

Comparative Outcomes of Minimally Invasive vs. Open Surgery: A Systematic Review

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Abstract

Background: Minimally invasive surgery (MIS) has evolved rapidly since the 1990s, primarily encompassing laparoscopic and video-assisted approaches designed to minimize surgical trauma, postoperative pain, and recovery time compared with conventional open procedures.

Objective: This systematic review aimed to compare perioperative, postoperative, and long-term outcomes of laparoscopic MIS and open surgery in adult patients undergoing common general surgical procedures, including cholecystectomy, appendicectomy, and hernia repair.

Methods: A systematic literature search was performed across PubMed, Embase, Cochrane CENTRAL, and Web of Science from database inception through October 2025. Eligible studies included randomized controlled trials (RCTs) and comparative cohort studies involving adults (≥ 18 years) who underwent laparoscopic versus open surgery. Primary outcomes were operative time, intraoperative blood loss, postoperative complications, hospital stay, mortality, and long-term survival. Study quality was assessed using RoB 2 for RCTs and ROBINS-I for non-randomized studies.

Results: Forty-seven studies (26 RCTs and 21 cohort studies) met the inclusion criteria. Laparoscopic MIS demonstrated significantly lower intraoperative blood loss (mean difference -93 mL), shorter hospital stay (mean difference -2.8 days), and fewer postoperative complications (OR = 0.54, 95% CI 0.44–0.67) compared with open procedures. Operative time was moderately longer for laparoscopic surgery (MD = +28 minutes). Mortality was marginally lower in emergency laparoscopic cases (OR = 0.44, 95% CI 0.35–0.54). Long-term outcomes, including recurrence and survival, were comparable between both approaches.

Conclusions: Laparoscopic minimally invasive surgery offers clear short-term benefits—reduced blood loss, fewer complications, and faster postoperative recovery—without compromising long-term outcomes. These advantages are influenced by surgeon expertise, appropriate case selection, and institutional experience.

Keywords: Laparoscopic Surgery, Open Surgery, Cholecystectomy, Appendicectomy, Hernia Repair, Postoperative Recovery, Systematic Review.

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Introduction

Minimally invasive surgery (MIS) represents one of the most transformative developments in modern surgical practice, allowing major operations to be performed through small incisions with the aid of optical magnification and specialized instruments. Compared with traditional open surgery, MIS is associated with reduced postoperative pain, fewer wound infections, faster mobilization, and shorter hospital stays (Park et al., 2021). These advantages have led to its widespread adoption in general surgical procedures such as laparoscopic

cholecystectomy, appendicectomy, and hernia repair, as well as in colorectal, gynecologic, hepatobiliary, and urologic fields (Liu et al., 2022). Over the past three decades, the field has evolved from diagnostic laparoscopy to advanced therapeutic techniques, incorporating high-definition visualization, ergonomic instrument design, and improved energy devices. Such refinements have expanded the indications for laparoscopy—from gallbladder and appendix removal to more complex gastrointestinal and

abdominal wall surgeries (Kim et al., 2017; Arezzo et al., 2017). As surgeons have gained proficiency and as instrumentation has become more versatile, the distinction between open and laparoscopic approaches has become increasingly blurred. Nevertheless, outcomes continue to depend on several modifiable and non-modifiable factors, including patient comorbidities, surgeon expertise, institutional case volume, and adherence to Enhanced Recovery after Surgery (ERAS) protocols (Huang et al., 2021; Zhou et al., 2022).

Despite its advantages, debate persists regarding operative time, cost, and long-term outcomes such as recurrence rates and postoperative complications (Arevalo et al., 2020). Laparoscopic procedures may initially involve longer operative times due to port placement, setup, and instrument coordination challenges during the learning phase (Lee et al., 2020). Furthermore, the reduced tactile feedback in laparoscopy can occasionally limit lesion palpation or compromise lymphadenectomy adequacy in oncologic cases (Kim et al., 2017). Economic analyses also suggest that while shorter hospital stays may reduce overall expenditure, the cost of laparoscopic instruments, maintenance, and ongoing training can offset financial benefits in low-volume centers (Arevalo et al., 2020).

Certain emergency or complex cases—such as trauma laparotomies, dense adhesiolysis, or extensive malignancies—still favor the open approach, which provides greater exposure and direct tactile feedback for effective hemostasis and lesion identification (Santos et al., 2021). Moreover, limitations in surgeon training, availability of equipment, and infrastructural constraints in resource-limited settings may influence the widespread and safe implementation of laparoscopic techniques (Wang et al., 2023).

Therefore, a systematic comparison of outcomes between laparoscopic and open surgery is essential to support evidence-based decision-making. By evaluating perioperative safety, complication rates, postoperative recovery, cost implications, and long-term results, such analyses provide a balanced understanding of the clinical and practical advantages of laparoscopy. The present review synthesizes current evidence comparing laparoscopic and open surgery in adult populations, focusing on perioperative outcomes, recovery profiles, and overall efficacy across commonly performed general surgical procedures. It also aims to identify research gaps, highlight procedure-specific advantages, and guide future strategies toward improving patient-centered surgical care.

Methodology

Search Strategy: This systematic review was conducted in accordance with the Preferred

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021) and was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; registration ID: CRD42025214367).

A comprehensive electronic search was performed across four major databases—PubMed, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL), and Web of Science—to identify relevant studies published from database inception to October 2025.

The Boolean search strategy was constructed and adapted for each database as follows:

“minimally invasive” OR laparoscop* OR “keyhole”) AND (surg* OR operat*) AND (open OR laparotom*) AND (random* OR trial OR cohort*)

This combination of controlled vocabulary (e.g., MeSH/Emtree terms) and free-text keywords ensured high sensitivity for studies comparing laparoscopic and open surgical procedures. The reference lists of included studies and relevant reviews were also manually screened to identify additional eligible articles.

No restrictions were imposed on language, publication status, or geographical region. Non-English studies were translated when necessary to minimize language bias.

Eligibility Criteria: Studies were considered eligible if they met the following predefined criteria: (a) involved adult participants (≥ 18 years) undergoing any general surgical procedure, particularly laparoscopic cholecystectomy, appendectomy, or hernia repair; (b) provided a direct comparison between minimally invasive (laparoscopic) and conventional open surgical approaches; and (c) reported at least one relevant clinical outcome, such as operative time, intraoperative blood loss, postoperative pain, complication rates, length of hospital stay, or recovery-related parameters.

Studies were excluded if they were case reports, case series without a control arm, pediatric or animal studies, editorials, letters, or narrative reviews. This inclusion strategy ensured that only comparative and clinically meaningful evidence relevant to real-world general surgery practice was analyzed.

Data Extraction and Quality Assessment: Two independent reviewers systematically screened titles and abstracts, followed by full-text evaluation to confirm eligibility. Data were extracted using a standardized form that captured key study details, including author, publication year, study design, sample size, patient demographics, surgical

indication, type of laparoscopic or open procedure performed, and outcome measures. Any disagreements between reviewers were resolved through discussion or consultation with a third senior reviewer to ensure methodological rigor and reduce selection bias.

For quality assessment, randomized controlled trials (RCTs) were evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool, focusing on randomization, deviations from intended interventions, missing outcome data, and selective reporting (Higgins et al., 2022). Non-randomized studies, such as prospective or retrospective cohorts, were assessed using the ROBINS-I tool, which evaluates potential bias due to confounding, participant selection, intervention classification, and outcome measurement.

Given the expected heterogeneity across study designs and surgical types, a narrative synthesis approach was primarily adopted. When appropriate, findings from previously published high-quality meta-analyses were incorporated to provide pooled estimates. Results were summarized descriptively and stratified according to procedure type (e.g., cholecystectomy, appendectomy, hernia repair) and outcome domains to ensure clear comparison and clinical applicability.

Results

Study Selection and Characteristics: A total of 1,283 records were identified through electronic database searches. After removing duplicates and screening according to predefined inclusion and exclusion criteria, 47 studies met the eligibility criteria for final analysis. Collectively, these studies included over 42,000 adult patients who underwent either laparoscopic (minimally invasive) or open surgical procedures. Of these, 26 were randomized controlled trials (RCTs) and 21 were comparative cohort studies.

The distribution of surgical specialties showed a predominance of general surgical procedures, particularly laparoscopic cholecystectomy, appendectomy, and hernia repair, which were the focus of most included studies. Additional evidence was derived from colorectal (18 studies), gastric

and hepatobiliary (8 studies), and selected gynecologic (7 studies) operations. The majority of studies were conducted in tertiary academic hospitals and included both elective and emergency cases. Study design, sample size, and follow-up duration varied considerably, reflecting differences in institutional practices but providing a robust comparative evidence base between laparoscopic and open surgical techniques.

Quantitative Outcomes: Across pooled data, laparoscopic approaches consistently outperformed open surgery in most perioperative and postoperative parameters. The mean intraoperative blood loss was significantly lower with laparoscopy, with a mean difference (MD) of -93 mL (95% CI: -132 to -54) (Arezzo et al., 2017). Similarly, overall morbidity was significantly reduced, with a pooled odds ratio (OR) of 0.54 (95% CI: 0.44–0.67), indicating nearly a 46% reduction in postoperative complications (Wang et al., 2023).

Patients undergoing laparoscopy experienced a shorter hospital stay—by an average of 2.8 days (95% CI: -3.5 to -2.1)—compared with those who underwent open procedures (Zhou et al., 2022).

However, operative time tended to be slightly longer in the laparoscopic group, with a mean increase of 28 minutes (95% CI: $+15$ to $+39$), largely attributable to port placement and equipment setup during the early learning phase (Lee et al., 2020).

In emergency appendectomy, laparoscopic intervention demonstrated lower postoperative morbidity and earlier return to oral feeding and ambulation.

Similarly, in laparoscopic cholecystectomy, intraoperative bleeding and postoperative infection rates were significantly lower compared with the open approach, while laparoscopic hernia repair showed reduced postoperative pain and faster resumption of daily activities. Long-term outcomes were generally equivalent, indicating comparable recurrence and survival rates across both techniques (Kim et al., 2017).

Table 1: Quantitative comparison of outcomes between laparoscopic and open surgery

Outcome	Effect Estimate (95% Confidence Interval)	Interpretation	Representative Source
Estimated blood loss	MD = -93 mL (-132 to -54)	Significantly lower intraoperative bleeding in laparoscopy	Arezzo et al., 2017
Overall morbidity	OR = 0.54 (0.44–0.67)	46% reduction in postoperative complications	Wang et al., 2023
Length of hospital stay	MD = -2.8 days (-3.5 to -2.1)	Earlier recovery and discharge in laparoscopic group	Zhou et al., 2022
Operative time	MD = $+28$ min ($+15$ to $+39$)	Slightly longer operative time due to setup and port placement	Lee et al., 2020

Postoperative complications (appendicectomy)	OR = 0.58 (0.46–0.71)	Fewer wound infections and ileus in laparoscopic appendicectomy	Park et al., 2021
Postoperative pain (hernia repair)	MD = -1.9 (-2.7 to -1.1)	Significantly reduced early postoperative pain	Liu et al., 2022

Additional Observations

In addition to the primary quantitative outcomes, several procedure-specific findings were consistently observed across general surgical domains:

- Laparoscopic cholecystectomy demonstrated markedly lower wound infection rates, reduced postoperative ileus, and earlier discharge compared with open cholecystectomy, making it the current standard of care for gallbladder disease.
- Laparoscopic appendicectomy showed clear advantages in postoperative pain control, early ambulation, and faster return to work, without increasing the risk of intra-abdominal abscess or readmission.
- Laparoscopic hernia repair, including both TAPP and TEP techniques, resulted in reduced chronic pain, improved cosmesis, and earlier physical rehabilitation, though it required longer operative time during the initial learning curve.

Collectively, these findings highlight the versatility and clinical safety of laparoscopy across common general surgical procedures, demonstrating consistent reductions in tissue trauma, infection risk, and hospitalization duration, while maintaining equivalent long-term outcomes compared with open surgery.

Risk of Bias

Quality assessment of included studies revealed an overall low-to-moderate risk of bias.

Among randomized controlled trials, random sequence generation and allocation concealment were generally well-documented, though blinding was rarely feasible due to the visible nature of surgical incisions.

For non-randomized cohort studies, ROBINS-I assessment identified moderate risks mainly related to selection bias and confounding, as surgeons often selected lower-risk or younger patients for laparoscopic interventions.

However, the consistency of findings across multiple high-quality trials and independent centers reinforces the robustness of the conclusions.

Overall, the evidence strongly supports that laparoscopic surgery offers superior short-term outcomes—including reduced pain, complications, and hospital stay—while maintaining comparable

long-term efficacy and safety to traditional open procedures in general surgery practice.

Discussion

This systematic review comprehensively compared outcomes of laparoscopic (minimally invasive) and open surgical approaches across major adult general surgery procedures. The collective evidence clearly demonstrates that laparoscopy offers significant short-term advantages including reduced intraoperative blood loss, fewer postoperative complications, and shorter hospital stays without compromising long-term outcomes or procedural safety. These findings reinforce the growing body of literature advocating for wider adoption of laparoscopic techniques in appropriately selected patients (Arezzo et al., 2017; Wang et al., 2023).

Principal Findings

The present analysis confirmed that laparoscopic surgery significantly reduces intraoperative blood loss by approximately 93 mL, which—although numerically modest—translates into clinically meaningful reductions in transfusion needs, postoperative anemia, and hemodynamic instability. The observed 46 % decrease in overall morbidity (OR = 0.54) highlights the advantages of smaller incisions, limited tissue trauma, and superior visualization inherent to laparoscopic procedures (Zhou et al., 2022).

A mean reduction of 2.8 days in hospital stay for laparoscopic cases reflects faster mobilization and recovery of physiological function, key objectives of Enhanced Recovery After Surgery (ERAS) protocols (Huang et al., 2021). Although operative times were about 28 minutes longer, this difference was primarily attributable to setup, port placement, and the early learning curve (Lee et al., 2020). Importantly, longer operative duration did not offset postoperative advantages, as complication and mortality rates remained lower than in open procedures (Zhang et al., 2023). In long-term follow-up, laparoscopic and open approaches showed comparable recurrence and survival outcomes, reaffirming that laparoscopic techniques achieve adequate exposure and resection margins while enhancing perioperative recovery (Kim et al., 2017).

Comparison with Previous Literature

The results of this review align with previous meta-analyses in the field. Arezzo et al. (2017) reported significantly lower morbidity and blood loss in

laparoscopic colorectal and general surgical resections. Zhou et al. (2022) also confirmed shorter hospitalization and reduced postoperative pain when laparoscopy was combined with ERAS principles.

Within general surgery, laparoscopic cholecystectomy has become the gold standard for symptomatic gallstone disease, offering reduced postoperative pain, shorter recovery, and lower wound infection rates compared with open cholecystectomy. Laparoscopic appendectomy consistently yields faster return to oral feeding and ambulation, while laparoscopic hernia repair (TAPP/TEP) demonstrates reduced chronic pain and better cosmesis relative to conventional open repair.

The benefits of laparoscopy are most pronounced in high-volume centers, where surgeon experience mitigates the learning curve effect and ensures procedural consistency and safety (Park et al., 2021).

Mechanistic Insights

The superior outcomes observed with laparoscopy can be explained by its physiological and technical advantages. Smaller incisions and limited dissection minimize the systemic inflammatory response, lower cytokine release, and reduce postoperative pain (Huang et al., 2021). Magnified high-definition visualization allows precise dissection, meticulous hemostasis, and minimal collateral tissue injury. Furthermore, reduced exposure of viscera to ambient air decreases evaporative losses and postoperative ileus. Collectively, these mechanisms promote faster recovery, earlier bowel function, and reduced hospital resource utilization.

Limitations

Despite robust findings, several limitations must be acknowledged. First, heterogeneity among surgical procedures, study designs, and patient characteristics limits precise pooled analysis.

Second, most cohort studies carried moderate risk of bias, as surgeons often selected lower-risk patients for laparoscopic intervention, potentially overestimating benefits (Santos et al., 2021). Third, long-term functional and quality-of-life outcomes were inconsistently reported, restricting full evaluation of patient-centered recovery.

Fourth, cost analyses were limited; while shorter hospitalization reduces expenses, the initial cost of laparoscopic equipment and maintenance may offset savings, especially in low-volume or resource-limited hospitals (Arevalo et al., 2020). Finally, blinding of participants and surgeons was inherently impossible in surgical trials, introducing potential performance bias. Nonetheless, the

consistency of results across multiple randomized and observational studies enhances confidence in the conclusion that laparoscopic surgery offers genuine clinical advantages over open techniques.

Clinical and Research Implications

From a clinical perspective, the findings confirm that laparoscopy should be the preferred approach for suitable patients undergoing general surgical operations such as cholecystectomy, appendectomy, and hernia repair—provided that procedures are performed by trained surgeons in facilities equipped with appropriate instruments. The incorporation of ERAS protocols further augments recovery by reducing postoperative ileus, encouraging early mobilization, and facilitating timely discharge.

Future research should focus on:

- Conducting large multicenter randomized controlled trials to standardize outcome assessment across different general surgery indications.
- Including comprehensive cost-effectiveness and quality-of-life analyses to guide implementation in resource-limited settings.
- Evaluating the environmental and sustainability aspects of disposable laparoscopic instruments within the framework of green surgical practices.

By consolidating current evidence and addressing these gaps, future investigations can refine clinical guidelines and optimize patient-centered care in general surgical practice.

Conclusion

This systematic review provides comprehensive evidence that laparoscopic (minimally invasive) surgical techniques outperform conventional open surgery in short-term perioperative outcomes across general surgical domains, particularly in cholecystectomy, appendectomy, and hernia repair. Laparoscopic procedures consistently result in lower intraoperative blood loss, fewer postoperative complications, reduced pain intensity, and shorter hospital stays, demonstrating clear advantages in recovery time, wound healing, and patient comfort. Importantly, these benefits are achieved without compromising long-term outcomes, including recurrence rates or procedural safety, reaffirming that laparoscopy is a reliable and effective alternative to open surgery when performed by trained surgeons.

Although laparoscopic surgery may involve longer operative times and a greater initial investment in instruments and training, these factors are offset by improved patient outcomes, faster recovery, and lower rates of postoperative morbidity and readmission. Collectively, the available evidence

supports laparoscopy as the preferred approach for most elective and selected emergency procedures within general surgery, provided adequate expertise, infrastructure, and perioperative support systems are available.

Moving forward, emphasis should be placed on standardizing surgical training programs, adopting uniform outcome reporting frameworks, and expanding access to laparoscopic facilities, especially in low- and middle-income healthcare settings. Future multicenter randomized controlled trials that incorporate cost-effectiveness, quality-of-life, and sustainability metrics will help refine the role of minimally invasive surgery in contemporary practice.

In summary, laparoscopic surgery represents the modern surgical paradigm of precision, safety, and enhanced recovery, offering a sustainable pathway toward improved outcomes and more patient-centered care in general surgical practice.

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