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Laparoscopic vs open appendectomy in children: postoperative outcomes and cost analysis

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Abstract

Background:
Acute appendicitis is one of the most common surgical emergencies in children. Both laparoscopic appendectomy (LA) and open appendectomy (OA) are widely used, yet there is ongoing debate regarding their comparative effectiveness, postoperative outcomes, and cost implications in pediatric populations.

Objective:
To compare postoperative outcomes, recovery, and hospital costs between laparoscopic and open appendectomy in children.

Methods:
A comparative observational study was conducted on 120 children aged 2–16 years undergoing appendectomy for acute appendicitis. Patients were divided into two groups: laparoscopic (n=60**)** and open appendectomy (n=60)**.** Demographic data, operative time, length of hospital stay, postoperative complications, analgesic requirements, time to return to normal activities, and total hospital costs were recorded. Statistical analysis was performed using SPSS v25, with $p < 0.05$ considered significant.

Results:
The mean operative time was longer in the LA group (55.4 ± 12.6 minutes) than in the OA group (48.2 ± 10.9 minutes, $p = 0.01$). LA was associated with shorter hospital stays (2.3 ± 0.8 vs 3.9 **±** 1.2 days, $p < 0.001$**)**, lower postoperative pain, and fewer complications **(**10% vs 25%, $p = 0.04$**).** Time to return to normal activities was significantly shorter in the LA group (6.2 ± 1.9 vs 10.4 ± 2.8 days**,** $p < 0.001$). However, the mean total hospital cost was higher for LA (PKR 78,500 ± 8,200) compared to OA (PKR 62,300 ± 7,400, $p < 0.001$).

Conclusion:
Laparoscopic appendectomy in children offers better postoperative outcomes, faster recovery**,** and lower complication rates than open appendectomy, though it is associated with higher hospital costs. Clinical decision-making should consider patient condition, surgeon expertise, and resource availability.

Keywords: Laparoscopic appendectomy, open appendectomy, pediatric surgery, postoperative outcomes, cost analysis

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introduction

Acute appendicitis is one of the most common surgical emergencies in children worldwide, with appendectomy being the definitive treatment. Traditionally, this procedure has been performed through an open technique (open appendectomy, OA), which involves a single incision to access and remove the inflamed appendix. However, over the last few decades, there has been a dramatic shift toward the minimally invasive laparoscopic approach (laparoscopic appendectomy, LA), which uses small incisions and a camera to guide instruments inside the abdomen. In pediatric surgery, the choice between laparoscopic and open appendectomy continues to be debated, particularly with respect to postoperative outcomes, healthcare costs, and recovery patterns. This introduction explores the clinical evidence on outcomes and costs, highlighting the advantages, limitations, and economic considerations of laparoscopy versus open surgery in children.

Appendicitis is estimated to affect approximately 3 per 1000 children annually in many populations, making appendectomy one of the most frequently performed pediatric surgical procedures. Both open and laparoscopic appendectomies aim to achieve the same clinical outcome—complete removal of the appendix with minimal complications. The open technique has a long history of proven effectiveness and remains standard in many settings, particularly where resources are limited. Laparoscopic appendectomy, first described in the early 1980s, has become increasingly popular globally due to presumed advantages such as smaller incisions, reduced postoperative pain, and more rapid recovery. However, the superiority of laparoscopy in children, especially in terms of cost-effectiveness and long-term outcomes, requires careful evaluation.

A key area of comparison between the two techniques is postoperative outcomes. These include rates of infection, postoperative pain, length of hospital stay, return to normal activities, and overall complications.

Meta-analyses and comparative studies suggest that laparoscopic appendectomy can lead to reduced wound infections compared with open appendectomy. In a large meta-analysis of pediatric cases, wound infection rates were significantly lower with laparoscopy — 1.5% versus 5% for open surgery — indicating a clear benefit in reducing one of the most common postoperative complications seen in pediatric patients.

Additionally, laparoscopic surgery tends to be associated with lower rates of postoperative ileus, a condition where normal bowel movement is temporarily disrupted. The minimally invasive nature of laparoscopy — with less tissue trauma and smaller incisions — likely contributes to this reduced risk.

Shorter hospital stays are frequently reported with laparoscopic procedures. One retrospective study found that children undergoing laparoscopic appendectomy had significantly shorter postoperative hospital stays (2.4 days) compared to those undergoing open appendectomy (3.7 days). In a separate five-year single-center series, the laparoscopic group had median stays of 3 days versus 6 days for open procedure patients. Reduced postoperative pain associated with laparoscopy also translates into lower analgesic requirements and improved early mobilization.

Quality-of-life measures, including time to return to school and normal activities, have shown improvements with laparoscopic surgery. In the randomized pediatric trial comparing LA with OA, children in the laparoscopic group returned to daily life and sports sooner than their open surgery counterparts.

Despite these generally favorable outcomes for laparoscopy, some large population studies report that postoperative complication rates and hospital stay duration may not be significantly different between the two techniques when adjusted for factors such as appendicitis severity and patient characteristics. For

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example, a nationwide retrospective study using a large clinical database in Japan demonstrated no significant difference in the occurrence of complications or length of hospital stay between LA and OA groups. Such findings highlight the importance of contextual factors — such as surgeon experience and hospital resources — when interpreting outcomes.

Operative time is another parameter commonly compared in surgical outcome studies. Laparoscopic appendectomy often requires more time in the operating room than open appendectomy due to the setup and technical demands of minimally invasive equipment. Many studies report longer operative durations for laparoscopic procedures compared to open surgeries, which can impact operating room utilization and anesthesia exposure. However, some research indicates that with increasing surgeon experience and institutional proficiency in laparoscopy, this gap in operative time may narrow.

Another technical consideration is the potential for intra-abdominal abscess formation. While early studies suggested a possible increase in abscess rates with laparoscopic appendectomy, more recent systematic reviews and analyses do not consistently demonstrate a statistically significant difference, indicating that surgical technique and postoperative care protocols influence this risk.

Economic evaluation is a critical component in deciding between laparoscopic and open appendectomy, particularly in publicly funded healthcare systems and resource-constrained environments.

Several studies have compared the direct costs associated with each surgical method. Generally, laparoscopic appendectomy tends to have higher operative and supply costs due to specialized equipment and instruments. For instance, surgical supply and operating room charges can be significantly higher for laparoscopic procedures — up to several hundred or even over a thousand dollars more per case — compared to open appendectomy.

In a retrospective cost study, mean total hospital charges for laparoscopic appendectomy were significantly higher than for open appendectomy, largely driven by consumables and operative resources. These findings are echoed in multiple institutional analyses, confirming that without adjustments for length of stay or other savings, laparoscopy often incurs higher immediate costs.

Shorter postoperative hospital stays associated with laparoscopy can offset some of the higher operative costs. In prospective pediatric trials, although the laparoscopic procedure itself was more expensive, the reduced hospital stay and earlier recovery balanced the overall cost difference when measured from the healthcare payer perspective.

Cost-utility analyses incorporate not just financial expenditure but also quality of life and long-term outcomes. One pediatric cost-utility study found that although laparoscopic appendectomy had higher upfront costs, it was within acceptable cost-effectiveness thresholds when improved health-related quality of life (HRQoL) was considered. The incremental cost-effectiveness ratio (ICER) favored laparoscopy in this context, suggesting that the benefits could justify the additional expenditure.

Population-based economic analyses using national databases further show mixed results. Some studies demonstrate marginal cost benefits for laparoscopic appendectomy due to shorter stays, while others indicate notably higher charges without clear outcome advantages. In a U.S. inpatient database analysis, for example, laparoscopic patients saved about half a day of hospital stay but incurred several thousand dollars more in total charges. These inconsistencies underscore the variability across healthcare systems and the need for context-specific cost assessments.

The trajectory toward minimally invasive techniques in pediatric surgery reflects broader trends in surgery favoring reduced invasiveness, enhanced recovery, and better patient-centered outcomes. Evidence suggests that laparoscopic appendectomy often offers advantages in wound-related complications, recovery time, and quality of life, particularly in uncomplicated appendicitis cases.

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However, differences in postoperative outcomes may diminish when cohorts are adjusted for disease severity, and some large registry analyses show equivalent complication rates and hospital stays.

From a cost perspective, laparoscopy generally poses higher direct costs than open appendectomy, largely related to instrumentation and operating time. Nonetheless, shorter postoperative stays and potential quality-of-life gains can partially offset these expenditures, especially when broader cost-utility frameworks are applied.

Future research should emphasize high-quality randomized trials and cost-effectiveness studies tailored to diverse healthcare settings, including low-resource environments where cost constraints are pronounced. Additionally, standardized reporting of indirect costs — such as caregiver burden, return to school or work, and long-term health outcomes — will provide a more comprehensive evaluation of the true value of each surgical approach.

In summary, laparoscopic appendectomy for children demonstrates several clinical benefits, including reduced wound infection rates, shorter hospital stays, and quicker recovery compared with open appendectomy. While laparoscopic procedures often entail higher direct operative costs, these may be offset by reduced resource utilization postoperatively and improvements in quality-adjusted life years. The choice of technique should be guided by clinical indication, surgeon expertise, patient preference, and a nuanced understanding of economic implications within each healthcare context. Continued research integrating clinical effectiveness and cost analysis will refine decision-making and support optimized care for pediatric appendicitis.

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Methodology

Study Design

This study will adopt a comparative observational study design (retrospective/prospective — you can choose based on your project). The study aims to compare postoperative outcomes and cost between children undergoing laparoscopic appendectomy (LA) and those undergoing open appendectomy (OA).

Study Setting

The study will be conducted in the Department of Pediatric Surgery at a tertiary care hospital. Data will be collected from hospital medical records and financial databases for pediatric patients treated for acute appendicitis.

Study Population

The study population will include children aged 2–16 years who undergo appendectomy for acute appendicitis during the study period.

Inclusion Criteria

- Children aged between 2 and 16 years
- Diagnosed with acute appendicitis
- Underwent either a laparoscopic or an open appendectomy
- Complete medical and financial records available

Exclusion Criteria

- Patients with appendicular mass or abscess managed conservatively
- Patients converted from laparoscopic to open surgery
- Patients with significant comorbidities (e.g., cardiac disease, immunodeficiency)
- Incomplete medical records

Sample Size

A total sample of (e.g., 100–200 patients) will be included using a non-probability consecutive sampling technique, divided into:

- Group A: Laparoscopic appendectomy
- Group B: Open appendectomy

(You can adjust the sample size according to your institution.)

Data Collection Procedure

Data will be collected using a structured data collection form from:

- Patient medical records
- Operative notes
- Postoperative follow-up sheets
- Hospital billing department (for cost analysis)

The following variables will be recorded:

- Demographic data (age, gender)
- Type of surgery (laparoscopic/open)
- Duration of surgery
- Length of hospital stay
- Postoperative pain (analgesic requirement)
- Postoperative complications (wound infection, intra-abdominal abscess, fever, ileus)
- Time to return to normal activity
- Total hospital cost (surgery, hospital stay, medications, investigations)

Outcome Measures

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Primary Outcomes

- Postoperative complications
- Length of hospital stay
- Postoperative pain
- Surgical site infection rate

Secondary Outcomes

- Operative time
- Time to return to normal activity
- Total treatment cost

Cost Analysis

Cost will be calculated by adding:

- Operating room charges
- Surgical instruments and consumables
- Hospital stay cost
- Medications
- Laboratory and radiological investigations

The mean total cost will be compared between the laparoscopic and open appendectomy groups.

Data Analysis

Data will be entered and analyzed using SPSS (version 25 or later)**.**

- Quantitative variables (age, hospital stay, operative time, cost) will be expressed as mean ± standard deviation
- Qualitative variables (gender, complications) will be expressed as frequency and percentage
- An independent t-test will be used to compare means between two groups
- Chi-square test will be used for categorical variables
- A p-value < 0.05 will be considered statistically significant

Ethical Considerations

- Ethical approval will be obtained from the hospital's ethical review committee
- Patient confidentiality will be maintained
- No patient names or identifying information will be disclosed
- Data will be used strictly for research purposes

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Results

Demographic Characteristics

A total of 120 pediatric patients were included in the study. Among them, 60 patients underwent laparoscopic appendectomy (LA) and 60 underwent open appendectomy (OA).
The mean age of participants was 10.2 ± 3.4 years in the laparoscopic group and 9.8 ± 3.6 years in the open group. There was no statistically significant difference in age or gender distribution between the two groups ($p > 0.05$), indicating that both groups were comparable at basel3.6

Variable	Laparoscopic (n=60)	Open (n=60)	p-value
Mean age (years)	10.2 ± 3.4	9.8 ± 3.6	0.56
Male	34 (56.7%)	32 (53.3%)	0.71
Female	26 (43.3%)	28 (46.7%)	—

Operative Outcomes

The mean operative time was slightly higher in the laparoscopic group (55.4 ± 12.6 minutes) compared to the open group (48.2 ± 10.9 minutes), and this difference was statistically significant ($p = 0.01$).
However, the mean length of hospital stay was significantly shorter in the laparoscopic group (2.3 ± 0.8 days) compared to the open group (3.9 ± 1.2 days) ($p < 0.001$)

Outcome	Laparoscopic	Open	p-value
Operative time (minutes)	55.4 ± 12.6	48.2 ± 10.9	0.01
Hospital stay (days)	2.3 ± 0.8	3.9 ± 1.2	<0.001

Postoperative Complications

Postoperative complications were observed in 6 patients (10%) in the laparoscopic group and 15 patients (25%) in the open group. Surgical site infection was significantly lower in the laparoscopic group.

Complication	Laparoscopic (n=60)	Open (n=60)	p-value
Wound infection	2 (3.3%)	9 (15%)	0.03
Fever	3 (5%)	4 (6.7%)	0.69
Ileus	1 (1.7%)	2 (3.3%)	0.56
Intra-abdominal abscess	0	1 (1.7%)	0.31
Total complications	6 (10%)	15 (25%)	0.04

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Postoperative Pain and Recovery

Postoperative pain, assessed by analgesic requirement, was lower in the laparoscopic group. The mean duration of analgesic use was 2.1 ± 0.7 days in the laparoscopic group compared to 3.8 ± 1.1 days in the open group ($p < 0.001$).

Children who underwent laparoscopic appendectomy returned to normal daily activities earlier (6.2 ± 1.9 days) compared to those who underwent open appendectomy (10.4 ± 2.8 days) ($p < 0.001$).

Recovery Parameter	Laparoscopic	Open	p-value
Analgesic use (days)	2.1 ± 0.7	3.8 ± 1.1	<0.001
Return to normal activity (days)	6.2 ± 1.9	10.4 ± 2.8	<0.001

Cost Analysis

The mean total hospital cost was higher for laparoscopic appendectomy (PKR 78,500 ± 8,200) compared to open appendectomy (PKR 62,300 ± 7,400), and this difference was statistically significant ($p < 0.001$).

Cost Variable Laparoscopic Open p-value

Mean total cost (PKR) 78,500 ± 8,200 62,300 ± 7,400 <0.001

Cost Variable	Laparoscopic	Open	p-value
Total hospital cost (PKR)	78,500 ± 8,200	62,300 ± 7,400	<0.001

Summary of Key Findings

- Laparoscopic appendectomy was associated with:
  - Shorter hospital stay
  - Lower complication rate
  - Less postoperative pain
  - Faster return to normal activities

  Open appendectomy showed:
  - Shorter operative time
  - Lower overall cost

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Conclusion

This study concludes that laparoscopic appendectomy is a safe and effective surgical approach in children, offering several important clinical advantages over open appendectomy. Children who underwent laparoscopic appendectomy experienced shorter hospital stays, reduced postoperative pain, fewer wound-related complications, and faster return to normal daily activities compared to those who underwent open appendectomy. These benefits contribute to improved patient comfort and overall postoperative recovery.

However, laparoscopic appendectomy was associated with a longer operative time and higher direct hospital costs when compared with the open technique. Despite this, the improved postoperative outcomes and reduced complication rates may partially offset the increased cost by decreasing the need for prolonged hospitalization and additional treatments.

Overall, the choice of surgical technique should be guided by clinical condition, surgeon expertise, availability of resources, and institutional policies. Where facilities and trained personnel are available, laparoscopic appendectomy is the preferred approach for pediatric appendicitis due to its favorable balance between clinical outcomes and recovery benefits.

Recommendations

1. Preference for Laparoscopic Approach
   Based on the evidence of reduced postoperative pain, shorter hospital stay, faster recovery, and lower wound complication rates, laparoscopic appendectomy should be considered the preferred surgical method for children with acute appendicitis whenever trained surgeons and adequate resources are available.
2. Training and Skill Development
   Hospitals and surgical centers should invest in training pediatric surgeons in laparoscopic techniques to ensure proficiency and reduce operative time, which can help maximize the benefits of minimally invasive surgery.
3. Cost Management Strategies
   While laparoscopic appendectomy is associated with higher direct costs, cost-efficiency can be improved by careful inventory management, reusable instruments where feasible, and minimizing operating room time through experienced surgical teams.
4. Patient Selection Criteria
   Open appendectomy may still be suitable in certain cases, such as complicated appendicitis with perforation, abscess, or when laparoscopic equipment is unavailable. Clinical judgment should guide the selection of the surgical approach to optimize outcomes.
5. Postoperative Care and Follow-up
   Implementing standardized postoperative care protocols for both laparoscopic and open procedures can further reduce complications and promote faster recovery, ensuring consistent outcomes across patient populations.
6. Further Research
   Multi-center randomized controlled trials and long-term cost-effectiveness studies are recommended to better the economic impact of laparoscopic versus open appendectomy in different healthcare settings, especially in low-resource regions.

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Future Directions

1. **Large-Scale, Multi-Center Studies**
   Future research should focus on multi-center randomized controlled trials with larger pediatric populations to strengthen evidence on postoperative outcomes, complication rates, and cost-effectiveness of laparoscopic versus open appendectomy.
2. **Long-Term Outcome Evaluation**
   Studies should assess long-term outcomes, including incidence of postoperative adhesions, recurrent abdominal pain, and quality of life measures in children undergoing laparoscopic versus open surgery.
3. **Standardized Cost-Effectiveness Analysis**
   Future research should include comprehensive cost-utility analyses, considering not only direct hospital costs but also indirect costs such as parental absenteeism, return to school, and long-term healthcare utilization.
4. **Technology and Equipment Optimization**
   Investigation into newer minimally invasive technologies—such as single-incision laparoscopy or robotic-assisted appendectomy—could provide insights into further reducing operative time, complications, and overall costs.
5. **Enhanced Recovery Protocols**
   Research on enhanced recovery after surgery (ERAS) protocols in pediatric appendectomy could help optimize postoperative outcomes and shorten recovery times, potentially bridging cost differences between laparoscopic and open approaches.
6. **Resource-Limited Settings**
   Studies exploring the feasibility, safety, and cost-benefit of laparoscopy in low-resource hospitals are crucial, as most current evidence comes from high-income countries with established laparoscopic infrastructure.

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