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RESULTS OF MINIMALLY INVASIVE VERSUS OPEN APPROACHES IN PEDIATRIC APPENDICITIS: A SYSTEMATIC REVIEW

RESULTADOS DAS ABORDAGENS MINIMAMENTE INVASIVAS VERSUS ABERTAS NA APENDICITE PEDIÁTRICA: UMA REVISÃO SISTEMÁTICA

RESULTADOS DE LOS ABORDAJES MÍNIMAMENTE INVASIVOS VERSUS ABIERTOS EN LA APENDICITIS PEDIÁTRICA: UNA REVISIÓN SISTEMÁTICA

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ABSTRACT

Introduction: Acute appendicitis is the most common surgical emergency in children and remains a major cause of hospital admission and perioperative morbidity worldwide. Over recent decades, laparoscopic appendectomy has increasingly replaced open appendectomy in pediatric practice, yet uncertainty persists regarding comparative outcomes in uncomplicated and complicated disease.

Objective: The primary objective of this systematic review was to compare clinical outcomes of minimally invasive appendectomy versus open appendectomy in pediatric patients with acute appendicitis. Secondary objectives were to evaluate differences in postoperative complication rates, length of hospital stay, operative time, readmission, cost-related outcomes, and patient-centered recovery metrics.

Methods: A systematic search was conducted in PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and the WHO International Clinical Trials Registry Platform. Comparative studies published within the last five years involving pediatric populations were included. Risk of bias was assessed using RoB 2 and ROBINS-I tools, and certainty of evidence was evaluated using the GRADE framework.

Results and Discussion: Twenty comparative studies were included in the final synthesis. Minimally invasive appendectomy was consistently associated with reduced wound infection rates, shorter hospital stay, and improved postoperative recovery metrics compared with open appendectomy. Intra-abdominal abscess rates were generally comparable between approaches, including in complicated appendicitis. Operative time was frequently longer with laparoscopy, but this did not translate into increased morbidity or readmission. Certainty of

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evidence was moderate for reductions in length of stay and surgical site infection, and low-to-moderate for organ-space infection due to heterogeneity across studies.

Conclusion: Contemporary evidence supports laparoscopic appendectomy as the preferred approach in most pediatric appendicitis cases when appropriate expertise is available. Benefits in recovery and wound morbidity appear robust across disease severities, while serious complication rates remain comparable to open surgery. Surgical decision-making should remain individualized, integrating disease severity, institutional capability, and multidisciplinary care pathways.

Keywords: Appendicitis. Laparoscopy. Pediatric Surgery. Minimally Invasive Surgical Procedures.

RESUMO

Introdução: A apendicite aguda é a emergência cirúrgica mais comum em crianças e permanece como uma das principais causas de internação hospitalar e morbidade perioperatória em todo o mundo. Nas últimas décadas, a apendicectomia laparoscópica tem progressivamente substituído a apendicectomia aberta na prática pediátrica; entretanto, ainda existem incertezas quanto aos desfechos comparativos em casos de doença não complicada e complicada.

Objetivo: O objetivo principal desta revisão sistemática foi comparar os desfechos clínicos da apendicectomia minimamente invasiva com a apendicectomia aberta em pacientes pediátricos com apendicite aguda. Como objetivos secundários, avaliaram-se diferenças nas taxas de complicações pós-operatórias, tempo de internação hospitalar, duração do procedimento cirúrgico, readmissões, custos relacionados e indicadores de recuperação centrados no paciente.

Métodos: Foi realizada uma busca sistemática nas bases PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov e na Plataforma Internacional de Registro de Ensaios Clínicos da OMS. Foram incluídos estudos comparativos publicados nos últimos cinco anos envolvendo populações pediátricas. O risco de viés foi avaliado por meio das ferramentas RoB 2 e ROBINS-I, e a certeza da evidência foi analisada utilizando o sistema GRADE.

Resultados e Discussão: Vinte estudos comparativos foram incluídos na síntese final. A apendicectomia minimamente invasiva esteve consistentemente associada à redução das taxas de infecção de ferida operatória, menor tempo de internação hospitalar e melhores indicadores de recuperação pós-operatória quando comparada à apendicectomia aberta. As taxas de abscesso intra-abdominal foram, em geral, semelhantes entre as abordagens, inclusive nos casos de apendicite complicada. O tempo operatório foi frequentemente maior na laparoscopia, porém sem aumento da morbidade ou das taxas de readmissão. A certeza da evidência foi moderada para redução do tempo de internação e infecção do sítio cirúrgico, e baixa a moderada para infecção de órgão/espaço devido à heterogeneidade entre os estudos.

Conclusão: As evidências contemporâneas sustentam a apendicectomia laparoscópica como a abordagem preferencial na maioria dos casos de apendicite pediátrica quando há disponibilidade de expertise adequada. Os benefícios relacionados à recuperação e à morbidade da ferida operatória mostram-se consistentes entre diferentes graus de gravidade da doença, enquanto as taxas de complicações graves permanecem comparáveis à cirurgia aberta. A tomada de decisão cirúrgica deve permanecer individualizada, considerando a gravidade da doença, a capacidade institucional e os fluxos assistenciais multidisciplinares.

Palavras-chave: Apendicite. Laparoscopia. Cirurgia Pediátrica. Procedimentos Cirúrgicos Minimamente Invasivos.

RESUMEN

Introducción: La apendicitis aguda es la emergencia quirúrgica más frecuente en niños y continúa siendo una causa importante de hospitalización y morbimortalidad perioperatoria a nivel mundial. En las últimas décadas, la apendicectomía laparoscópica ha reemplazado progresivamente a la apendicectomía abierta en la práctica pediátrica; sin embargo, persisten incertidumbres respecto a los resultados comparativos en casos de enfermedad no complicada y complicada.

Objetivo: El objetivo principal de esta revisión sistemática fue comparar los resultados clínicos de la apendicectomía mínimamente invasiva frente a la apendicectomía abierta en pacientes pediátricos con apendicitis aguda. Como objetivos secundarios, se evaluaron diferencias en las tasas de complicaciones postoperatorias, duración de la hospitalización, tiempo operatorio, readmisiones, costos asociados y métricas de recuperación centradas en el paciente.

Métodos: Se realizó una búsqueda sistemática en las bases de datos PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov y la Plataforma Internacional de Registro de Ensayos Clínicos de la OMS. Se incluyeron estudios comparativos publicados en los últimos cinco años que involucraran poblaciones pediátricas. El riesgo de sesgo fue evaluado mediante las herramientas RoB 2 y ROBINS-I, y la certeza de la evidencia mediante el sistema GRADE.

Resultados y Discusión: Veinte estudios comparativos fueron incluidos en la síntesis final. La apendicectomía mínimamente invasiva se asoció de manera consistente con menores tasas de infección de la herida quirúrgica, menor estancia hospitalaria y mejores indicadores de recuperación postoperatoria en comparación con la apendicectomía abierta. Las tasas de absceso intraabdominal fueron generalmente comparables entre ambos abordajes, incluso en casos de apendicitis complicada. El tiempo operatorio fue frecuentemente mayor en la laparoscopia, sin traducirse en mayor morbilidad ni tasas de readmisión. La certeza de la evidencia fue moderada para la reducción de la estancia hospitalaria y la infección del sitio quirúrgico, y de baja a moderada para la infección de órgano/espacio debido a la heterogeneidad entre los estudios.

Conclusión: La evidencia contemporánea respalda la apendicectomía laparoscópica como el abordaje preferido en la mayoría de los casos de apendicitis pediátrica cuando se dispone de experiencia quirúrgica adecuada. Los beneficios en la recuperación y en la morbilidad de la herida quirúrgica son consistentes en distintos grados de severidad de la enfermedad, mientras que las tasas de complicaciones graves permanecen comparables a la cirugía abierta. La toma de decisiones quirúrgicas debe individualizarse considerando la gravedad de la enfermedad, la capacidad institucional y los modelos de atención multidisciplinaria.

Palabras clave: Apendicitis. Laparoscopia. Cirugía Pediátrica. Procedimientos Quirúrgicos Mínimamente Invasivos.

1 INTRODUCTION

Acute appendicitis remains the most frequent surgical emergency in the pediatric population, representing a significant cause of morbidity and healthcare utilization worldwide[1]. The incidence peaks in school-aged children and adolescents, with considerable variability in clinical presentation across age groups[1]. Despite advances in diagnostic imaging and perioperative management, surgical removal of the inflamed appendix continues to be the standard of care in most health systems[1]. Over the past three decades, laparoscopic appendectomy has progressively replaced open appendectomy in many centers due to perceived advantages in recovery and cosmesis[2]. Minimally invasive techniques are associated with smaller incisions, reduced postoperative pain, and earlier mobilization in adult populations[2]. However, the translation of these benefits to children, particularly in complicated appendicitis, has been the subject of ongoing investigation[2].

Pediatric patients present unique anatomical and physiological characteristics that may influence operative strategy and outcomes[3]. Younger children often have delayed diagnosis and higher rates of perforation, which may modify the risk–benefit profile of laparoscopic approaches[3]. Additionally, concerns regarding operative time, intra-abdominal abscess formation, and resource utilization remain debated in the pediatric context[3]. Recent technological advances, including improved optics, energy devices, and pediatric-sized instruments, have enhanced the feasibility of minimally invasive surgery in smaller children[4]. These innovations have expanded indications for laparoscopy even in cases of complicated appendicitis with diffuse peritonitis[4]. Nonetheless, questions persist regarding comparative safety, length of stay, postoperative complications, and overall cost-effectiveness when compared with traditional open surgery[4].

Several contemporary cohort studies and randomized trials have compared laparoscopic and open appendectomy in children, producing heterogeneous findings[5]. Some reports suggest reduced wound infection rates and shorter hospital stays with laparoscopy, whereas others indicate comparable or increased intra-abdominal abscess rates[5]. Differences in study design, patient selection, and definitions of complicated appendicitis contribute to variability in reported outcomes[5].

In addition to clinical endpoints, patient-centered outcomes such as postoperative pain, return to normal activities, and cosmetic satisfaction have gained increasing attention[6]. Minimally invasive approaches may offer psychosocial advantages, particularly in adolescents concerned about visible scarring[6]. However, robust comparative data focusing on long-term quality-of-life metrics remain limited in the pediatric literature[6].

The economic implications of surgical technique are also relevant, especially in resource-constrained environments[7].

Laparoscopic surgery may involve higher upfront equipment costs but potentially lower overall expenditure due to reduced complications and shorter hospitalization[7]. Comprehensive evaluation of cost-effectiveness requires integration of operative time, consumables, readmissions, and postoperative morbidity[7]. Professional societies have gradually incorporated minimally invasive appendectomy into clinical guidelines for pediatric surgery, although recommendations vary according to disease severity and institutional expertise[8]. While laparoscopy is widely endorsed for uncomplicated appendicitis, its role in perforated or abscess-forming disease remains less uniformly defined[8]. Evidence synthesis focusing on recent high-quality studies is therefore essential to clarify best practices[8].

Given the rapid evolution of surgical techniques and perioperative care over the last decade, an updated systematic review is necessary to evaluate contemporary comparative outcomes[9]. Previous reviews may not reflect advances in instrumentation, enhanced recovery protocols, and standardized antibiotic regimens[9]. A rigorous assessment of current evidence is critical to inform surgeons, policymakers, and multidisciplinary pediatric teams regarding optimal operative management strategies[9].

2 OBJECTIVES

The primary objective of this systematic review is to compare clinical outcomes of minimally invasive appendectomy, primarily laparoscopic approaches, versus open appendectomy in pediatric patients diagnosed with acute appendicitis. Secondary objectives include: (1) evaluating differences in postoperative complication rates, including wound infection and intra-abdominal abscess; (2) comparing length of hospital stay and time to return to normal activities; (3) assessing operative time and conversion rates; (4) analyzing cost-related outcomes and resource utilization; and (5) examining patient-centered outcomes such as postoperative pain and cosmetic satisfaction when reported.

3 METHODOLOGY

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. A comprehensive literature search was performed in PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and the World Health Organization International Clinical Trials Registry Platform. The search strategy combined controlled vocabulary and free-text terms related to

pediatric appendicitis, laparoscopic appendectomy, open appendectomy, and surgical outcomes.

Eligible studies included randomized controlled trials, prospective and retrospective cohort studies, and comparative observational studies published within the last five years. If fewer than ten eligible studies had been identified, the time window would have been expanded to ten years; however, sufficient contemporary studies were available within the five-year period. Studies involving human pediatric populations were prioritized, while relevant animal or in vitro investigations were to be presented separately if included. No language restrictions were applied, and small sample sizes were accepted but identified as methodological limitations.

Two independent reviewers screened titles and abstracts, followed by full-text assessment for eligibility. Disagreements were resolved by consensus or consultation with a third reviewer. Data extraction included study design, population characteristics, definition of complicated appendicitis, intervention details, comparison groups, primary and secondary outcomes, follow-up duration, and funding sources. The study selection process followed the PRISMA flow structure.

Risk of bias was assessed using the Cochrane Risk of Bias 2 tool for randomized controlled trials and the ROBINS-I tool for non-randomized studies. Diagnostic accuracy studies, if present, would have been evaluated using QUADAS-2. Certainty of evidence across outcomes was assessed using the Grading of Recommendations Assessment, Development and Evaluation framework. The rationale for conducting this systematic review was based on heterogeneity in recent findings and evolving surgical practice patterns in pediatric appendicitis management.

4 RESULTS

A total of 742 records were identified through database searching across PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and ICTRP. After removal of 186 duplicates, 556 records underwent title and abstract screening. Of these, 487 were excluded for not meeting inclusion criteria, primarily due to adult populations, lack of direct comparison, or non-comparative design. Sixty-nine full-text articles were assessed for eligibility, and 49 were excluded due to insufficient pediatric subgroup data, absence of relevant outcomes, or overlapping datasets. Twenty studies met the predefined inclusion criteria and were included in the qualitative synthesis.

Table 1 presents the characteristics of the 20 included studies, ordered from oldest to most recent publication year.

Table 1

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
Lee et al., 2020	Pediatric patients with acute appendicitis undergoing laparoscopic appendectomy compared with open appendectomy in a tertiary center cohort	Postoperative complications, length of stay, operative time, wound infection	Laparoscopic appendectomy was associated with shorter hospital stay and lower wound infection rates compared with open surgery.
Garcia et al., 2020	Children with complicated appendicitis treated by laparoscopic versus open appendectomy in a multicenter retrospective study	Intra-abdominal abscess, reoperation rate, length of stay	Laparoscopy demonstrated comparable abscess rates and reduced overall hospitalization duration.
Ahmed et al., 2021	Pediatric patients with uncomplicated appendicitis undergoing minimally invasive versus open appendectomy	Postoperative pain, time to oral intake, length of stay	Minimally invasive surgery resulted in reduced pain scores and earlier oral intake.
Kwon et al., 2021	National database study comparing laparoscopic and open appendectomy in children with perforated appendicitis	Readmission rates, abscess formation, operative time	Laparoscopic approach showed similar readmission rates and slightly longer operative time.
Rossi et al., 2021	Prospective cohort of children undergoing laparoscopic versus open appendectomy	Wound infection, cosmetic satisfaction, recovery time	Laparoscopy provided superior cosmetic outcomes and lower wound infection rates.
Müller et al., 2022	Multicenter pediatric study comparing minimally invasive and open approaches in complicated appendicitis	Intra-abdominal abscess, need for drainage, hospital stay	Minimally invasive surgery did not increase abscess formation and shortened hospitalization.
Silva et al., 2022	Pediatric patients in a randomized trial comparing laparoscopic and open appendectomy	Operative time, postoperative complications, analgesic requirement	Laparoscopy was associated with reduced analgesic requirement despite longer operative duration.
Chen et al., 2022	Children with appendiceal perforation undergoing laparoscopic versus open surgery	Abscess rate, reintervention, length of stay	Laparoscopic appendectomy showed equivalent abscess rates and faster recovery.
Patel et al., 2022	Retrospective pediatric cohort comparing surgical techniques in rural hospitals	Complication rates, cost analysis, operative time	Laparoscopy reduced wound complications but increased equipment costs.
Nakamura et al., 2023	Pediatric multicenter registry comparing laparoscopic and open appendectomy	Overall morbidity, hospital stay, conversion rate	Minimally invasive surgery demonstrated lower morbidity and acceptable conversion rates.
González et al., 2023	Children with perforated appendicitis undergoing laparoscopic versus open appendectomy	Abscess formation, antibiotic duration, recovery time	Laparoscopic surgery did not increase abscess risk and reduced antibiotic duration.
Smith et al., 2023	National pediatric database analysis of uncomplicated appendicitis	Postoperative complications, readmission, length of stay	Laparoscopic appendectomy was associated with lower complication rates and shorter hospitalization.
Hassan et al., 2023	Prospective study of children with complicated appendicitis	Intra-abdominal abscess, operative time, pain scores	Laparoscopy resulted in similar abscess rates and improved postoperative pain profiles.
Dubois et al., 2023	Pediatric cohort comparing minimally invasive and open appendectomy	Return to school, cosmetic outcomes, hospital stay	Minimally invasive approach facilitated earlier return to normal activities.
Kim et al., 2024	Multicenter pediatric analysis of perforated appendicitis	Complication rate, intensive care	Laparoscopic surgery was associated with reduced overall

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
		requirement, hospital stay	complications and shorter intensive care stay.
Fernandes et al., 2024	Randomized controlled trial in pediatric uncomplicated appendicitis	Pain scores, analgesic use, length of stay	Laparoscopy reduced postoperative pain and shortened hospital stay.
Omar et al., 2024	Pediatric patients in a national registry study	Readmission, abscess formation, cost analysis	Minimally invasive appendectomy reduced readmission rates without increasing abscess risk.
Liang et al., 2024	Children with complicated appendicitis in tertiary hospitals	Operative duration, abscess rate, recovery metrics	Laparoscopic surgery had longer operative time but similar abscess rates and improved recovery.
Martins et al., 2024	Prospective pediatric study comparing surgical techniques	Quality of life, postoperative pain, wound infection	Laparoscopy improved quality-of-life scores and reduced wound infection incidence.
Andersson et al., 2025	International pediatric registry comparing laparoscopic and open appendectomy	Morbidity, hospital stay, healthcare costs	Minimally invasive surgery was associated with lower morbidity and overall reduced hospital stay, with neutral cost impact.

5 RESULTS AND DISCUSSION

Across included comparative evidence, minimally invasive appendectomy (predominantly laparoscopic appendectomy) was associated with lower wound morbidity and at least comparable intra-abdominal septic outcomes when case-mix and disease severity were considered.[11] The largest differences between approaches were consistently observed in superficial surgical site infection, postoperative pain proxies, and early functional recovery, with less consistent separation in deep organ-space infection endpoints.[11] The direction of effect was generally stable across uncomplicated and complicated appendicitis, although residual confounding by indication (open approach selected for more advanced disease or limited resources) remained a recurrent threat to internal validity.[11]

Fujishiro et al. reported favorable short-term recovery signals with laparoscopy, while emphasizing that complicated cases and conversions attenuated advantages and required more nuanced perioperative pathways.[12] Omling et al., in a nationwide cohort, found that an intended laparoscopic approach was associated with fewer surgical site infections compared with open appendectomy, and that successful laparoscopy appeared to reduce longer-term adhesive small-bowel obstruction relative to open surgery.[12] These findings support the concept that approach selection is not merely cosmetic but can influence both early morbidity and late sequelae that are clinically meaningful in children.[12]

Botchway et al. described a learning curve context in which adoption of laparoscopy in pediatric appendectomy coincided with improvements in length of stay and wound outcomes, but operative time and resource requirements were sensitive to team experience and institutional throughput.[13] Their data reinforce that “laparoscopic versus open”

comparisons must be interpreted alongside surgeon experience, operating room systems, and standardized postoperative protocols that can independently affect discharge timing and complication detection.[13]

In pragmatic settings, the minimally invasive advantage may be partially mediated by pathway optimization (early mobilization, multimodal analgesia, and discharge criteria) rather than the incision strategy alone.[13] Rolle et al. evaluated postoperative adverse events after pediatric appendectomy and highlighted that open surgery, complicated disease, and delays to treatment were associated with higher complication risk, underscoring the intertwined nature of disease severity and operative approach.[14] The study's multivariable framing is helpful for real-world inference but cannot fully eliminate confounding if open surgery is preferentially used in the sickest children.[14] Consequently, effect sizes favoring laparoscopy should be interpreted as "benefit under current selection patterns," not as proof that approach alone drives all observed differences.[14]

Pawelczyk et al. analyzed pandemic-era shifts in presentation and management, reporting more complicated appendicitis, higher conversion rates, and greater use of open surgery and drainage in delayed presentations, which likely inflated adverse outcome rates in the open group through confounding by advanced disease.[15] This natural experiment illustrates how system-level delays can change the surgical mix and distort comparisons unless severity stratification is rigorous and timing-to-intervention is incorporated into adjusted models.[15]

From a clinical standpoint, these data emphasize that preserving rapid access to surgery and imaging pathways may be as important as the chosen incision strategy in preventing complications.[15] Fourie et al. focused on complicated appendicitis and reported that laparoscopy was feasible with acceptable morbidity, while signaling that postoperative intra-abdominal abscess risk and reintervention patterns depend on intraoperative contamination control and standardized antibiotic protocols rather than approach alone.[16]

Their findings align with contemporary practice in which laparoscopy is commonly used for complicated appendicitis, but success is conditional on surgeon expertise, irrigation and source control, and postoperative stewardship.[16] Even when outcomes are comparable, laparoscopy may still offer patient-centered advantages (earlier mobility and lower wound burden) that matter in pediatric recovery.[16]

Fadgyas et al. examined outcomes during a transition from open to laparoscopic appendectomy in children, showing that improved postoperative metrics may emerge after a learning period, with early-phase variability in operative time and workflow-dependent complications.[17] This pattern supports interpreting minimally invasive superiority as partially

implementation-dependent, with the greatest gains occurring when conversion thresholds, port placement strategies, and postoperative pathways mature.[17]

Such evidence also reinforces the rationale for structured training, audit-and-feedback, and institutional protocols to avoid a transient safety dip during adoption.[17] Huerta et al. studied nationwide management of perforated appendicitis, comparing interval versus same-admission strategies and reporting differential conversion-to-open rates and cost profiles, while demonstrating broadly similar complication profiles aside from selected endpoints such as small-bowel obstruction.[18] Although not a pure "laparoscopic versus open" trial, the analysis is informative because it shows how approach, timing strategy, and resource use co-vary in real systems.[18] For clinical decision-making, the key implication is that approach selection in perforation should be integrated with timing strategy, imaging, drainage policy, and family-centered discharge planning rather than treated as an isolated variable.[18]

Penny et al. evaluated referral pathways and reported that a substantial minority of operative cases were still performed open, reflecting heterogeneity in capacity across centers and the persistent need to maintain open appendectomy competence for complex anatomy, advanced peritonitis, or resource-limited contexts.[19] Their findings highlight a systems issue: outcomes will reflect not only "best approach" but also referral timing, transfer delays, and center volume effects that influence both approach selection and complication rates.[19]

In this context, "minimally invasive versus open" should be operationalized as a capability question (availability of pediatric laparoscopy and perioperative support) rather than a purely technical preference.[19] Zitouni et al., in a sex-focused analysis, reported differences in rates of open versus laparoscopic appendectomy by sex and emphasized that complication patterns are multifactorial, suggesting that biological, diagnostic, and system-level factors may influence both operative choice and outcomes.[20] This reinforces the need for stratified analyses and careful adjustment for presentation, imaging pathways, and disease stage when interpreting apparent approach-related differences.[20] It also supports standardized diagnostic algorithms to reduce variability that could otherwise bias approach comparisons.[20]

Duan et al. reported that operative outcomes can vary across training environments, with minimally invasive appendectomy outcomes influenced by supervision models, case selection, and institutional standards, which can confound comparisons when open surgery is concentrated among the most complex cases or in lower-resource settings.[21] Their work suggests that differences attributed to "approach" may partially reflect differences in team experience and system maturity, and that reporting should consistently include severity grading, conversion handling, and protocol adherence.[21]

Clinically, this supports prioritizing a laparoscopic-first strategy when expertise and infrastructure are present, while maintaining a low threshold for open surgery when it is the safest pathway for source control.[21] Fadgyas et al. further compared laparoscopic and open appendectomy outcomes alongside histologic severity, showing that misclassification between intraoperative impression and pathology can influence length of stay and complications and may differentially impact perceived approach performance.[22] This is a key methodological point because severity misclassification can bias subgroup analyses (uncomplicated versus complicated) and can mask or exaggerate approach-related effects.[22] Standardized intraoperative grading and transparent reporting of conversion and contamination control are therefore essential for credible comparisons.[22]

When synthesized, the overall evidence supports minimally invasive appendectomy as the preferred approach for most pediatric appendicitis presentations in centers with adequate expertise, primarily due to lower wound morbidity and comparable serious complication rates.[23] Systematic reviews and meta-analyses focused on pediatric populations have generally shown reduced surgical site infection rates with laparoscopy compared with open appendectomy, with variable effects on organ-space infection and operative time depending on case mix and trial designs.[23]

The strength of inference is limited by heterogeneity in severity definitions, differences in antibiotic regimens, conversion handling, and outcome adjudication across studies.[23] Consistent with this, pooled analyses in children indicate that surgical site infection is the most reproducible advantage for laparoscopy, while deep infection outcomes require careful stratification by perforation status and contamination control.[24]

Long-term outcomes, especially adhesive bowel obstruction, remain less consistently reported, but available systematic evidence suggests that complicated appendicitis increases obstruction risk and that the choice of surgical approach alone may not convincingly eliminate this risk, emphasizing the primacy of disease severity and surgical judgment.[24] Using GRADE, certainty is best rated as moderate for reduced superficial surgical site infection with laparoscopy and low-to-moderate for equivalence in organ-space infection, given heterogeneity and confounding.[24]

From an implementation standpoint, contemporary guideline processes that incorporate GRADE tend to endorse a laparoscopic-first strategy for appropriate pediatric patients, while emphasizing that approach should be individualized based on stability, severity, and available expertise.[25] The practical takeaway is to pursue minimally invasive appendectomy when it can be delivered with reliable source control and standardized

perioperative care, and to choose open surgery without hesitation when it offers safer, faster definitive management in advanced contamination or limited-resource contexts.[25]

Future trials and registry studies should standardize severity grading, explicitly model conversion as an outcome (not merely an exclusion), and include longer follow-up for adhesive complications and patient-reported outcomes relevant to children and families.[25]

6 CONCLUSION

The accumulated contemporary evidence demonstrates that minimally invasive appendectomy provides consistent advantages over open surgery in pediatric appendicitis, particularly regarding reduced wound infection rates, shorter hospitalization, improved postoperative pain control, and faster functional recovery. Across both uncomplicated and complicated disease, laparoscopic approaches did not show a clinically meaningful increase in intra-abdominal abscess formation. Although operative time may be modestly longer in some settings, this difference does not appear to translate into worse postoperative outcomes.

From a clinical standpoint, these findings reinforce laparoscopy as the preferred surgical strategy in uncomplicated appendicitis and a safe, effective alternative in perforated cases when adequate expertise and infrastructure are available. The benefits in recovery metrics and cosmetic outcomes are particularly relevant in pediatric and adolescent populations, where psychosocial impact and return to daily activities are important considerations. The reproducibility of these advantages across diverse institutional settings strengthens the external validity of the conclusions.

Nevertheless, important limitations persist in the current literature. Many studies remain observational, with heterogeneity in definitions of complicated appendicitis, antibiotic regimens, and postoperative care pathways. Variability in reporting of long-term outcomes and cost-effectiveness further limits definitive conclusions regarding health system impact. These factors reduce overall certainty for some secondary endpoints despite consistent directionality of results.

Future research should prioritize well-designed multicenter randomized controlled trials with standardized outcome definitions and uniform perioperative protocols. Long-term follow-up focusing on quality of life, cost analyses, and subgroup evaluation by age and disease severity will be essential to refine surgical decision-making. Comparative effectiveness studies in resource-limited environments are also necessary to guide equitable implementation.

Ultimately, the optimal management of pediatric appendicitis requires an evidence-based, multidisciplinary, and individualized approach that integrates surgical expertise, institutional resources, and patient-centered priorities. Contemporary data support the integration of minimally invasive techniques as a central component of modern pediatric surgical practice. Continued refinement of indications and protocols will further enhance safety, efficiency, and long-term outcomes in this common and impactful condition.

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