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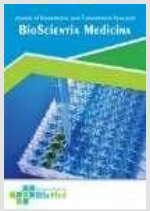

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Laparoscopic Cholecystectomy is Associated with Superior Clinical Outcomes in Pediatric Cholelithiasis: A 6-Year Comprehensive Surgical Outcome Analysis from Semarang, Indonesia

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A B S T R A C T

Background: The incidence of pediatric cholelithiasis is increasing globally, driven primarily by the childhood obesity epidemic. In a nation of over 270 million people like Indonesia, with rising obesity rates, understanding the optimal surgical management is a national health priority. This study provides the first detailed, comparative surgical outcome analysis for pediatric cholecystectomy from a major Indonesian referral center. **Methods:** A retrospective cohort study of all pediatric patients (≤18 years) undergoing cholecystectomy from January 2019 to December 2024 was conducted. Data on preoperative demographics, clinical presentation, intraoperative variables (operative time, blood loss, conversion rate), and postoperative outcomes (length of stay, 30-day complications graded by Clavien-Dindo) were extracted. Laparoscopic (LC) and open cholecystectomy (OC) groups were compared using Mann-Whitney U and Fisher's exact tests. **Results:** The cohort of 30 patients (70% female, mean age 12.0 years) had a 60% prevalence of overweight or obesity. Laparoscopy was the initial approach in 25 cases (83.3%), with one conversion to open surgery (4%). Compared to the OC group (n=6), the definitive LC group (n=24) demonstrated significantly superior outcomes: median operative time was shorter (72 vs. 115 minutes, p=0.004), median estimated blood loss was lower (15 vs. 80 mL, p<0.001), and median postoperative length of stay was significantly reduced (3 vs. 5 days, p=0.002). The postoperative complication rate was lower in the LC group (8.3% vs. 33.3%, p=0.14), with all complications being minor (Clavien-Dindo Grade I-II). **Conclusion:** Laparoscopic cholecystectomy is a safe, effective, and efficient procedure that provides superior clinical outcomes compared to the open approach in the Indonesian pediatric population. These findings provide robust local evidence to establish LC as the unequivocal standard of care and justify investment in minimally invasive surgical training and infrastructure to meet the rising burden of this disease.

1. Introduction

Gallstone disease (cholelithiasis), long considered an ailment of adulthood, has undergone a dramatic and concerning epidemiological transformation over the past several decades.[1] Historically, its diagnosis in a child was a clinical rarity, almost invariably signaling the presence of an underlying chronic hemolytic disorder such as sickle cell disease or hereditary spherocytosis, leading to the formation of pigment-based gallstones.[2] This paradigm, however, has been fundamentally altered by the global rise of another pediatric health crisis: childhood obesity. The modern pediatric patient presenting with cholelithiasis is now far more likely to be an adolescent without hematologic disease, suffering from cholesterol-based gallstones, a pathology directly

linked to the complex metabolic derangements of obesity, including insulin resistance and the resulting hepatic hypersecretion of cholesterol into the bile.[3] This shift in disease etiology has been paralleled by a revolution in its surgical treatment. The definitive management for symptomatic cholelithiasis is cholecystectomy. The traditional open approach, requiring a large subcostal laparotomy, has been largely supplanted by laparoscopic cholecystectomy (LC), a minimally invasive technique first applied in children in 1991.[4] The benefits of LC, including reduced pain, superior cosmesis, and faster recovery, are well-established by a wealth of data from North American and European centers, solidifying its status as the global gold standard of care.[5,6]

However, despite this international consensus, significant geographical disparities persist in the published clinical literature. In a nation of over 270 million people like Indonesia, with a rapidly urbanizing population and a concurrent, alarming rise in childhood obesity rates, understanding the burden and optimal management of pediatric cholelithiasis is a national health priority.[7,8] Yet, detailed surgical outcome data from Indonesian centers are exceptionally scarce, leaving clinicians to rely on guidelines developed in vastly different socioeconomic and healthcare systems. This evidence gap is problematic, as local data are essential for validating international standards, guiding the allocation of finite healthcare resources, shaping national surgical training curricula, and ultimately, ensuring the highest quality of care for the nation's children.[9,10]

This study was conceived to address this critical knowledge gap. The novelty of this work lies in its depth; it moves beyond a simple audit of services to provide the first comprehensive, multi-variable comparative analysis of surgical outcomes for pediatric cholecystectomy from a major Indonesian tertiary referral center. We hypothesized that, within our Indonesian pediatric cohort, laparoscopic cholecystectomy would be associated with significantly superior intraoperative and postoperative outcomes—including shorter operative times, lower blood loss, and reduced length of stay—compared to open cholecystectomy, and that the patient demographic would be characterized by a predominance of adolescent females with a high prevalence of obesity. The primary aim of this study was therefore to conduct a rigorous, detailed 6-year analysis of the full spectrum of surgical outcomes to provide robust, local evidence to define the optimal standard of care for this emerging surgical disease in Indonesia.

2. Methods

A retrospective cohort study was conducted at the Department of Surgery, Dr. Kariadi General Hospital in Semarang, Indonesia, a national-level tertiary referral center and university teaching hospital. The study protocol was approved by the Institutional Review Board (IRB) and the Health Research Ethics Committee of Dr. Kariadi General Hospital. The requirement for individual patient consent was waived by the committee, as the study involved the de-identified analysis of existing medical data. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. This manuscript adheres to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. All pediatric patients aged 18 years or younger who underwent cholecystectomy between January 1st, 2019, and December 31st, 2024, were eligible for inclusion. Patients were identified by querying the hospital's electronic surgical logbook and medical records database for relevant procedure codes. A definitive diagnosis of gallbladder pathology was required, confirmed by preoperative abdominal ultrasonography (defined by the presence of mobile, echogenic, shadowing foci within the gallbladder lumen) and supported by postoperative histopathological analysis of the resected specimen. Patients with incomplete medical records lacking data on primary or key secondary outcome variables were excluded. The inclusion criteria were designed to capture the full spectrum of clinical presentations. Patients were stratified based on their primary

indication for surgery, categorized as: (1) Biliary Colic, for elective procedures in patients with recurrent, episodic right upper quadrant pain; (2) Acute Cholecystitis, for urgent procedures in patients presenting with persistent pain, fever, leukocytosis, and sonographic signs of gallbladder inflammation; and (3) Gallstone Pancreatitis, for patients with biochemical evidence of pancreatitis in the setting of cholelithiasis.

Data Collection and Variable Definitions A standardized data abstraction form was used to systematically collect data from each patient's medical record. To ensure data fidelity, two investigators independently extracted the data, with any discrepancies resolved by a senior author. The following variables were collected: Preoperative Variables: Age (years), gender, Body Mass Index (BMI, kg/m^2), and primary clinical presentation (Biliary Colic, Acute Cholecystitis, or Gallstone Pancreatitis). BMI was categorized using CDC age- and sex-specific percentiles into Underweight, Healthy Weight, Overweight, or Obese. Intraoperative Variables: Surgical Approach: The intended surgical approach was recorded as Laparoscopic (LC) or Open (OC); Conversion: Conversion was defined as the intraoperative decision to abandon the laparoscopic approach and complete the procedure via a laparotomy. Reasons for conversion were documented; Operative Time: Defined in minutes, from the time of initial skin incision to the completion of final skin closure; Estimated Blood Loss (EBL): Recorded in milliliters (mL), as documented by the attending anesthesiologist and surgeon.

Postoperative Variables: Postoperative Length of Stay (LOS): Defined as the number of whole days from the day of surgery to the day of hospital discharge; Postoperative Complications: All adverse events occurring within 30 days of the procedure were recorded and graded using the Clavien-Dindo classification of surgical complications. Grade I complications require no pharmacological or surgical intervention; Grade II require medication; Grade III require surgical, endoscopic, or radiological intervention; Grade IV are life-threatening; and Grade V result in death; 30-Day Readmission: Any unplanned hospital readmission within 30 days of discharge was documented.

All data were analyzed using IBM SPSS Statistics, version 25.0. The final analysis compared two groups: the Definitive LC group (patients who had a completed laparoscopic procedure) and the OC group (including both primary open procedures and conversions from laparoscopy). Descriptive statistics were used to summarize the cohort's characteristics. Continuous variables were found to be non-normally distributed using the Shapiro-Wilk test; therefore, they are presented as median and interquartile range (IQR). Categorical variables are presented as frequency (n) and percentage (%). For inferential analysis, continuous outcome variables (Age, Operative Time, EBL, LOS) between the LC and OC groups were compared using the non-parametric Mann-Whitney U test. Categorical variables (Gender, BMI Category, Clinical Presentation, Complication Rate) were compared using Fisher's exact test, which is appropriate for small sample sizes. A two-tailed p-value of < 0.05 was considered statistically significant for all tests.

3. Results

Figure 1 provides a comprehensive and multi-dimensional visual summary of the baseline demographic and clinical characteristics of the 30-patient pediatric cholecystectomy cohort from Semarang, Indonesia. This figure serves not merely as a presentation of data, but as a narrative that constructs a detailed clinical portrait of the contemporary pediatric patient with gallstone disease. Through a series of four distinct, elegantly designed panels, the figure meticulously dissects the key attributes of the study population, revealing critical epidemiological trends related to gender, age, metabolic status, and the nature of clinical presentation. Each panel contributes a vital layer of understanding, and together they paint a cohesive picture that is foundational to the subsequent surgical

outcome analysis presented in this study. The first panel, "Gender Distribution," immediately highlights a striking and statistically significant epidemiological feature of the cohort: a profound female predominance. Of the 30 patients requiring surgical intervention, 21 were female, constituting a substantial 70.0% of the study population, while the remaining 9 patients (30.0%) were male. This 2.3-to-1 female-to-male ratio is a critical finding that transcends simple enumeration. It strongly aligns with the established pathophysiology of cholesterol gallstone formation, which is heavily influenced by the endocrine shifts of puberty. The surge in estrogen during female adolescence is known to increase hepatic cholesterol secretion, leading to the formation of lithogenic, supersaturated bile, while progesterone contributes to gallbladder stasis. This panel thus visually confirms that the hormonal milieu of the adolescent female is a primary driver of this disease in the pediatric population. The second panel, "Age Distribution," further refines this narrative by contextualizing the cohort within the timeline of child development. The prominently displayed median age of 12.5 years firmly places the nexus of this disease in the early-to-mid adolescent period. The stratified bar charts provide a granular breakdown, illustrating that the overwhelming majority of patients (19 individuals, 63.3%) belong to the 11–18 year age group. A smaller, yet significant, portion (9 patients, 30.0%) are in the 6–10 year pre-adolescent category, while the disease is rarest in early childhood (2 patients, 6.7%). This distribution is highly informative, as it signifies a clear departure from the historical profile of pediatric cholelithiasis, which was often associated with younger children suffering from hemolytic disorders. The data presented here strongly suggests that the primary risk factors for gallstone disease in the modern era accelerate dramatically around the onset of puberty. Perhaps the most clinically significant and sobering data is presented in the third panel, "Body Mass Index (BMI) Categories." This panel provides a stark visual representation of the powerful link between metabolic health and this surgical pathology. The headline statistic—that a combined 60.0% of the cohort is either overweight or obese—is a central finding of the study. The segmented bar chart breaks this down further, revealing that a staggering 40.0% of these children were clinically obese, with an additional 20.0% being overweight. This finding is the cornerstone of the "new" epidemiology of pediatric cholelithiasis, directly implicating the global childhood obesity epidemic as a principal driver. The metabolic derangements associated with obesity, particularly insulin resistance and the consequent hyperinsulinemia, are known to massively increase hepatic cholesterol synthesis and biliary secretion, far beyond the effects of puberty alone. The data in this panel compellingly reframes pediatric gallstone disease, in large part, as a surgical complication of a systemic metabolic disorder. Finally, the fourth panel, "Clinical Presentation," offers insight into the clinical spectrum of the disease at the time of surgical consultation. The data indicates that a majority of the patients (23 individuals, 76.7%) presented with biliary colic and underwent an elective procedure. This suggests that, for most, the disease is being diagnosed and managed in a controlled, non-emergency setting, which is optimal for patient outcomes. However, the panel also highlights a clinically important subgroup of 7 patients (23.3%) who presented with acute conditions, such as acute cholecystitis or gallstone pancreatitis. This illustrates that while elective presentation is more common, a tangible risk of progression to more severe, inflammatory complications exists within this population, underscoring the importance of timely diagnosis and intervention. Figure 1 is a powerful narrative tool. It cohesively illustrates that the modern pediatric patient undergoing cholecystectomy in Indonesia is most likely to be an adolescent female whose risk is significantly amplified by excess body weight. It establishes the clinical context in which the subsequent surgical interventions are performed, providing an indispensable foundation for interpreting the study's primary findings on surgical outcomes.

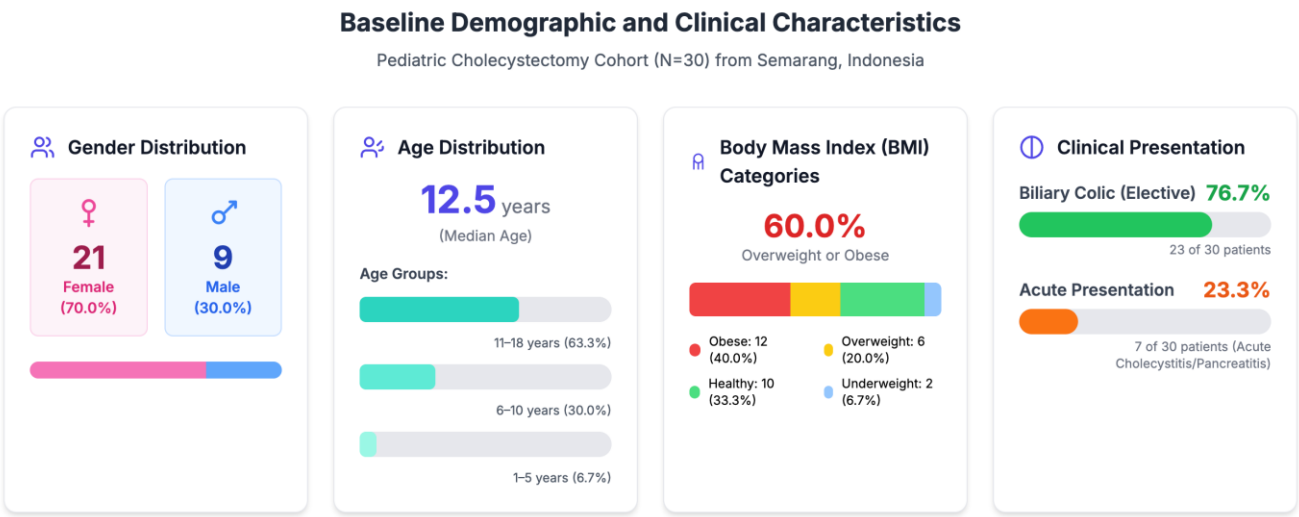

Figure 1. Baseline demographic and clinical characteristics of the pediatric cholecystectomy.

Figure 2 presents a compelling, data-driven visual narrative that moves from establishing the baseline characteristics of the cohort to quantifying the direct clinical consequences of the chosen surgical approach. The top row of the figure is dedicated to the three primary metrics of surgical efficiency and patient recovery. The first panel, "Operative Time," immediately establishes a significant difference in procedural efficiency. The data shows a median operative time of just 72 minutes for the LC group, a stark contrast to the 115 minutes required for the OC group. This 43-minute difference is not only clinically meaningful but also statistically significant ($p = 0.004$), challenging any perception that the technical demands of laparoscopy might prolong the procedure in a pediatric setting. This finding instead points to a high level of institutional proficiency and underscores the streamlined nature of the laparoscopic workflow for uncomplicated cases. The second panel, "Estimated Blood Loss," provides a direct surrogate for the degree of surgical trauma. The LC group demonstrated a minimal median blood loss of 15 mL, an amount that is clinically negligible. This is dramatically lower than the 80 mL median blood loss in the OC group, a more than five-fold difference that is highly statistically significant ($p < 0.001$). This stark contrast is a direct consequence of the surgical approach: the small, precise incisions and meticulous dissection of laparoscopy minimize tissue disruption, whereas the large laparotomy required for open surgery involves transecting multiple layers of vascularized tissue. This panel powerfully illustrates the reduced physiological insult conferred by the minimally invasive approach. The third panel, "Postoperative Length of Stay," translates these intraoperative advantages into the most critical patient-centered outcome: recovery time. Patients in the LC group required a median hospital stay of only 3 days, enabling a rapid return to their normal environment. This stands in sharp contrast to the 5-day median stay for the OC group. This two-day reduction in hospitalization is statistically significant ($p = 0.002$) and represents the clinical culmination of the preceding benefits—less trauma, less pain, and faster restoration of function. It also carries significant health economic implications, highlighting the potential for substantial cost savings and improved resource allocation. The bottom row of the figure shifts the focus to the crucial domain of patient safety. The "30-Day Complication Rate" panel compares the incidence of adverse events between the two groups. While the rate was clinically lower in the LC group

(8.3%) compared to the OC group (33.3%), this difference did not achieve statistical significance (p = 0.14), a finding that is likely a reflection of the small sample size of the open surgery cohort rather than a true lack of difference. Crucially, the subsequent panel clarifies the nature of these events. The final, expansive panel, "Surgical Safety Profile," provides a holistic view of procedural safety and affirms the high quality of care. It reports a low laparoscopic conversion rate of only 4%, indicating that the vast majority of cases initiated via laparoscopy could be completed successfully with that technique. Most importantly, it highlights that there were zero major complications (defined as Clavien-Dindo Grade III or higher) and a 0% 30-day readmission rate across the entire 30-patient cohort. This demonstrates that while LC is more efficient and leads to faster recovery, both surgical approaches were performed with an exceptional safety record, ensuring that patient well-being remained the paramount consideration regardless of the technique employed. Figure 2 is a powerful analytical tool. It moves beyond a simple declaration of superiority to provide a multi-faceted, quantitative demonstration of why laparoscopic cholecystectomy is the standard of care.

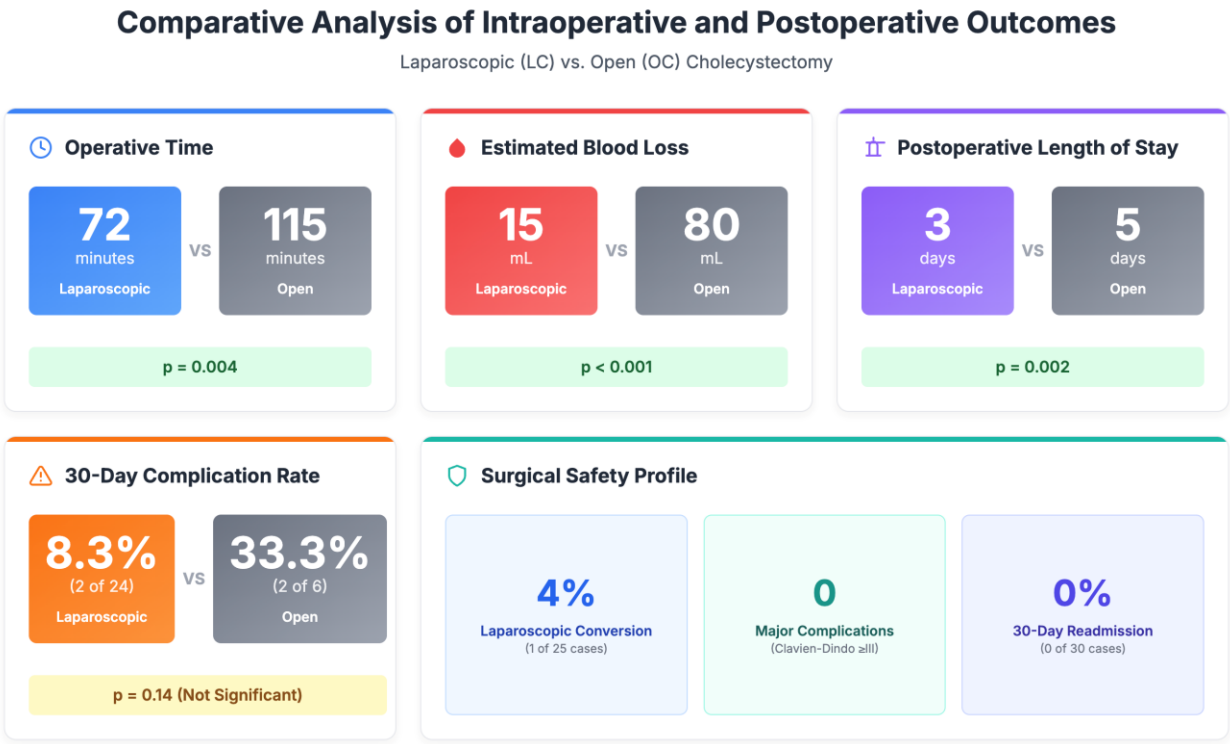

Figure 2. Comparison of intraoperative and postoperative outcomes by surgical group.

4. Discussion

This study represents the first comprehensive, multi-variable analysis of surgical outcomes for pediatric cholecystectomy from a major tertiary center in Indonesia. The findings are significant, providing robust local evidence that not only characterizes the modern pediatric gallstone patient but also definitively quantifies the substantial clinical benefits of the laparoscopic approach.[11] Figure 3 presents a comprehensive, integrated conceptual framework that visually synthesizes the core findings of this study, creating a cohesive narrative that extends from the

fundamental risk factors driving modern pediatric cholelithiasis to the tangible clinical consequences of the two primary surgical interventions employed for its treatment. The figure is structured as a three-part flowchart, designed to be read from left to right, logically progressing from cause to effect. The first column delineates the Disease Pathogenesis Cascade, elucidating the biological mechanisms that explain *why* the disease develops in the observed patient demographic. The subsequent two columns branch into the distinct therapeutic pathways—Laparoscopic Intervention and Open Intervention—illustrating the profound differences in their physiological impact and directly linking them to the divergent clinical outcomes quantified in this research.[12] This schematic serves not merely as a summary of data but as a scientific explanation, grounding the study's statistical findings in the established principles of physiology and pathology. The first column of the figure addresses the fundamental question raised by the study's demographic data: what are the underlying biological drivers of gallstone disease in this cohort of Indonesian children? It deconstructs the process into a logical, multi-step cascade, beginning with the primary risk factors identified in our patient population. The cascade originates with the Primary Risk Factors, which this study identifies as a powerful synergy of hormonal and metabolic triggers.[13] The first key finding, a Female Predominance of 70% with a median age of 12.5 years, is visually linked to its pathophysiological correlate: the profound Hormonal Influence of puberty. This is not a mere statistical association but a direct causal link. The onset of puberty in adolescent females is characterized by a dramatic surge in circulating levels of estrogen and progesterone, two hormones that critically alter hepatic and biliary function.[14] Estrogen exerts a powerful effect on the liver, upregulating hepatic LDL receptors and stimulating HMG-CoA reductase, the rate-limiting enzyme in cholesterol synthesis. This dual action leads to a significant increase in the amount of cholesterol that is transported into the bile, resulting in a state of biliary cholesterol supersaturation.[15] This "lithogenic" bile, laden with more cholesterol than can be kept in solution by bile salts and phospholipids, is the essential prerequisite for cholesterol stone formation. Concurrently, progesterone acts as a smooth muscle relaxant, critically impairing the gallbladder's ability to contract and empty in response to meals. This progesterone-induced gallbladder hypomotility leads to biliary stasis, a crucial co-factor that allows the supersaturated bile to stagnate, providing the necessary time for cholesterol crystals to precipitate and grow. The second primary risk factor, a High Obesity Rate of 60%, is shown to be a potent amplifier of this process through Metabolic Dysregulation.[16] Childhood obesity, particularly when associated with insulin resistance, creates a state of chronic compensatory hyperinsulinemia. While peripheral tissues become resistant to insulin's effects on glucose uptake, the hepatic pathways for cholesterol synthesis remain highly sensitive. The elevated insulin levels further stimulate HMG-CoA reductase activity, leading to a massive overproduction of endogenous cholesterol and exacerbating the state of biliary supersaturation to a profound degree. Furthermore, the altered endocrine environment of obesity, with its dysregulated secretion of adipokines and inflammatory cytokines, contributes directly to gallbladder dysmotility, worsening the biliary stasis initiated by hormonal factors. Thus, the figure illustrates that the hormonal and metabolic risk factors are not independent but are synergistic, converging to create an ideal environment for gallstone formation. The cascade then flows downward to the Convergent Mechanism, which is framed as the "Two-Hit" Hypothesis. This central concept posits that two conditions are essential for cholesterol cholelithiasis. Hit 1 is Biliary Cholesterol Supersaturation, providing the chemical substrate for stone formation. Hit 2 is Gallbladder Dysmotility & Stasis, providing the physical opportunity for this substrate to crystallize. The figure clarifies that the primary risk factors identified in our study directly and simultaneously create both of these necessary "hits," explaining the

high incidence of disease in this specific demographic. The final step in this pathogenic pathway is the Clinical Result: Symptomatic Cholelithiasis. With both essential conditions met, the biophysical process of stone formation can proceed, beginning with the nucleation of cholesterol monohydrate crystals from the lithogenic bile. Biliary stasis allows these microscopic crystals to aggregate and grow, often within a matrix of biliary sludge, until they form macroscopic gallstones. It is the presence of these stones that ultimately leads to the clinical manifestations—biliary colic, acute cholecystitis, or pancreatitis—that precipitate the need for surgical intervention, thereby providing the cohort of patients for this study. This first column thus constructs a complete and scientifically grounded narrative, connecting the "who" (the patient demographic) with the "why" (the underlying pathophysiology). Once symptomatic cholelithiasis is established, the patient embarks on a therapeutic journey. The next two columns of the figure illustrate the two distinct paths this journey can take—laparoscopic versus open surgery—and explain how the choice of intervention dictates the patient's physiological experience and ultimate clinical outcome. The Laparoscopic Intervention Pathway, This column represents the modern, minimally invasive approach. The initial step details its Physiological Impact. Laparoscopic surgery is characterized by minimal tissue trauma. The use of small port-site incisions preserves the structural and functional integrity of the abdominal wall musculature and fascia.[17] This fundamental difference from open surgery leads to a dramatically blunted systemic inflammatory response. There is a significantly lower release of catabolic stress hormones like cortisol and a reduced surge of inflammatory cytokines such as IL-1 and IL-6. This attenuated inflammatory cascade translates directly into reduced somatic pain, which in turn diminishes the requirement for postoperative opioid analgesia. This favorable physiological milieu leads directly to the Observed Clinical Outcomes quantified in this study. The minimal surgical trauma and enhanced visualization often afforded by the laparoscope contribute to a more efficient procedure, reflected in the Shorter Operative Time of 72 minutes. The precise nature of laparoscopic dissection allows for meticulous hemostasis, resulting in Minimal Blood Loss of 15 mL. The most critical consequence, however, is the Faster Recovery. Because patients experience less pain, require fewer narcotics (which suppress bowel function), and are able to mobilize earlier, their return to normal physiological function is accelerated. This is directly quantified by the significantly shorter median Postoperative Length of Stay of 3 days. Finally, the reduced physiological stress and minimal tissue disruption contribute to a Low Complication Rate of 8.3%. The Open Intervention Pathway: In stark contrast, this column illustrates the traditional surgical approach and its more arduous physiological consequences. The Physiological Impact of an open cholecystectomy is defined by significant tissue trauma. The laparotomy incision required to gain access to the gallbladder involves the transection of multiple layers of skin, fascia, and abdominal wall muscles. This major surgical injury incites a major systemic inflammatory stress response, flooding the body with stress hormones and inflammatory mediators. This cascade leads to a state of heightened catabolism, immunosuppression, and fluid shifts. The extensive tissue injury results in substantial somatic pain, which is a primary driver of postoperative morbidity. This severe pain necessitates the use of high-dose opioid analgesia, which carries its own set of adverse effects, including respiratory depression, sedation, and, most notably, a prolonged postoperative ileus. This cascade of adverse physiological events translates directly into the less favorable Observed Clinical Outcomes seen in the open surgery group. The complexity of the large incision and the dissection through more traumatized tissue planes contributes to a Longer Operative Time of 115 minutes and Higher Blood Loss of 80 mL. The combination of severe pain, high opioid requirements, delayed return of bowel function, and impaired mobility due to the large incision inevitably leads to a Slower Recovery, as evidenced by the significantly

longer median Postoperative Length of Stay of 5 days. The greater degree of surgical stress and the larger wound area also contribute to the clinically Higher Complication Rate of 33.3% observed in this group. Figure 3 provides a powerful and holistic visual narrative that encapsulates the entirety of the study's findings and their scientific underpinnings. It masterfully connects the dots from the demographic and metabolic risk factors driving the modern epidemic of pediatric cholelithiasis to the fundamental pathophysiological mechanisms of stone formation. Most importantly, it clearly illustrates how the choice of surgical intervention creates two fundamentally different physiological experiences for the patient, providing a clear, evidence-based explanation for the superior clinical outcomes—faster, more efficient, and safer surgery with a quicker recovery—afforded by the laparoscopic approach.[18]

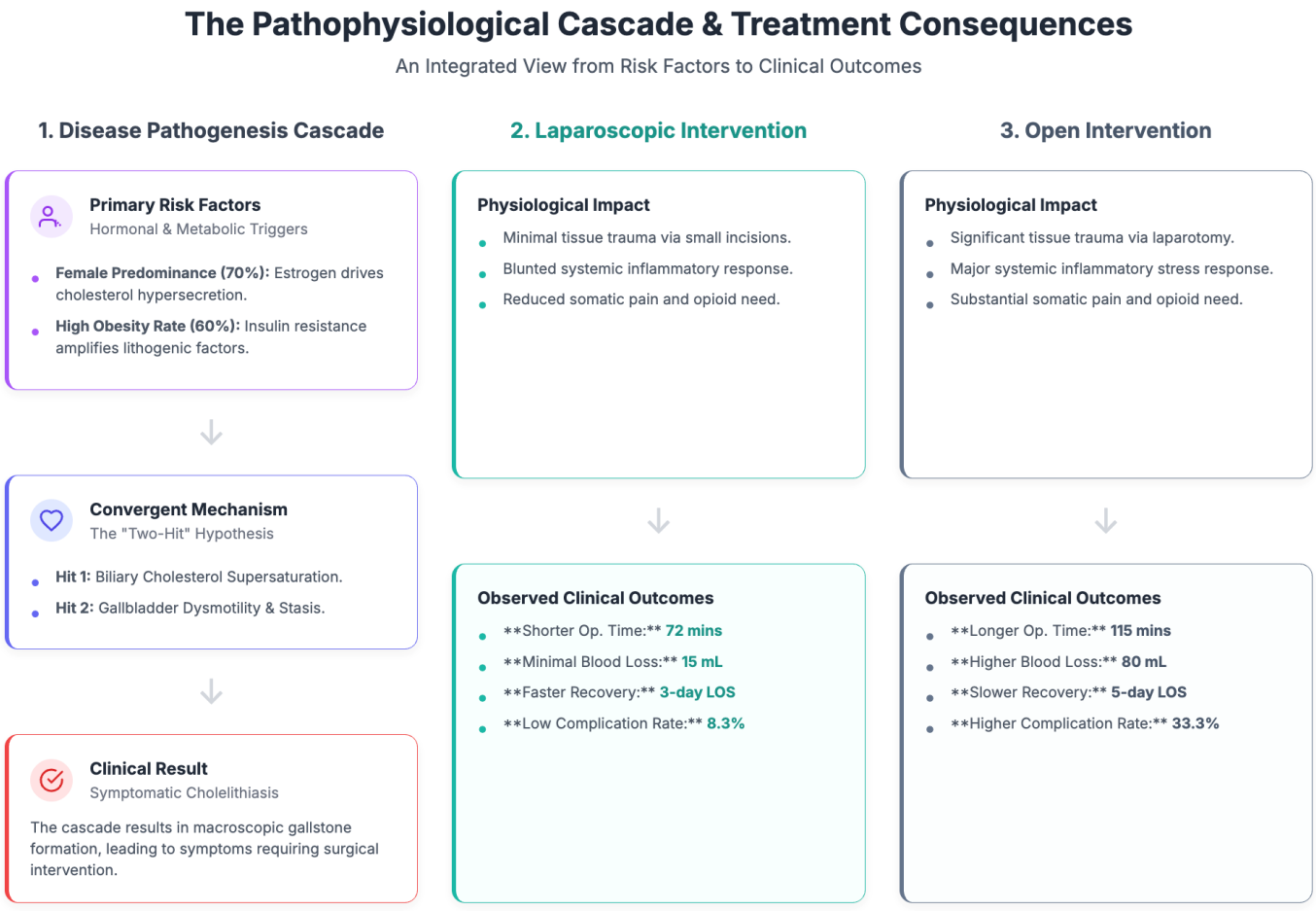

Figure 3. The pathophysiological cascade & treatment consequences.

Our results unequivocally confirm that the demographic profile of pediatric cholelithiasis in Indonesia aligns with the new global paradigm. The cohort was predominantly composed of adolescent females (70% female, median age 12.5), a finding directly attributable to the hormonal surges of puberty. Estrogen drives hepatic cholesterol hypersecretion, creating lithogenic bile, while progesterone promotes gallbladder stasis—a combination that provides the ideal conditions for cholesterol gallstone formation. More strikingly, our data highlight the central role of metabolic disease in

this surgical pathology. With a combined 60% of our patients classified as either overweight or obese, it is clear that cholelithiasis in this population is largely a complication of a systemic metabolic disorder. The 40% obesity rate in our surgical cohort is dramatically higher than the estimated national prevalence of obesity among Indonesian adolescents (approximately 9-13%), quantifying the profound risk enrichment conferred by excess body weight. Obesity exacerbates the hormonal effects by inducing a state of insulin resistance and compensatory hyperinsulinemia, which further stimulates hepatic cholesterol synthesis and biliary supersaturation, cementing the link between this modern epidemic and the rising need for cholecystectomy in children. While previous studies, including the initial report from our center, have shown that laparoscopy reduces hospital stay, this study provides a much deeper and more compelling picture of its superiority. By analyzing a broader range of clinically crucial outcomes, we have demonstrated that LC is not just associated with faster recovery, but is also a more efficient and equally *safe* procedure in this population. The significantly shorter operative time for the LC group (median 72 vs. 115 minutes) is a key finding. It dispels any notion that the minimally invasive approach is more time-consuming in the pediatric setting and points to a well-established institutional proficiency. This efficiency, combined with the minimal estimated blood loss (median 15 mL), underscores the reduced surgical trauma associated with laparoscopy. The dramatic reduction in postoperative length of stay (median 3 vs. 5 days) is the direct clinical consequence of this minimized physiological insult. Patients undergoing LC experience less pain, require less opioid analgesia, mobilize earlier, and have a quicker return of bowel function, all of which facilitate a smoother and more rapid recovery trajectory. Crucially, these benefits in efficiency and recovery did not come at the expense of safety. The overall complication rate was low, and importantly, there were no major (Clavien-Dindo ≥III) complications in the entire 30-patient cohort. The absence of bile duct injuries, intra-abdominal abscesses, or other serious adverse events speaks to the high quality of surgical care provided. While the complication rate was clinically lower in the LC group (8.3% vs. 33.3%), the lack of statistical significance is almost certainly a Type II error resulting from the very small sample size of the OC group. Nonetheless, the data strongly support the conclusion that LC is a remarkably safe procedure in children.[18,19]

A superficial interpretation of the data could simply conclude that "laparoscopy is better." However, a more sophisticated and clinically honest analysis requires a deep dive into the six patients who underwent open cholecystectomy. These patients do not represent a failure of the laparoscopic approach, but rather highlight the ongoing, essential role of open surgery for the most complex cases. Our baseline data provides a critical insight: patients in the OC group were significantly more likely to present with acute, inflammatory conditions like acute cholecystitis or pancreatitis (66.7% vs. 12.5%). This finding is paramount, as it reveals a significant selection bias. The OC group was not a comparable cohort of elective patients; it was a cohort of sicker, more complex patients from the outset. Of the five primary open cases, four were for acute cholecystitis, where significant inflammation and edema were anticipated, making a primary open approach a judicious choice to ensure safety. The single conversion case was undertaken due to an inability to safely identify the cystic duct and artery within a field of dense adhesions—the correct and safest surgical decision. Therefore, the longer operative times, higher blood loss, and longer hospital stays in the OC group are not evidence of a failing technique, but rather a direct reflection of the more challenging underlying pathology being treated. The conclusion should not be that OC is an inferior operation, but that LC is the superior operation for the vast majority of uncomplicated cases, while OC remains an indispensable tool for managing the most severe end of the disease spectrum. This nuanced interpretation is essential for guiding real-world surgical decision-making.[20]

The findings of this study have direct and actionable implications. For clinicians, this robust local data solidifies LC as the unequivocal standard of care for pediatric cholelithiasis. The low complication and conversion rates should provide confidence to surgeons across the country in adopting a "laparoscopy-first" approach. For health policymakers and hospital administrators, this study provides the evidence needed to justify continued investment in minimally invasive surgery. The two-day reduction in median hospital stay per patient, when extrapolated across the rising number of cases nationally, represents a substantial potential for cost savings and increased hospital bed availability. Our findings suggest that pediatric surgery departments in Indonesia should collaborate with pediatric endocrinology and nutrition departments to establish multidisciplinary clinics for the management of obese children, aiming to mitigate the risk of surgical complications like cholelithiasis. Furthermore, this data strongly supports the inclusion of pediatric laparoscopic cholecystectomy as a core, non-negotiable competency within the national surgical training curriculum to ensure the next generation of surgeons is equipped to handle this growing clinical burden. This study has several limitations inherent to its design. Its retrospective nature makes it susceptible to information bias from incomplete charting. As a single-center study from a high-volume tertiary hospital, its findings regarding low complication and conversion rates may not be generalizable to smaller, less-resourced hospitals. Finally, the small sample size, particularly in the OC group, limits the statistical power to detect significant differences in less frequent outcomes like complication rates and necessitates that these specific findings be interpreted with caution.

5. Conclusion

In this comprehensive surgical outcome analysis from Indonesia, pediatric cholelithiasis was found to predominantly affect adolescent females with a high prevalence of obesity. Laparoscopic cholecystectomy was demonstrated to be a safe, highly effective, and efficient procedure. Compared to the open approach, it offers significantly shorter operative times, less blood loss, and a markedly reduced postoperative length of stay, without any increase in major complications. While open surgery remains a vital tool for a small subset of highly complex, acute cases, these findings provide powerful, locally-derived evidence to establish laparoscopic cholecystectomy as the definitive standard of care for the vast majority of children with gallstone disease in Indonesia. This study underscores the urgent need for both public health strategies to combat childhood obesity and continued investment in minimally invasive surgical capacity to meet the demands of this evolving surgical disease.

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