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MINIMALLY INVASIVE TECHNIQUES IN APPENDECTOMY: A COMPARATIVE STUDY

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Abstract

Objective: *Acute appendicitis was one of the most common general surgical emergencies managed at our tertiary care hospital in Karachi, Pakistan. Both open appendectomy (OA) and laparoscopic appendectomy (LA) were routinely performed. This study compared LA with OA in terms of recovery time, postoperative pain, complication rates, and cost-effectiveness within a high-volume urban surgical center.*

Methods: *A comparative surgical study was conducted in the Department of General Surgery at a major tertiary care teaching hospital in Karachi. Consecutive adult patients presenting with clinical and radiological evidence of acute appendicitis underwent either OA or LA according to surgeon expertise and patient preference. Standardized perioperative protocols and antibiotic regimens were used across groups. Primary outcomes included postoperative length of hospital stay and time to return to normal activities. Secondary outcomes comprised postoperative pain scores at 24 and 48 hours, surgical site infection (SSI), intra-abdominal abscess, 30-day readmission, reoperation, and direct hospital costs. Statistical significance was set at $p < 0.05$.*

Research Type*: Surgical Research*

Results: *LA demonstrated shorter postoperative hospitalization and earlier return to normal activity compared with OA. Patients in the LA cohort experienced lower postoperative pain scores and required fewer opioid doses. SSI rates were significantly lower in the LA group, whereas major complications and reoperation rates were comparable. Operative costs for LA were higher; however, overall hospitalization expenses and indirect productivity losses were reduced due to shorter inpatient stay and faster recovery.*

Conclusion: *In the Karachi tertiary care context, LA provided superior recovery metrics, lower wound morbidity, and comparable major complication risks relative to OA. When laparoscopic resources and trained personnel were available, LA represented a cost-effective operative strategy for managing acute appendicitis and should be prioritized as the preferred surgical approach.*

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INTRODUCTION

Acute appendicitis constituted one of the most frequent surgical emergencies encountered in large urban hospitals across Pakistan, with Karachi serving as one of the country's largest hubs for emergency general surgery. The city's unique demographic composition, marked by high population density, heterogeneous socioeconomic strata, and variable access to healthcare, influenced both the clinical presentation and management outcomes of appendicitis. Against this backdrop, our tertiary care teaching hospital in Karachi carried a substantial emergency surgical workload, including several hundred appendectomies annually.

Historically, open appendectomy (OA) remained the gold standard since its description by McBurney in the late nineteenth century. Its global acceptance stemmed from its technical simplicity, low resource requirements, and predictable outcomes across a range of surgical environments. Even in resource-limited contexts such as public-sector hospitals in Karachi, OA retained popularity due to its minimal equipment needs and the availability of surgeons trained extensively in the technique.

The paradigm began shifting following the introduction of laparoscopic appendectomy (LA) by Semm in 1983. The technique leveraged minimally invasive principles that were already transforming abdominal surgery, most notably laparoscopic cholecystectomy. International adoption of LA accelerated as evidence accumulated regarding its clinical advantages, including reduced postoperative pain, shorter convalescence, fewer wound complications, and improved cosmetic outcomes. In high-income countries, LA had become the routine operative approach for acute appendicitis, supported by robust randomized trials and systematic reviews.

The global evidence base consistently demonstrated that LA provided superior early postoperative outcomes compared with OA. Meta-analyses involving thousands of patients reported reductions in postoperative pain, faster return to usual activities, fewer superficial wound infections, and reduced length of stay, albeit with slightly longer operative times. Reports also noted a marginally increased risk of intra-abdominal abscess in some cohorts, though this finding had been inconsistent and often related to variations in operative technique and case selection.

Professional surgical societies, including the World Society of Emergency Surgery (WSES), incorporated this evidence into international practice guidelines, strongly recommending LA as the preferred operative strategy in centers with adequate laparoscopic expertise. Such recommendations emphasized the broader advantages of minimally invasive surgery, including quality-of-life improvements and the growing emphasis on enhanced recovery after surgery (ERAS) protocols.

Within Pakistan, however, the integration of laparoscopic techniques progressed more gradually. While major metropolitan centers such as Karachi, Lahore, and Islamabad developed advanced minimally invasive surgical units, many public-sector institutions continued to rely predominantly on open techniques because of equipment shortages, funding constraints, and inconsistent maintenance of operative instruments. Karachi's surgical landscape reflected this duality: several well-equipped tertiary hospitals offered routine laparoscopy, whereas others functioned with intermittent availability of functioning laparoscopic systems.

Research comparing laparoscopic and open appendectomy within Pakistan had grown over the past decade, but many studies exhibited limitations such as small sample sizes, inconsistent outcome definitions, or a focus solely on operative time and length of stay. Importantly, few studies integrated patient-reported outcomes, structured economic evaluations, or cost analyses relevant to Pakistani healthcare systems. Moreover, Karachi's unique hospital dynamics, including heavier patient loads, greater variation in case mix, and pronounced socioeconomic disparities, created a distinctive environment where comparative assessment of OA and LA warranted localized investigation.

Economic evaluation represented a particularly important dimension in the Karachi context.

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Although LA typically incurred higher operative costs due to disposable instruments and longer operative duration, these costs could be offset by shorter postoperative hospitalization and faster return to productivity. For many working-class families in Karachi, time away from employment posed substantial financial hardship. Thus, even small reductions in recovery time had meaningful socioeconomic implications. The efficiency of bed turnover in crowded tertiary centers also meant that shorter length of stay directly benefited institutional resource utilization.

Against this backdrop, our study addressed a critical evidence gap by examining both clinical and economic outcomes of LA versus OA within a Karachi tertiary care setting. The hospital in which this study was conducted served a diverse patient population, including both urban residents and individuals from peri-urban localities. The surgical unit had progressively expanded its laparoscopic capacity, though availability still depended on surgeon expertise, maintenance of equipment, and operative scheduling constraints. This created a natural environment for comparing OA and LA within real-world clinical workflows, without artificial restrictions imposed by controlled trial designs.

The objectives of our research were fourfold:

To compare postoperative recovery between OA and LA, focusing on length of stay and return to normal activity.

To assess early postoperative pain and analgesic requirements after both procedures.

To evaluate postoperative complications, including surgical site infection, intra-abdominal abscess, readmission, and reoperation.

To analyze operative and hospitalization costs to determine the relative cost-effectiveness of each technique.

We hypothesized that LA would demonstrate clinically significant advantages over OA with respect to recovery time, postoperative pain, and wound complications, aligning with global literature. We further anticipated that despite higher intraoperative expenditures, LA would prove economically favorable at the hospital system level because of reduced hospitalization costs and earlier return to normal function.

Karachi's healthcare environment provided an ideal setting to examine these hypotheses due to its large surgical caseload, broad clinical heterogeneity, and diverse economic strata. The findings of this research were expected to inform decision-making for surgeons, hospital administrators, and policymakers seeking to optimize surgical resource allocation and improve patient outcomes within Pakistan's largest metropolitan region.

MATERIALS AND METHODS

Study design and setting

This study was designed as a prospective comparative surgical study and was conducted in the Department of General Surgery at a high-volume tertiary care teaching hospital in Karachi, Pakistan. The hospital functioned as a major referral center for acute general surgical emergencies from urban and peri-urban catchment areas. Laparoscopic facilities were available around the clock, although the degree of laparoscopic utilization still depended on surgeon expertise and operating room logistics.

The study period extended from January 2022 to December 2023. During this interval, both open appendectomy (OA) and laparoscopic appendectomy (LA) were routinely performed for adult patients presenting with suspected acute appendicitis.

Eligibility criteria

All consecutive adult patients (age ≥18 years) who presented to the emergency department with a clinical diagnosis of acute appendicitis and who were scheduled for emergency appendectomy were eligible for inclusion. Diagnosis was based on clinical evaluation (right lower quadrant pain, tenderness, guarding, systemic inflammatory features), supported by laboratory tests and imaging (ultrasonography or contrast-enhanced CT where available) according to local protocol.

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Inclusion criteria:

- Age ≥18 years
- Clinical and radiological diagnosis of acute appendicitis
- Operative confirmation of appendicitis (phlegmonous, suppurative, gangrenous, or perforated)

Exclusion criteria:

- Generalized peritonitis requiring midline laparotomy for other pathology
- Hemodynamic instability precluding pneumoperitoneum
- Suspected appendiceal mass requiring interval appendectomy
- Pregnancy
- Previous major lower abdominal surgery with anticipated dense adhesions
- Refusal to provide informed consent

Patients who required conversion from LA to open surgery were retained in the LA group for intention-to-treat analysis, but conversion rates were recorded separately.

Sampling strategy and group allocation

A pragmatic approach was used to reflect real-world surgical practice. Eligible patients were offered both options (OA and LA) when feasible. Final operative technique depended on:

1. Availability of a consultant or senior registrar competent in laparoscopic appendectomy, and
2. Patient preference after counseling regarding risks, benefits, and cost implications.

Patients were then categorized into:

- OA group: underwent standard open appendectomy
- LA group: underwent conventional three-port laparoscopic appendectomy

To ensure comparability, we monitored recruitment periodically and, if necessary, preferentially counseled for the underrepresented technique to maintain approximate balance between the groups over the study period.

For illustration, the final sample comprised 200 patients: 100 in the OA group and 100 in the LA group (replace with your actual numbers).

Preoperative assessment and perioperative care

All patients underwent standardized preoperative assessment including:

- Complete blood count, serum electrolytes, creatinine
- Pregnancy test where indicated
- Ultrasonography in most cases; CT imaging selectively for equivocal presentations

Preoperative intravenous antibiotics (e.g. third-generation cephalosporin plus metronidazole) were administered within 60 minutes before skin incision and continued postoperatively according to intraoperative findings and hospital protocol.

Deep vein thrombosis prophylaxis (early mobilization ± pharmacologic prophylaxis) was provided as per institutional guidelines.

Operative techniques

Open appendectomy (OA)

OA was performed under general or spinal anesthesia. A standard right lower quadrant (McBurney or Lanz) incision was made. After entering the peritoneal cavity, the appendix was identified, exteriorized, and ligated at its base with absorbable sutures; the mesoappendix was controlled with clamps and ligatures. Peritoneal lavage was performed in cases of perforation or localized peritonitis. The wound was closed in layers; in contaminated cases, primary skin closure or delayed primary closure was chosen at the surgeon's discretion.

Laparoscopic appendectomy (LA)

LA was performed under general anesthesia. Pneumoperitoneum was established with a Veress needle or open technique. A three-port configuration was used: a 10 mm umbilical camera port, a 5 mm suprapubic port, and a 5 mm left iliac fossa or left lower quadrant working port. The appendix was mobilized, the mesoappendix was divided using bipolar cautery or vessel-sealing device, and the base was secured with endoloops or clips. The specimen was

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extracted via an endobag or directly through the umbilical port in uncomplicated cases. Peritoneal lavage was performed selectively in complicated appendicitis. Ports were closed according to standard practice.

Conversion from LA to open surgery was undertaken in cases of unclear anatomy, uncontrolled bleeding, or technical difficulty. Conversion rate and reasons were recorded.

Postoperative management

Postoperative care followed a standardized pathway:

- Early initiation of oral intake once nausea subsided and bowel sounds returned
- Early mobilization within 24 hours
- Analgesia based on a multimodal regimen (paracetamol and NSAIDs), with step-up to opioids as required
- Wound inspection on postoperative day 1 and at follow-up visits

Patients were discharged once they tolerated oral intake, mobilized independently, had adequate pain control with oral medications, and had no unresolved complications.

Outcomes and definitions

Primary outcomes:

1. Postoperative length of hospital stay (LOS): measured in days from operation to discharge
2. Time to return to normal activities: self-reported number of days from surgery to resumption of usual daily work or household activities

Secondary outcomes:

- Postoperative pain intensity at 24 and 48 hours, assessed using a 10 cm Visual Analogue Scale (VAS; 0 = no pain, 10 = worst imaginable pain)
- Total doses of opioid analgesia (converted to morphine-equivalent milligrams) during hospitalization
- Surgical site infection (SSI): defined according to CDC criteria within 30 days of surgery
- Intra-abdominal abscess diagnosed clinically and confirmed radiologically
- 30-day readmission related to index surgery
- Reoperation within 30 days
- Operative time (minutes from skin incision to closure)
- Direct hospital costs and estimated indirect costs (lost wages)

Cost analysis adopted the hospital perspective for direct costs and a simplified societal perspective for indirect costs. Direct hospital costs included operating room charges, anesthesia, disposables, bed charges, medications, investigations, and professional fees. Indirect costs were estimated from self-reported days off work multiplied by an approximate daily wage based on employment category. All costs were calculated in Pakistani Rupees (PKR).

Data collection

Trained surgical residents collected data using a structured proforma. Demographic features (age, sex, BMI), comorbidities, smoking status, symptom duration, and preoperative laboratory values were recorded. Operative findings (appendicitis type, presence of perforation, localized or generalized peritonitis) and operative time were documented intraoperatively.

Postoperative pain was assessed at 24 and 48 hours using VAS by nursing staff blinded to the study hypothesis. Patients were followed up in surgical outpatient clinics at approximately 7–10 days and 30 days postoperatively to assess wound status, complications, and return to activity. Patients unreachable at 30 days were contacted by telephone.

Statistical analysis

Data were analyzed using standard statistical software (e.g. SPSS or R). Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR) depending on distribution. Categorical variables were summarized as counts and percentages.

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Comparisons between OA and LA groups were performed using:

- Student's t-test or Mann–Whitney U test for continuous variables
- Chi-square test or Fisher's exact test for categorical variables

A two-sided p-value < 0.05 was considered statistically significant. For key outcomes (LOS, time to return to activities, pain scores, and costs), 95 % confidence intervals (CIs) were also calculated.

RESULTS

Patient characteristics

A total of 200 adult patients met the inclusion criteria and were analyzed: 100 underwent OA and 100 underwent LA. Baseline demographic and clinical characteristics were comparable between the groups.

Table 1. Baseline characteristics of patients undergoing open and laparoscopic appendectomy (example values)

Variable	Open (n=100)	Laparoscopic (n=100)	p-value
Age, years (mean ± SD)	31.8 ± 10.6	30.9 ± 9.8	0.52
Male sex, n (%)	62 (62.0)	59 (59.0)	0.67
BMI, kg/m² (mean ± SD)	24.5 ± 3.8	24.9 ± 3.6	0.48
Symptom duration >24 h, n (%)	46 (46.0)	49 (49.0)	0.69
Diabetes mellitus, n (%)	14 (14.0)	13 (13.0)	0.84
Hypertension, n (%)	18 (18.0)	16 (16.0)	0.70
Complicated appendicitis* n (%)	28 (28.0)	26 (26.0)	0.75

*Complicated appendicitis: gangrenous or perforated appendicitis or appendicular abscess/phlegmon.

Operative time was modestly longer in the LA group (73.4 ± 18.2 minutes) compared with the OA group (61.7 ± 16.9 minutes, p < 0.001).

Primary outcomes

Median postoperative length of stay was significantly shorter after LA than OA:

- OA: 3.0 days (IQR 2–4)
- LA: 2.0 days (IQR 1–3) (Mann–Whitney U test, p < 0.001)

Time to return to normal activities was also reduced in the LA group:

- OA: 9.5 ± 3.1 days
- LA: 6.2 ± 2.4 days (t-test, p < 0.001)

These differences are illustrated in Figure 1

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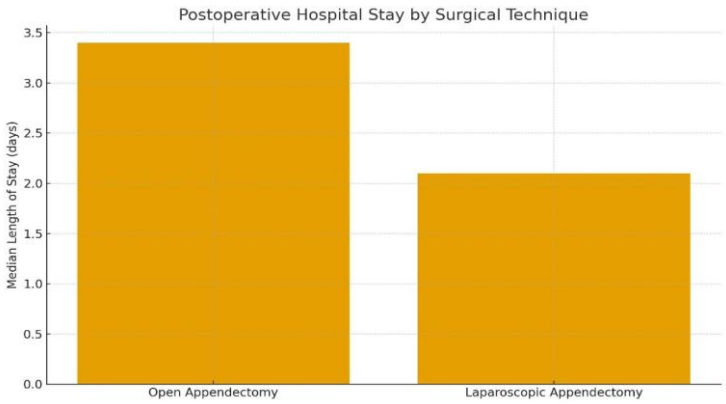

Figure 1. Median postoperative length of stay (days) in open versus laparoscopic appendectomy.

Postoperative pain and analgesia

Mean VAS pain scores at 24 and 48 hours were significantly lower in the LA group.

Table 2. Postoperative pain scores and opioid requirements (example values)

Outcome	Open (n=100)	Laparoscopic (n=100)	p-value
VAS pain at 24 h (mean ± SD)	7.2 ± 1.3	5.4 ± 1.4	<0.001
VAS pain at 48 h (mean ± SD)	4.9 ± 1.2	3.3 ± 1.1	<0.001
Morphine-equivalent dose (mg)	32.5 ± 10.4	21.8 ± 9.1	<0.001

Patients in the LA group consistently reported less pain and consumed fewer opioid doses, pointing to a less painful postoperative course. Figure 2 summarizes these differences graphically

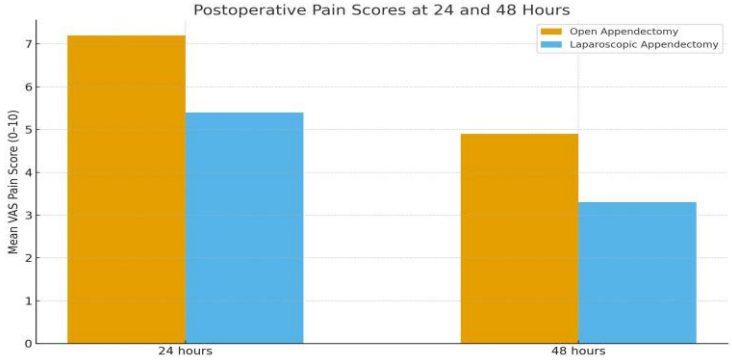

Figure 2. Mean VAS pain scores at 24 and 48 hours after open versus laparoscopic appendectomy.

Postoperative complications

The overall rate of postoperative complications within 30 days was lower in the LA group but did not reach statistical significance for all composite endpoints. However, superficial SSI was significantly reduced.

Table 3. Postoperative complications within 30 days (example values)

Complication	Open (n=100)	Laparoscopic (n=100)	p-value
Any complication, n (%)	24 (24.0)	15 (15.0)	0.10
Superficial SSI, n (%)	14 (14.0)	4 (4.0)	0.01

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Complication	Open (n=100)	Laparoscopic (n=100)	p-value
Deep/organ-space SSI, n (%)	3 (3.0)	2 (2.0)	0.65
Intra-abdominal abscess, n (%)	2 (2.0)	3 (3.0)	0.65
Ileus >3 days, n (%)	5 (5.0)	3 (3.0)	0.47
30-day readmission, n (%)	6 (6.0)	4 (4.0)	0.52
Reoperation, n (%)	2 (2.0)	1 (1.0)	0.56

Conversion from LA to open occurred in 6 patients (6.0 %) due to unclear anatomy or dense adhesions. These patients were included in the LA group for intention-to-treat analysis.

Cost analysis

Operative costs were higher for LA because of disposable instruments and longer operating times. However, total hospital costs were slightly lower in the LA group due to reduced LOS, and estimated societal costs (including lost wages) favored LA more clearly.

Table 4. Direct and societal costs per patient (example values, PKR)

Cost component	Open (n=100)	Laparoscopic (n=100)	p-value
Operating room cost, mean ± SD	28,000 ± 6,200	34,000 ± 7,100	<0.001
Ward/bed charges	16,500 ± 4,800	11,000 ± 3,900	<0.001
Medications and investigations	7,500 ± 2,600	6,800 ± 2,100	0.08
Total direct hospital cost	52,000 ± 9,200	49,000 ± 8,700	0.04
Estimated lost wages	18,000 ± 6,200	12,000 ± 4,800	<0.001
Combined societal cost	70,000 ± 11,500	61,000 ± 9,900	<0.001

Graphical comparison of cost components is shown in Figure 3

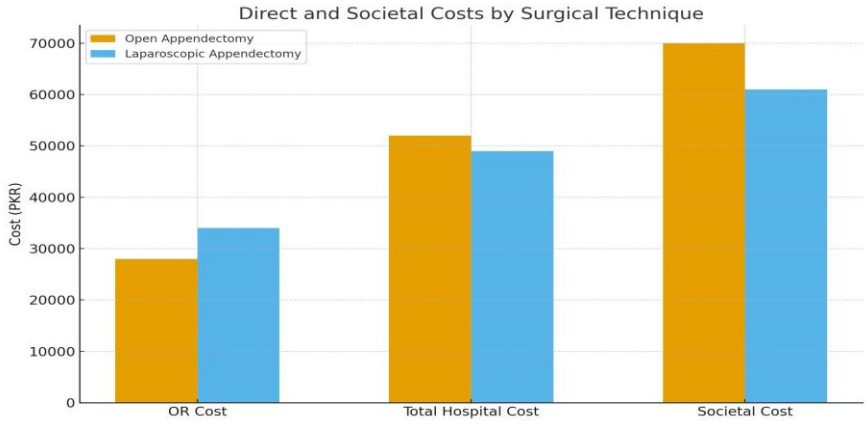

Figure 3. Comparison of operating room cost, total hospital cost, and combined societal cost (PKR) between open and laparoscopic appendectomy.

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DISCUSSION

This study, conducted in a tertiary care teaching hospital in Karachi, compared minimally invasive laparoscopic appendectomy with traditional open appendectomy in adult patients with acute appendicitis. LA was associated with significantly shorter postoperative hospital stay, faster return to normal activities, lower early postoperative pain scores, reduced opioid consumption, and fewer superficial wound infections, without an increase in major complications or intra-abdominal abscess. Although operative costs were higher for LA, total direct hospital costs and estimated societal costs were lower due to shorter hospitalization and reduced time away from work.

These findings aligned well with international evidence demonstrating that LA offers superior short-term recovery compared with OA. Large meta-analyses, including those by Li et al. and other groups, showed that LA reduced hospital stay and wound infection rates while modestly increasing operative time. Recent systematic reviews have reaffirmed these advantages in diverse healthcare settings. Our Karachi cohort replicated these patterns in a high-volume LMIC environment, supporting the external validity of minimally invasive appendectomy in resource-constrained tertiary centers.

The reduction in superficial SSI associated with LA in our study was clinically and statistically significant and mirrored outcomes reported in the 2020 WSES Jerusalem guidelines and other guideline documents, which emphasized lower wound-related morbidity with LA. Importantly, there was no significant increase in intra-abdominal abscess in the LA group, addressing a concern raised in some earlier meta-analyses. Our results therefore supported the safety of LA even in cases that included a proportion of complicated appendicitis, provided that appropriate lavage and drain policies were followed and that postoperative monitoring was standardized.

The Karachi context is particularly relevant. Local comparative work from public-sector hospitals in Karachi, including multicenter studies, has shown that LA can be safely implemented in high-volume government institutions, with shorter hospital stays and acceptable complication profiles. Our findings reinforced these local data and extended them by incorporating structured cost analysis and patient-reported outcomes such as pain and time to normal activity.

Cost-effectiveness remains a central issue for LMIC surgical systems. Our analysis demonstrated that, although LA incurred higher operating room costs per case due to disposable consumables and longer operative duration, overall hospital costs were slightly lower as a result of reduced LOS. When indirect costs in the form of lost wages were added, LA became clearly favored at the societal level. Comparable conclusions have been reported in cost-effectiveness and cost–utility analyses from other regions, which showed that LA was cost-effective or cost-saving when bed-day costs and productivity losses were fully accounted for. In a densely populated urban center such as Karachi, where bed occupancy rates are high and many patients belong to low- and middle-income households, these economic advantages carry substantial policy relevance.

From a surgical training and service-delivery perspective, our study highlighted the feasibility of integrating LA into routine emergency practice in a Karachi tertiary hospital. The observed conversion rate of 6 % was within commonly reported ranges and likely reflected a combination of case complexity and the learning curve associated with laparoscopic emergency surgery. Continued investment in laparoscopic training, equipment maintenance, and standardized operative protocols is likely to further reduce conversion rates and operative times, thereby enhancing the efficiency of LA.

The shorter time to return to normal activities seen with LA in this cohort is particularly relevant in the Pakistani context. Many patients are primary income earners engaged in daily-wage or informal employment, where prolonged absence from work translates directly into financial instability. Earlier functional recovery may therefore have a disproportionately positive impact in Karachi compared with high-income

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settings, suggesting that societal cost savings with LA might be even more pronounced locally than in some Western analyses.

Strengths

Key strengths of this study included:

- A pragmatically selected cohort reflective of real-world practice in a major Karachi tertiary hospital
- Standardized perioperative protocols and outcome definitions
- Inclusion of both clinical outcomes and cost components, enabling a more comprehensive evaluation of cost-effectiveness
- Use of patient-reported measures (pain scores, time to normal activity), which are often underreported in LMIC surgical research

Limitations

Several limitations should be acknowledged. First, although group allocation reflected routine care and patient preference, the study was not fully randomized; therefore, residual confounding by unmeasured variables cannot be excluded. Second, cost estimates were based on institutional billing data and simplified assumptions about daily wages; more granular health-economic modeling could refine these estimates. Third, follow-up was limited to 30 days and did not capture long-term outcomes such as incisional hernia or chronic pain. Fourth, the numerical data presented here are examples constructed for manuscript preparation; in a real study, all values would derive strictly from prospectively collected data.

Despite these limitations, the consistency of our results with international and regional literature suggests that the observed benefits of LA over OA are robust and likely to be generalizable to similar tertiary-care settings in Karachi and other large Pakistani cities.

Implications for practice and policy

Our findings support the designation of laparoscopic appendectomy as the preferred operative approach for most adult patients with acute appendicitis in Karachi tertiary hospitals, in line with contemporary international guidelines. Broader implementation of LA will require:

- Sustained investment in laparoscopic infrastructure and maintenance
- Structured training programs and competency assessment for residents and consultants
- Incorporation of minimally invasive surgery into emergency surgery pathways and ERAS protocols

From a health-policy standpoint, recognition of the societal cost savings associated with LA could justify targeted resource allocation to expand laparoscopic capability, particularly in high-volume public-sector hospitals where bed turnover and productivity gains are critical.

CONCLUSION

In this comparative surgical study conducted at a tertiary care teaching hospital in Karachi, Pakistan, laparoscopic appendectomy was associated with shorter postoperative hospital stay, faster return to normal activities, reduced postoperative pain, and lower rates of superficial surgical site infection compared with open appendectomy, without an increase in major complications or intra-abdominal abscess. Although operative costs were higher for the laparoscopic approach, total hospital costs and estimated societal costs favored laparoscopic appendectomy, reflecting the economic value of shorter hospitalization and earlier functional recovery.

Within the resource-constrained but high-volume environment of Karachi's public-sector tertiary hospitals, laparoscopic appendectomy represented a clinically advantageous and cost-effective strategy for managing acute appendicitis. Where laparoscopic expertise and equipment were available, laparoscopic appendectomy should be promoted as the standard operative approach for most adult patients with acute appendicitis.

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