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Research Article

Comparative Study of Robotic vs. Laparoscopic Cholecystectomy in Terms of Operative Outcomes

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Abstract

Robotic cholecystectomy has emerged as an advanced minimally invasive approach offering three-dimensional visualization, wristed instrumentation, and improved ergonomics compared with conventional laparoscopic techniques. This comparative cross-sectional study evaluated operative outcomes of robotic versus laparoscopic cholecystectomy in an urban tertiary-care setting. Primary outcomes were operative time, intraoperative blood loss, conversion rate to open surgery, and postoperative pain. Secondary outcomes included length of hospital stay, 30-day readmission, and complication rates (Clavien-Dindo classification). Sample-size computation with Epi-Info (anticipated difference of 10 minutes in mean operative time, α 0.05, power 80%) yielded 140 patients per group; the final cohort comprised 300 patients (150 robotic, 150 laparoscopic) matched on age, sex, and ASA class. Robotic procedures had longer mean operative times (78.4 ± 19.3 vs 64.7 ± 15.1 minutes, $p < 0.001$) but lower mean blood loss (42 ± 12 ml vs 65 ± 20 ml, $p < 0.001$). Conversion to open was lower in robotic cases (0.7% vs 4.0%, $p = 0.04$). Postoperative pain scores at 24 hours were reduced in the robotic group (VAS 2.8 ± 0.9 vs 3.6 ± 1.1, $p < 0.001$), with shorter mean hospital stays (1.9 ± 0.6 vs 2.4 ± 0.8 days, $p < 0.001$). Complication rates were similar, though major complications were slightly fewer in robotic cases (2.0% vs 5.3%, $p = 0.12$). Findings suggest robotic cholecystectomy, while associated with longer operative duration, offers

advantages in blood loss, postoperative pain, and hospital stay, supporting its role in selected patients.

Introduction

Gallstone disease is one of the most common digestive disorders globally, with cholecystectomy remaining the definitive treatment for symptomatic cholelithiasis and gallbladder pathology. Since its introduction in the late 1980s, laparoscopic cholecystectomy has become the gold-standard minimally invasive approach, replacing open procedures in most clinical settings due to its well-documented advantages in terms of postoperative recovery, reduced pain, shorter hospitalization, and improved cosmesis. However, laparoscopic surgery is not without limitations: restricted degrees of freedom of rigid instruments, two-dimensional visualization, surgeon fatigue, and potential ergonomic strain may influence operative performance, particularly in complex or anatomically challenging cases.1-4

Robotic surgery, introduced in general surgery two decades ago and gaining traction in hepatobiliary procedures, seeks to overcome these limitations. Systems such as the da Vinci robotic platform provide three-dimensional magnified vision, articulated instruments with seven degrees of freedom, tremor filtration, and superior ergonomics for the operating surgeon. These technological refinements promise enhanced precision, dissection accuracy, and suturing capability. Advocates argue that such improvements can translate into safer dissections in Calot's triangle, potentially reducing bile duct injuries, lowering conversion rates, and facilitating complex cholecystectomy cases such as those with dense adhesions or obesity.5-9

Nevertheless, robotic cholecystectomy raises critical questions regarding cost-effectiveness, resource utilization, and its comparative benefit over standard laparoscopy for routine gallbladder surgery. While robotic surgery has demonstrated clear advantages in complex reconstructive procedures (e.g., colorectal resections, prostatectomy), its incremental value in relatively standardized operations such as cholecystectomy remains under scrutiny. Operative outcomes—including operative time, intraoperative blood loss, postoperative pain, complications, length of stay, and readmissions—must therefore be rigorously compared between techniques to inform surgical practice, patient counseling, and healthcare policy.10

Recent literature (2021–2024) has reported mixed results. Some studies confirm reduced pain scores and shorter recovery times with robotic approaches, while others emphasize longer operative times and higher costs without significant differences in complication rates. The balance between clinical benefits and economic sustainability is particularly relevant in health systems facing constrained budgets. Moreover, the rapid evolution of robotic platforms and increased surgeon experience may change outcomes over time, necessitating ongoing comparative evaluations.

From a training perspective, robotic cholecystectomy offers opportunities to reduce ergonomic strain and shorten the learning curve for complex laparoscopic skills, potentially improving surgical education. Yet critics argue that routine cholecystectomy may not justify the steep capital and maintenance costs associated with robotic systems. Patients and policymakers must weigh incremental benefits against expenditure, particularly in regions where access to basic laparoscopic surgery remains limited.

Given these considerations, a comparative study was undertaken to systematically evaluate operative outcomes of robotic versus laparoscopic cholecystectomy in a tertiary-care hospital. The hypothesis was that robotic procedures would demonstrate improved intraoperative and postoperative outcomes—particularly in terms of blood loss, pain scores, and hospital stay—albeit at the cost of longer operative duration. Findings from this analysis aim to provide evidence for clinicians and decision-makers regarding the role of robotic systems in routine gallbladder surgery and identify contexts in which robotic advantages may outweigh their drawbacks.

Methodology

A prospective comparative study was conducted at Doctors Hospital Lahore in Collaboration with National Hospital Lahore and Our Lady of Lourdes Hospital, Drogheda, Ireland. Sample size was calculated using Epi-Info, anticipating a 10-minute mean difference in operative time between robotic and laparoscopic cholecystectomy (SD 25 minutes, α 0.05, power 80%), yielding 280 patients; 300 were enrolled to compensate for attrition. Inclusion criteria: adults aged 18–70 years undergoing elective cholecystectomy for symptomatic gallstones or chronic cholecystitis. Exclusion criteria: acute cholecystitis, gallbladder empyema, choledocholithiasis requiring exploration, previous upper abdominal surgery, ASA IV or higher. Patients provided informed

written consent after detailed explanation of risks, benefits, and alternatives. Group allocation (robotic vs laparoscopic) was based on surgeon availability and operating room scheduling; both groups were matched on age, sex, and ASA class. Standardized anesthesia and perioperative protocols were applied. Data collected included operative duration (skin incision to closure), intraoperative blood loss, need for conversion to open, and intraoperative complications. Postoperative outcomes included pain assessment (visual analog scale at 6, 12, 24, and 48 hours), length of hospital stay, wound infection, bile leaks, major complications (Clavien-Dindo ≥III), and 30-day readmission. Data were entered in SPSS v27, with t-tests and chi-square for bivariate comparisons, and logistic regression adjusting for age, sex, BMI, and comorbidity. Ethical approval was obtained from the institutional review board.

Results

Table 1. Baseline characteristics of patients

Variable	Robotic (n=150)	Laparoscopic (n=150)	p-value
Mean age (years ± SD)	44.1 ± 12.3	43.7 ± 11.8	0.79
Female sex, n (%)	96 (64.0)	99 (66.0)	0.72
Mean BMI (kg/m² ± SD)	27.6 ± 4.1	27.2 ± 3.9	0.44
ASA I–II, n (%)	141 (94.0)	138 (92.0)	0.53

Table 2. Operative outcomes

Outcome	Robotic	Laparoscopic	p-value
Operative time (min ± SD)	78.4 ± 19.3	64.7 ± 15.1	<0.001
Intraoperative blood loss (ml ± SD)	42 ± 12	65 ± 20	<0.001
Conversion to open, n (%)	1 (0.7)	6 (4.0)	0.04
Intraoperative bile duct injury, n (%)	0	1 (0.7)	0.32

Table 3. Postoperative outcomes

Outcome	Robotic	Laparoscopic	p-value
Pain score at 24h (VAS ± SD)	2.8 ± 0.9	3.6 ± 1.1	<0.001
Mean hospital stay (days ± SD)	1.9 ± 0.6	2.4 ± 0.8	<0.001
Major complications (Clavien ≥III), n (%)	3 (2.0)	8 (5.3)	0.12
30-day readmission, n (%)	2 (1.3)	5 (3.3)	0.28

Explanatory note: Robotic surgery was associated with longer operative times but lower blood loss, fewer conversions, and reduced pain and hospitalization. Complication rates were comparable between groups.

Discussion

First, this study demonstrates that robotic cholecystectomy offers certain intraoperative and postoperative advantages over standard laparoscopy. Although operative times were longer, blood loss and conversion rates were significantly reduced, aligning with contemporary reports suggesting robotic wristed instruments facilitate precise dissection in Calot's triangle.11-13

Second, the reduction in postoperative pain and shorter hospital stay in the robotic group are clinically relevant. Enhanced dexterity and lower tissue trauma may account for these outcomes, corroborated by randomized and observational studies published since 2021 that reported similar findings.14-16

Third, complication rates were low and not significantly different. The trend toward fewer major complications in the robotic group, though not statistically significant, echoes findings from recent meta-analyses suggesting a possible protective effect with greater surgeon control. However, the overall rarity of bile duct injuries makes it difficult to detect meaningful differences without very large multicenter cohorts.17-20

Fourth, the longer operative time for robotic cases reflects docking and setup requirements, though this difference has been shown to diminish with increased surgeon experience and system familiarity. Future studies should incorporate surgeon learning-curve analyses to determine when efficiency gains offset the initial time penalty.

Fifth, cost considerations remain paramount. While robotic surgery may provide measurable clinical benefits, capital and maintenance costs are high. Economic analyses are essential to determine whether incremental improvements in pain reduction and hospital stay justify expenditure, particularly in resource-limited settings.

Sixth, strengths of this study include prospective data collection, matched cohorts, standardized perioperative protocols, and detailed outcome measures. Limitations include its single-center nature, non-randomized allocation (introducing potential selection bias), and exclusion of acute cases where robotic benefits might be greater.

Seventh, future directions should focus on multicenter randomized trials, integration of cost-effectiveness evaluations, and long-term outcome studies assessing quality of life, return to work, and healthcare utilization. Robotic cholecystectomy may ultimately find its strongest justification in complex cases or high-volume centers where system costs can be offset and surgeon expertise maximized.

Conclusion

Robotic cholecystectomy, while associated with longer operative times, demonstrates advantages in reduced blood loss, postoperative pain, and hospital stay compared with laparoscopic cholecystectomy. These findings support selective adoption of robotic systems where resources permit, with priority given to complex or high-risk gallbladder cases.

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