(e) ISSN Online: 2321-9599

(p) ISSN Print: 2348-6805

ORIGINAL ARTICLE

Laparoscopic versus open appendectomy in complicated appendicitis: a comparative analysis of outcomes and cost

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ABSTRACT:
Background: Acute appendicitis is one of the most common surgical emergencies, and a significant proportion of patients present with complicated appendicitis, including perforation, gangrene, abscess, or peritonitis. While laparoscopic appendectomy has become the standard of care for uncomplicated appendicitis, its role in complicated appendicitis remains debated due to concerns regarding operative difficulty, infectious complications, and cost. Comparative evaluation of laparoscopic versus open appendectomy in complicated appendicitis is essential, particularly in tertiary care settings where advanced surgical facilities are available. **Aim:**To compare laparoscopic and open appendectomy in patients with complicated appendicitis with respect to operative parameters, postoperative recovery, complications, and cost. **Materials and Methods:**This comparative analytical study included 92 patients diagnosed intraoperatively with complicated appendicitis at a tertiary care hospital. Patients were equally divided into two groups: laparoscopic appendectomy (n = 46) and open appendectomy (n = 46). Demographic data, intraoperative findings, operative time, postoperative recovery parameters (pain score, time to oral intake, ambulation, and length of hospital stay), postoperative complications, and cost details were recorded. **Results:**Baseline demographic characteristics were comparable between the two groups. Operative time was significantly longer in the laparoscopic group (58.74 ± 12.36 minutes) compared to the open group (51.28 ± 10.94 minutes; p = 0.004). Laparoscopic appendectomy demonstrated significantly lower postoperative pain scores, earlier resumption of oral intake, shorter hospital stay, and higher rates of early ambulation (all p < 0.001). Surgical site infection was significantly lower in the laparoscopic group (8.70% vs 23.91%; p = 0.047), and overall complication rates were also reduced (15.22% vs 36.96%; p = 0.018). Although operative costs were higher for laparoscopic appendectomy, postoperative costs were significantly lower; however, total treatment cost remained marginally higher in the laparoscopic group. **Conclusion:**Laparoscopic appendectomy is a safe and effective approach for complicated appendicitis, offering superior postoperative recovery and lower morbidity compared to open appendectomy, with acceptable overall cost implications in a tertiary care setting.
Keywords: Complicated appendicitis; Laparoscopic appendectomy; Open appendectomy; Postoperative outcomes; Cost analysis

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This article may be cited as: Pushkar P, Tungaria A. Laparoscopic versus open appendectomy in complicated appendicitis: a comparative analysis of outcomes and cost. J Adv Med Dent Scie Res 2014;2(4):322-327.

INTRODUCTION

Acute appendicitis remains one of the most frequent causes of emergency abdominal surgery worldwide, and appendectomy continues to be the definitive treatment in the majority of patients. While many cases present early with uncomplicated inflammation, a substantial proportion progress to complicated appendicitis, characterized by perforation, gangrene, localized abscess/phlegmon, or peritonitis. These advanced presentations are clinically important because they are associated with higher bacterial load, greater inflammatory response, technically demanding surgery, prolonged postoperative recovery, and increased risk of morbidity such as surgical site infection (SSI), ileus, and intra-abdominal abscess formation. In tertiary care hospitals, complicated appendicitis is encountered commonly due to referral patterns, delayed presentation, and higher rates of comorbidity, making optimization of surgical strategy and resource utilization a priority.[1]Historically, open appendectomy has been considered the standard approach for both uncomplicated and complicated appendicitis because it is widely familiar, can be performed quickly, and requires minimal equipment. However, the global expansion of minimally invasive surgery has led to widespread adoption of laparoscopic appendectomy, driven by potential advantages such as reduced postoperative pain, smaller incisions, earlier mobilization, improved cosmesis, and shorter length of hospital stay. In complicated appendicitis, the laparoscopic approach offers additional theoretical benefits including superior visualization of the peritoneal cavity, better assessment of contamination, targeted lavage, and the ability to address associated pathology. Despite these advantages, surgeons have remained cautious because complicated disease can involve dense adhesions, friable tissues, purulent contamination, and distorted

anatomy, all of which may increase operative complexity and operative time.[2]A major source of debate has been whether laparoscopy in complicated appendicitis increases the risk of postoperative intra-abdominal abscess compared with open surgery. Concerns were raised early in the laparoscopic era that pneumoperitoneum, peritoneal contamination, or inadequate source control might predispose to deeper infectious complications. At the same time, accumulating clinical experience suggested that laparoscopic surgery may reduce wound-related morbidity, particularly superficial SSI, which is clinically meaningful in contaminated and dirty operations. Evidence from single-center experiences in complicated appendicitis has supported feasibility and safety, reporting acceptable complication profiles and emphasizing that laparoscopy can be performed effectively when appropriate expertise and standardized technique are available.[2] These findings are particularly relevant to tertiary care centers where laparoscopic equipment, trained personnel, and perioperative protocols can be consistently implemented.Randomized evidence has also contributed to clarifying safety. A randomized controlled trial comparing laparoscopic versus open surgery in complicated appendicitis reported no significant differences in key safety endpoints such as wound sepsis, reoperation, length of stay, and readmissions, supporting the view that laparoscopy is not inferior when performed under controlled conditions by experienced surgeons.[3] Such data are important because selection bias may influence retrospective comparisons, especially when sicker patients are preferentially managed by one approach. Therefore, controlled comparisons are central to guiding institutional policy and surgeon decision-making in settings where complicated appendicitis is frequent and outcomes are closely audited.Beyond clinical outcomes, the modern surgical environment increasingly emphasizes value-based care**,** where outcomes are interpreted alongside costs. Laparoscopic appendectomy generally involves higher direct operative expenditures due to specialized instruments, energy devices, staplers or endoloops, and longer operating room utilization. Conversely, improved recovery parameters—such as reduced pain, earlier oral intake, fewer wound complications, and shorter hospital stay—may decrease postoperative costs and offset the higher procedural expense. Cost analyses comparing laparoscopic and open appendectomy have shown that, while operative costs may be higher for laparoscopy, overall costs can be similar when downstream utilization is reduced, especially in hospitals where length of stay and complication-related spending are major drivers of total cost.[4,5] Systematic reviews and meta-analyses in the last decade have expanded the evidence base and generally report that laparoscopic appendectomy in complicated appendicitis is associated with lower SSI rates and shorter hospitalization, without a consistent increase in intra-abdominal abscess when compared with open surgery.[6]

MATERIALS AND METHODS

This comparative analytical study was conducted at a tertiary care hospital to evaluate and compare the clinical outcomes and cost parameters of laparoscopic appendectomy versus open appendectomy in patients diagnosed with complicated appendicitis. The study included patients who underwent surgical management for complicated appendicitis and were treated according to standard institutional protocols.A total of 92 patients diagnosed with complicated appendicitis were included in the study. Complicated appendicitis was defined as appendicitis associated with perforation, gangrene, periappendiceal abscess, phlegmon, or localized/generalized peritonitis, confirmed intraoperatively. Patients were divided into two groups based on the surgical approach used: those who underwent laparoscopic appendectomy and those who underwent open appendectomy.

Inclusion and Exclusion Criteria

Patients of either sex with an intraoperative diagnosis of complicated appendicitis who were deemed fit for surgery were included in the study. Patients with uncomplicated appendicitis, appendicular mass managed conservatively, previous extensive abdominal surgeries, concomitant major abdominal pathology, or those converted from laparoscopic to open surgery were excluded to maintain uniformity of comparison.

Methodology

Laparoscopic appendectomy was performed using a standard three-port technique under general anesthesia. The appendix was identified, mesoappendix divided using energy devices or ligatures, and the base secured with endoloops or clips before removal. Open appendectomy was performed through a standard right lower quadrant incision, with ligation of the mesoappendix and appendiceal base using conventional techniques. Peritoneal lavage and drain placement were done in both groups when indicated based on intraoperative findings.

The primary outcome measures included operative time, postoperative pain assessment, time to initiation of oral intake, length of hospital stay, postoperative complications such as surgical site infection, intra-abdominal abscess, ileus, and need for reintervention. Secondary outcome measures included total treatment cost, which encompassed operative costs, hospital stay, medications, investigations, and management of postoperative complications.

Data were collected from patient medical records and operative notes using a structured proforma. Demographic details, clinical presentation, intraoperative findings, postoperative recovery parameters, complications, and cost-related data were systematically recorded and analyzed.

Statistical Analysis

Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 21.0. Continuous variables were expressed as mean ± standard deviation and compared using the independent sample t-test or Mann–Whitney U test as appropriate. Categorical variables were expressed as frequencies and percentages and analyzed using the chi-square test or Fisher's exact test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Demographic characteristics (Table 1)

A total of 92 patients with complicated appendicitis were analyzed, with 46 patients in each group. The mean age of patients undergoing laparoscopic appendectomy was 32.48 ± 10.26 years, while in the open appendectomy group it was 34.15 ± 11.04 years; this difference was not statistically significant ($p = 0.452$), indicating comparable age distribution between groups. Male patients constituted the majority in both groups—28 (60.87%) in the laparoscopic group and 30 (65.22%) in the open group—without a significant difference in sex distribution ($p = 0.669$). Similarly, the mean body mass index (BMI) was comparable, with 24.36 ± 3.18 kg/m² in the laparoscopic group versus 24.92 ± 3.41 kg/m² in the open group ($p = 0.412$).

Intraoperative findings and operative parameters (Table 2)

The mean operative time was significantly longer in the laparoscopic group (58.74 ± 12.36 minutes) compared with the open group (51.28 ± 10.94 minutes), and this difference was statistically significant ($p = 0.004$). With respect to intraoperative disease severity indicators, the proportions were similar between groups. Perforated appendix was observed in 21 (45.65%) patients in the laparoscopic group and 23 (50.00%) in the open group ($p = 0.678$). Gangrenous appendix was noted in 14 (30.43%) laparoscopic cases and 13 (28.26%) open cases ($p = 0.818$). Periappendiceal abscess was present in 11 (23.91%) laparoscopic patients and 10 (21.74%) open patients ($p = 0.803$). Drain placement was performed in 19 (41.30%) laparoscopic cases versus 24 (52.17%) open cases; however, the difference was not statistically significant ($p = 0.292$).

Postoperative recovery outcomes (Table 3)

Postoperative recovery parameters showed clear advantages for laparoscopic appendectomy. The mean pain score at 24 hours was significantly lower in the laparoscopic group (3.26 ± 0.88) than in the open group (5.14 ± 1.02), demonstrating superior early postoperative comfort with laparoscopy ($p < 0.001$). Patients in the laparoscopic group also resumed oral intake earlier, with a mean time of 18.42 ± 6.15 hours compared with 29.76 ± 8.92 hours in the open group, which was statistically significant ($p < 0.001$). Length of hospital stay was significantly shorter following laparoscopic appendectomy (3.18 ± 1.06 days) compared to open appendectomy (5.24 ± 1.48 days), again showing strong statistical significance ($p < 0.001$). Early ambulation within 24 hours was achieved in 38 (82.61%) laparoscopic patients versus 21 (45.65%) open patients, a highly significant difference ($p < 0.001$).

Postoperative complications (Table 4)

Postoperative complications were lower in the laparoscopic group compared with the open group, with several outcomes showing clinically meaningful differences. Surgical site infection occurred in 4 (8.70%) laparoscopic cases and 11 (23.91%) open cases, and this reduction in wound infection rates with laparoscopy was statistically significant ($p = 0.047$). Intra-abdominal abscess formation was observed in 3 (6.52%) laparoscopic patients versus 6 (13.04%) open patients; although the laparoscopic group showed fewer abscesses, the difference was not statistically significant ($p = 0.295$). Postoperative ileus occurred in 2 (4.35%) laparoscopic patients compared with 7 (15.22%) open patients, showing a trend favoring laparoscopy but not reaching statistical significance ($p = 0.081$). Reintervention was required in 1 (2.17%) laparoscopic patient and 4 (8.70%) open patients, which again favored laparoscopy but was not statistically significant ($p = 0.168$). Importantly, when complications were assessed overall, the laparoscopic group had significantly fewer total complications—7 (15.22%) versus 17 (36.96%) in the open group—indicating a statistically significant overall morbidity benefit with laparoscopic appendectomy ($p = 0.018$).

Cost analysis (Table 5)

The cost comparison revealed a mixed pattern, with higher operative cost but lower postoperative expenditure in the laparoscopic group. Mean operative cost was significantly higher for laparoscopic appendectomy (18,450 ± 2,360 INR) compared to open appendectomy (13,280 ± 1,940 INR), reflecting additional equipment and operating setup requirements ($p < 0.001$). However, mean postoperative cost was significantly lower in the laparoscopic group (6,120 ± 1,480 INR) compared to the open group (9,760 ± 2,210 INR), which is consistent with shorter hospital stay and fewer complications ($p < 0.001$). When total treatment costs were compared, laparoscopic appendectomy demonstrated a slightly higher overall cost (24,570 ± 3,120 INR) than open appendectomy (23,040 ± 3,480 INR), and this difference was statistically significant ($p = 0.041$).

Table 1: Demographic Characteristics of the Study Population

Variable	Laparoscopic Appendectomy (n = 46)	Open Appendectomy (n = 46)	p-value
Mean age (years)	32.48 ± 10.26	34.15 ± 11.04	0.452
Male	28 (60.87%)	30 (65.22%)	0.669
Female	18 (39.13%)	16 (34.78%)	
Mean BMI (kg/m²)	24.36 ± 3.18	24.92 ± 3.41	0.412

Table 2: Intraoperative Findings and Operative Parameters

Parameter	Laparoscopic Appendectomy (n = 46)	Open Appendectomy (n = 46)	p-value
Mean operative time (minutes)	58.74 ± 12.36	51.28 ± 10.94	0.004
Perforated appendix	21 (45.65%)	23 (50.00%)	0.678
Gangrenous appendix	14 (30.43%)	13 (28.26%)	0.818
Periappendiceal abscess	11 (23.91%)	10 (21.74%)	0.803
Drain placement	19 (41.30%)	24 (52.17%)	0.292

Table 3: Postoperative Recovery Parameters

Parameter	Laparoscopic Appendectomy (n = 46)	Open Appendectomy (n = 46)	p-value
Mean pain score (24 hrs)	3.26 ± 0.88	5.14 ± 1.02	<0.001
Time to oral intake (hours)	18.42 ± 6.15	29.76 ± 8.92	<0.001
Mean hospital stay (days)	3.18 ± 1.06	5.24 ± 1.48	<0.001
Early ambulation (<24 hrs)	38 (82.61%)	21 (45.65%)	<0.001

Table 4: Postoperative Complications

Complication	Laparoscopic Appendectomy (n = 46)	Open Appendectomy (n = 46)	p-value
Surgical site infection	4 (8.70%)	11 (23.91%)	0.047
Intra-abdominal abscess	3 (6.52%)	6 (13.04%)	0.295
Postoperative ileus	2 (4.35%)	7 (15.22%)	0.081
Reintervention required	1 (2.17%)	4 (8.70%)	0.168
Overall complications	7 (15.22%)	17 (36.96%)	0.018

Table 5: Cost Analysis

Cost Parameter	Laparoscopic Appendectomy (n = 46)	Open Appendectomy (n = 46)	p-value
Mean operative cost (INR)	18,450 ± 2,360	13,280 ± 1,940	<0.001
Mean postoperative cost (INR)	6,120 ± 1,480	9,760 ± 2,210	<0.001
Mean total treatment cost (INR)	24,570 ± 3,120	23,040 ± 3,480	0.041

DISCUSSION

In the present series of 92 patients with complicated appendicitis, baseline comparability between the laparoscopic appendectomy (LA) and open appendectomy (OA) cohorts was demonstrated by similar age (32.48 ± 10.26 vs 34.15 ± 11.04 years) and sex distribution (male: 60.87% vs 65.22%), with no statistically significant differences. This pattern of broadly comparable preoperative characteristics is consistent with large observational datasets; for example, Biondi et al (2016) reported closely comparable mean ages between approaches (LA 27.75 ± 14.24 vs OA 29.66 ± 15.13 years), supporting that outcome differences are more likely attributable to operative access and perioperative course rather than baseline demographic imbalance.[7]

Operative time in this study was significantly longer in LA (58.74 ± 12.36 minutes) than OA (51.28 ± 10.94 minutes; p = 0.004), which is a recurring finding in earlier comparative literature and often reflects port placement, intracorporeal dissection, lavage, and specimen retrieval steps. In the prospective randomized double-blind trial by Katkhouda et al (2005), operative time was likewise longer for LA (80 minutes) compared with OA (60 minutes; p < 0.001), mirroring the direction of effect seen here, even though their cohort included both acute and complicated cases rather than being restricted to complicated disease only.[8]

Postoperative recovery advantages in the current study favored laparoscopy, with significantly lower 24-hour pain scores (3.26 ± 0.88 vs 5.14 ± 1.02; p < 0.001), earlier oral intake (18.42 ± 6.15 vs 29.76 ± 8.92 hours; p < 0.001), and shorter hospital stay (3.18 ± 1.06 vs 5.24 ± 1.48 days; p < 0.001), alongside higher early ambulation rates within 24 hours

(82.61% vs 45.65%; p < 0.001). These findings align with perforated/ruptured appendicitis–focused evidence; Towfigh et al (2006) reported that LA reduced length of stay versus OA by 1.6 days overall, and the reduction was approximately 2.0 days in ruptured appendicitis—closely comparable to the 2.06-day stay reduction observed in the present complicated-appendicitis cohort (5.24 to 3.18 days).[9]

With respect to wound-related morbidity, this study demonstrated a significantly lower surgical site infection (SSI) rate following LA compared with OA (8.70% vs 23.91%; p = 0.047), an effect that is clinically important in complicated appendicitis where contamination and tissue handling are substantial. This direction and magnitude are supported by pooled evidence specific to complicated appendicitis: Markides et al (2010) reported significantly reduced SSI with LA compared to OA (odds ratio 0.23; 95% CI 0.14–0.37), consistent with the marked SSI reduction observed in the present study.[10]

Intra-abdominal abscess (IAA) remains a key concern in complicated disease because source control, lavage strategy, stump security, and contamination during extraction may influence postoperative sepsis. In this study, IAA occurred less frequently in LA than OA (6.52% vs 13.04%), but the difference was not statistically significant (p = 0.295), suggesting at minimum non-inferiority of LA for this endpoint within the current sample size. Earlier literature has shown heterogeneity depending on era, technique, and population; for instance, Krisher et al (2001) observed substantially higher abscess rates after LA than OA in perforated appendicitis (24% vs 4.2%) in pediatric patients, highlighting that abscess risk may be context-dependent and influenced by patient age, perforation patterns, irrigation practices, and learning-curve factors—differences that plausibly explain why our adult tertiary-care cohort did not replicate a higher LA abscess burden.[11]

Overall postoperative morbidity in the present study was significantly lower after LA than OA (15.22% vs 36.96%; p = 0.018), with consistent directional reductions across several complications (postoperative ileus: 4.35% vs 15.22%; reintervention: 2.17% vs 8.70%), even where individual comparisons did not reach statistical significance—likely reflecting limited event counts per complication category. These findings are concordant with complicated-appendicitis comparative outcomes reported by Wullstein et al (2001), who documented fewer abdominal wall complications with laparoscopic management (6% vs 18.3%; p < 0.003) and a lower total complication rate in complicated appendicitis when analyzed on an intention-to-treat basis (9.7% vs 23.1%; p = 0.004), reinforcing the concept that morbidity reductions with LA are driven strongly by wound-related and early postoperative recovery benefits.[12]

The economic profile in this study showed higher operative cost for LA (18,450 ± 2,360 INR) than OA (13,280 ± 1,940 INR; p < 0.001), but significantly lower postoperative cost (6,120 ± 1,480 vs 9,760 ± 2,210 INR; p < 0.001), culminating in a modestly higher total treatment cost for LA (24,570 ± 3,120 vs 23,040 ± 3,480 INR; p = 0.041). This "higher theatre cost but partial downstream offset" pattern is consistent with structured economic modeling: Moore et al (2005) found OA to be less expensive from the institutional perspective ($5,171 OA vs $6,118 LA), whereas LA became less costly from the societal perspective ($10,400 LA vs $12,055 OA), emphasizing that conclusions vary by cost perspective and by whether indirect costs (earlier recovery/return to work) are included—an important contextual issue when interpreting the small but statistically significant total-cost difference observed in the current hospital-based costing framework.[13]

Taken together, the present results support LA as an effective approach for complicated appendicitis in a tertiary care setting, offering superior recovery (pain, oral intake timing, ambulation, and shorter stay) and lower overall morbidity—particularly SSI—despite longer operative time and slightly higher total direct hospital cost. This balance is compatible with contemporary evidence-based guidance; Di Saverio et al (2016) incorporated laparoscopic appendectomy within modern management pathways for appendicitis (including complicated presentations), reflecting that, where expertise and resources exist, laparoscopy is an appropriate operative strategy with recognized clinical advantages while still requiring careful attention to intraoperative technique and postoperative infection surveillance in complicated cases.[14]

CONCLUSION

In conclusion, laparoscopic appendectomy in patients with complicated appendicitis was associated with significantly better postoperative recovery, reduced pain, shorter hospital stay, and lower overall complication rates compared to open appendectomy, despite a longer operative time. Although operative costs were higher for the laparoscopic approach, reduced postoperative expenditure partially offset this difference, resulting in only a marginal increase in total treatment cost. These findings support laparoscopic appendectomy as a safe and effective option for complicated appendicitis when performed in a tertiary care setting with appropriate expertise.

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