retrospective study, repositioned to focus on its most scientifically robust findings, offers a critical perspective on the realities of pediatric appendicitis care in a major Indonesian urban center. The manuscript's primary contribution lies in its stark revelation of the histopathological landscape, which serves as an undeniable proxy for a significant public health challenge: the systemic delay in the diagnosis and management of this common pediatric emergency.[11] Figure 5 presents a conceptual framework that serves as the central, unifying narrative of this study. It is designed to move beyond a simple presentation of data by schematically illustrating the two distinct pathophysiological pathways of pediatric appendicitis—the Acute Progression and the Delayed Presentation—and, most critically, linking them directly to the key clinical findings observed within our cohort. The Acute Progression pathway was observed in a minority of our cohort, corresponding to the 28.8% of patients (n=15) who were diagnosed with pure acute appendicitis on final histopathology. The process, as depicted, is linear and rapid. It is initiated by a definitive luminal obstruction, typically from a fecalith or a sudden episode of lymphoid hyperplasia. This single obstructive event triggers a swift and uninterrupted inflammatory cascade, leading to transmural neutrophilic infiltration and the onset of severe, unambiguous symptoms. The critical feature of this pathway is the timeliness of the clinical response. The clear and severe nature of the symptoms prompts patients to seek immediate medical attention, leading to a prompt diagnosis and subsequent surgical intervention.[12] The "Study Finding Correlation" section within this pathway explicitly links this pathophysiological process to our study's most favorable outcomes. Patients who follow this acute trajectory were found to be the most likely candidates for a minimally invasive Laparoscopic Appendectomy. Their early presentation with uncomplicated inflammation allows the surgeon to leverage the full benefits of this technique. Consequently, this pathway is strongly associated with a shorter postoperative recovery, with the majority of these patients experiencing a length of stay of three days or less. This pathway, therefore, represents the ideal clinical scenario: a rapid pathological process met with an equally rapid and effective clinical and surgical response.

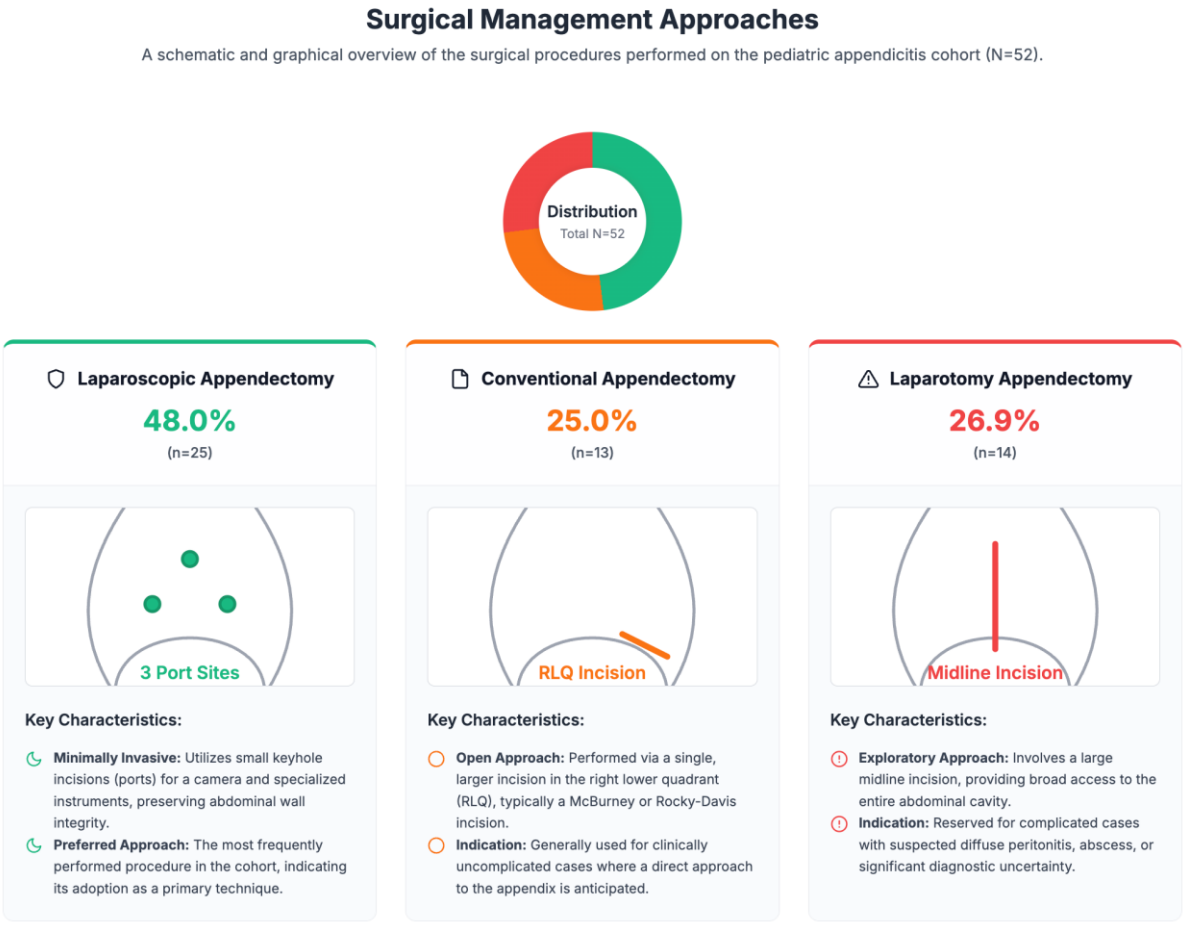

Figure 3. Distribution of surgical procedures performed.

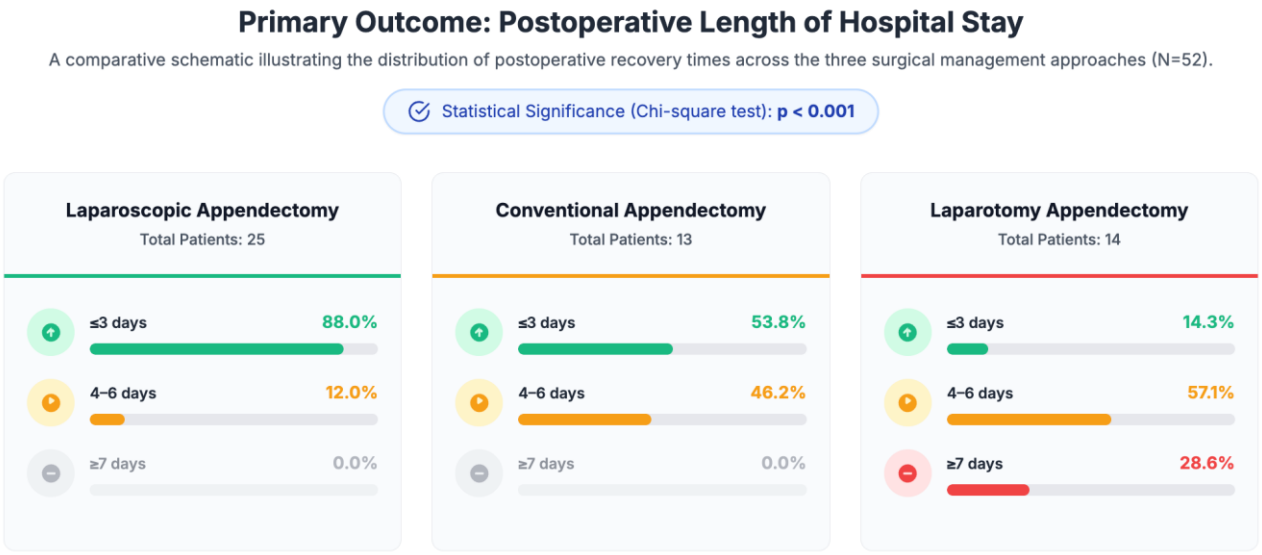

Figure 4. Comparative analysis of postoperative length of stay by surgical procedure.

The Delayed Presentation pathway corresponds to the overwhelming majority of our cohort—the 71.2% of patients (n=37) whose histopathology revealed evidence of a chronic inflammatory component. This model is not a single, linear event but a multi-stage progression that unfolds over a prolonged period. It begins with an initial or recurrent inflammatory insult that is sub-acute and often self-limiting. These are the episodes of nagging, intermittent abdominal pain that may be dismissed by caregivers as minor ailments. Crucially, these episodes are not met with definitive intervention. The physiological consequence of these repeated, unresolved inflammatory insults is the second stage: Fibrosis & Scarring. The body's healing response leads to the deposition of collagen and the development of mural fibrosis, creating the pathological state of chronic appendicitis. This scarred, less compliant appendix is a locus of decreased resistance, vulnerable to future events. The final stage is the Acute Exacerbation on Chronic, where a definitive obstructive event occurs in the already compromised, chronically inflamed organ. This triggers a superimposed acute inflammatory response, leading to severe symptoms that finally compel the patient to seek surgical care. The "Study Finding Correlation" for this pathway synthesizes this complex pathophysiology with the less favorable outcomes observed in our study. The presence of dense, fibrotic tissue and adhesions makes the surgery technically more challenging, increasing the likelihood that a more invasive Open Surgery, including Laparotomy, is required for safe dissection and management of complications like abscesses or phlegmons. This more extensive surgical trauma, coupled with the higher baseline disease severity, is directly correlated with a prolonged postoperative recovery, with the majority of these patients requiring a hospital stay longer than three days. This pathway, therefore, provides a powerful explanatory model for the majority of our cohort, linking a history of delayed presentation directly to more invasive surgery and a longer, more complicated recovery.[13,14]

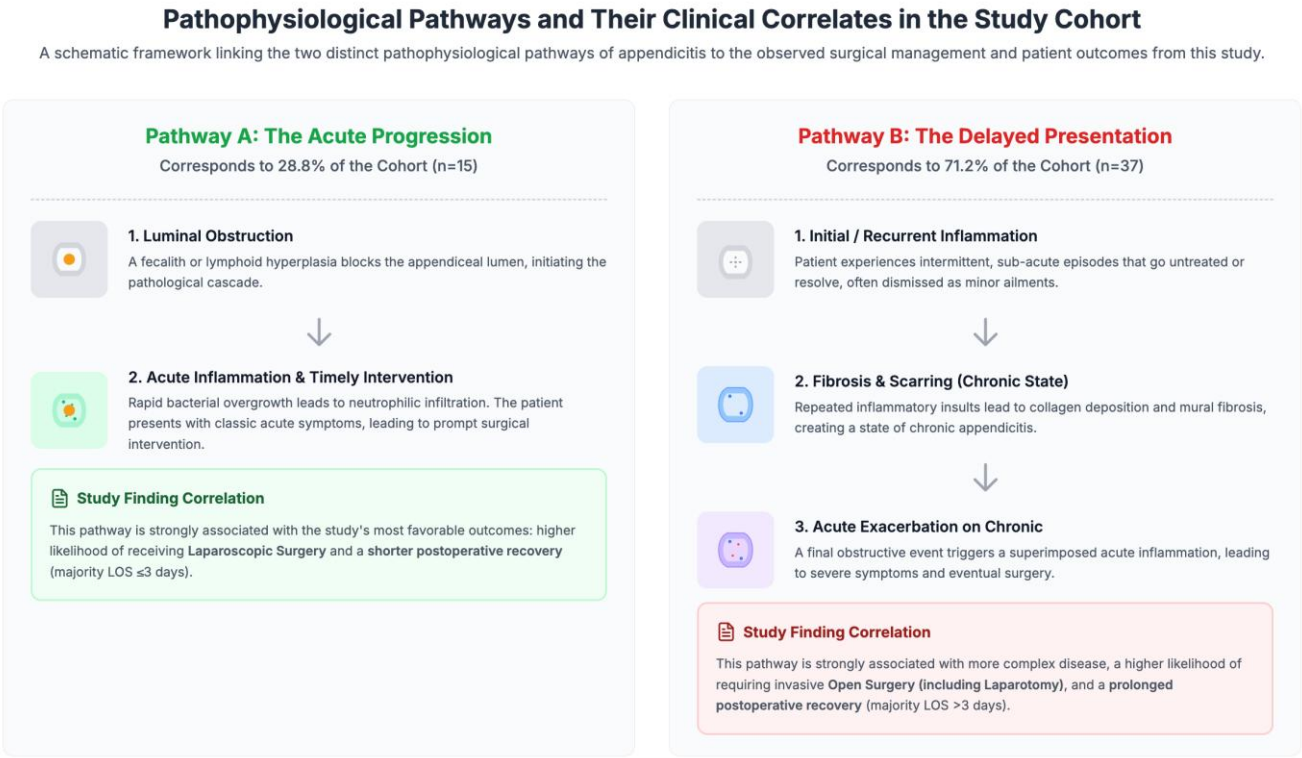

Figure 5. Pathophysiological pathways and their clinical correlates in the study.

Our study's demographic findings—a clear male predominance (63.4%) and a peak incidence in school-aged children and adolescents—are a faithful reflection of the global epidemiology of appendicitis. This remarkable consistency across disparate populations suggests that fundamental, intrinsic biological factors, rather than extrinsic environmental ones, are the primary drivers of this disease pattern. A deeper dive into the developmental physiology and endocrinology of childhood provides a compelling explanation for this distinct epidemiological signature. The appendix is not a vestigial, functionless organ; it is an immunologically active structure, rich in gut-associated lymphoid tissue (GALT). The volume and activity of this tissue change dramatically throughout life. In infancy and early childhood, the GALT is still developing. However, from the age of 5 or 6, and peaking during the peripubertal and adolescent years (precisely the age range most represented in our cohort), the appendix becomes densely populated with lymphoid follicles. These follicles are a key component of the body's mucosal immune system, constantly sampling luminal antigens and mounting immune responses. This period of maximal lymphoid mass directly correlates with the highest risk of appendicitis. The primary mechanism of obstruction in this age group is lymphoid hyperplasia—a reactive swelling of these follicles in response to systemic or enteric viral or bacterial infections.[15] Common childhood illnesses, therefore, become direct triggers for appendiceal obstruction. The larger the baseline volume of lymphoid tissue, the higher the probability that a given infectious stimulus will cause swelling sufficient to occlude the narrow appendiceal lumen. As individuals enter adulthood, this lymphoid tissue begins a slow, progressive atrophy, and the appendiceal lumen tends to widen, both factors contributing to the declining incidence of appendicitis with age. Our data, which show a concentration of cases in the 6-10 year and ≥11 year age groups, are a direct clinical manifestation of this underlying immunological and anatomical developmental arc. The male predominance is a more complex phenomenon, likely driven by the profound endocrinological shifts of puberty. The surge of androgenic hormones, particularly testosterone, in adolescent males has significant immunomodulatory effects. Androgen receptors are expressed on various immune cells, and testosterone has been shown to influence the proliferation and function of lymphocytes within the GALT. It is hypothesized that androgens may promote a more aggressive or sustained state of lymphoid hyperplasia in response to an inflammatory stimulus compared to the hormonal environment in females.[16] This could create a lower threshold for luminal obstruction in males during their peak years of GALT activity. Furthermore, emerging research into gender-based differences in the gut microbiome may offer additional clues. Different microbial compositions could influence the propensity for fecalith formation or modulate the local inflammatory milieu of the appendix, potentially contributing to the observed male predisposition. While our study cannot prove these mechanisms, our demographic results are entirely consistent with this intricate interplay between developmental immunology and pubertal endocrinology.

The central and most impactful finding of this investigation is that a combined 71% of pediatric patients undergoing appendectomy at our institution had histopathological evidence of a chronic inflammatory process, with 48% fitting the specific criteria for chronic appendicitis with an acute exacerbation. This is not merely a point of academic interest; it is a quantifiable signal of a profound and widespread delay in the patient care pathway.[17] The pathophysiology of chronic appendicitis, characterized by mural fibrosis and scarring, is the direct result of recurrent, sub-acute, or partially treated inflammatory episodes. This pathological footprint tells a clear story: for the majority of children in this cohort, the appendectomy was not an intervention for a single, acute event but rather the culmination of a protracted disease course. This finding compels a deep and structured analysis of the potential "upstream" factors within the local healthcare ecosystem that

contribute to such delays. Health Systems Analysis I: The Primary Care and Referral Bottleneck. In Indonesia, the primary point of contact for many families is the local community health center, or *Puskesmas*. While essential for public health, these centers can be variably equipped and staffed. A child presenting with non-specific abdominal pain might be diagnosed with gastroenteritis or constipation, common pediatric ailments. Without immediate access to diagnostic adjuncts like C-reactive protein testing or, most crucially, ultrasound, the primary care physician may adopt a "wait and see" approach. This initial misstep can account for days of delay. Subsequently, the formal referral process from a primary clinic to a tertiary hospital like ours can be slow, involving administrative hurdles and further queues, all while the subclinical inflammation in the appendix progresses and fibrotic changes set in.[18] Health Systems Analysis II: The Ultrasound Accessibility Problem. Abdominal ultrasound is the preferred imaging modality for suspected pediatric appendicitis due to its non-invasive nature and lack of ionizing radiation. However, its availability and the expertise required for its interpretation are often concentrated in tertiary centers. A child in a peripheral or rural area of Central Java may not have access to this diagnostic tool. The alternative, computed tomography (CT), is often even less accessible and carries radiation risks. This "ultrasound bottleneck" forces clinicians to rely solely on clinical judgment, which is notoriously fallible in children, thereby contributing to both delayed diagnosis and a higher rate of negative appendectomies (though the latter was not the focus of this study). Socio-economic and Cultural Dimensions: The decision to seek care is complex. In many Indonesian communities, financial barriers remain significant. Even with national health insurance schemes, indirect costs such as transportation to a major city like Semarang, lost wages for parents, and accommodation can be prohibitive. This may lead families to delay seeking formal medical care until the child's symptoms become severe and unmanageable at home. Furthermore, the use of traditional medicine and remedies (*jamu*) as a first-line treatment for ailments like abdominal pain is culturally ingrained. While often harmless, this practice can consume critical time, allowing appendicitis to evolve from a simple to a complicated state, leaving the pathological scars we observed.

Our results show a clear statistical association between laparoscopic appendectomy and a shorter LOS. It is tempting to conclude, as many studies do, that this proves the superiority of the minimally invasive technique. However, such a conclusion would be scientifically unsound given the design of this study. The data are powerfully influenced by confounding by indication, a type of selection bias where the patient's underlying clinical condition dictates the choice of treatment.[19] As defined in our methods, laparotomy was explicitly reserved for the most severe cases—those with suspected diffuse peritonitis or complications requiring broad abdominal exploration. Conversely, laparoscopic appendectomy was more likely chosen for patients who presented earlier and appeared to have uncomplicated disease. Therefore, this study does not compare the outcomes of two different procedures on similar patients; rather, it compares the outcomes of two different patient populations (the critically ill vs. the less ill) who received appropriately selected, different procedures. The longer LOS in the laparotomy group is an expected consequence of their more severe baseline pathology. The scientifically honest interpretation is therefore not one of causality, but of validation. Our finding that patients selected for laparoscopy experienced rapid recovery (88% discharged in ≤3 days) is entirely consistent with the vast body of high-quality evidence from randomized controlled trials worldwide. It validates that the benefits of MIS are being successfully realized in our institution for the appropriate patient population. It does not, however, prove that laparoscopy is "better" than laparotomy for a patient with severe, diffuse peritonitis, for whom a laparotomy may well be the

safer and more definitive procedure. This deep-seated difference in the physiological insult between surgical approaches forms the biological basis for the observed outcomes.[20]

Open surgery necessitates a significant breach of the abdominal wall's anatomical integrity. The incision transects skin, subcutaneous tissue, fascia, and multiple muscle layers, triggering a powerful local and systemic inflammatory response. The damaged tissues release a flood of pro-inflammatory mediators, including cytokines like Interleukin-6 (IL-6) and Tumor Necrosis Factor-alpha (TNF-α), which drive the systemic inflammatory response syndrome (SIRS). This manifests clinically as fever, tachycardia, and leukocytosis, and contributes to a catabolic state that impedes recovery. The significant somatic pain from the large wound impairs respiratory mechanics, leading to splinting, reduced tidal volumes, and an increased risk of atelectasis. It also severely limits early mobilization, which in turn predisposes the patient to venous thromboembolism and prolongs postoperative ileus. Laparoscopic surgery, in contrast, minimizes the trauma of access. The small port-site incisions preserve the fascial and muscular layers, leading to a markedly attenuated systemic inflammatory response. The reduction in tissue trauma translates into significantly less postoperative pain, which breaks the vicious cycle of immobility and respiratory compromise. Patients are able to ambulate sooner, promoting faster return of bowel function and reducing pulmonary complications. The sealed intra-abdominal environment of laparoscopy also prevents the desiccation and evaporative cooling of the viscera that occurs during open surgery, further reducing the stimulus for postoperative ileus. Therefore, the shorter LOS seen in our laparoscopic group is not simply a statistical observation; it is the predictable clinical result of a fundamentally less traumatic physiological event, a testament to the core principles of minimally invasive surgery.

5. Conclusion

This study provides a critical window into the clinical reality of pediatric appendicitis in Central Java, Indonesia. The principal and most compelling conclusion is that the remarkably high prevalence of chronic exacerbated appendicitis—found in nearly half our cohort—is a definitive indicator of significant, systemic delays in the pediatric acute care pathway. This pathological evidence transforms the conversation from one of surgical technique to one of public health and health systems strengthening. While our findings confirm that minimally invasive surgery is associated with a rapid recovery for appropriately selected patients, this is a secondary point. The urgent priority highlighted by our data is the need to address the "upstream" factors that prevent children from reaching timely surgical care. Future efforts must be directed towards enhancing public health literacy on the symptoms of appendicitis, streamlining primary care diagnostic and referral pathways, and improving access to essential diagnostic tools like ultrasound. By tackling the challenge of early diagnosis, we can reduce the cumulative morbidity of this common condition and ensure that children not only receive the best possible surgery but also receive it at the best possible time.

6. References

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