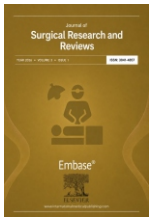
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Research Article

Section: Surgical Gastroenterology

Robotic vs Laparoscopic Cholecystectomy for Benign Gallbladder Disease: A Comparative Analysis of Early Perioperative Outcomes & Postoperative Analgesia in an Indian Tertiary Care Setting

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HIGHLIGHTS

- Robotic cholecystectomy is safe.
- Operative times remained comparable.
- Robotic surgery reduced postoperative pain.
- Opioid requirements were significantly reduced.
- Robotic surgery offers opioid-sparing benefits.

Key Words:
Robotic cholecystectomy
Laparoscopic cholecystectomy
Benign gallbladder disease
Surgical Gastroeneterology

ABSTRACT

Introduction: Laparoscopic cholecystectomy (LC) remains the reference gold standard for benign gallbladder disease. While robotic cholecystectomy (RC) addresses key ergonomic and visualization constraints of laparoscopy, real-world comparative evidence from the Indian subcontinent remains scarce. **Aim & Objective:** This study evaluates early perioperative outcomes and acute postoperative analgesia between multiport RC and multiport LC in an Indian tertiary care setting. **Materials & Methods:** A retrospective cohort analysis was conducted on 100 consecutive adult patients who underwent elective, non-complex cholecystectomy for benign disease (50 RC vs. 50 LC) between July 2024 and January 2026 at a single tertiary center in Bengaluru, India. To eliminate inter-operator variability, all procedures were performed by a single surgeon beyond the RC learning curve (>20 cases). Primary endpoints included operative time, intraoperative complications, conversions, surgical site infections (SSIs), length of hospital stay (LOS), 24-hour Numerical Rating Scale (NRS) pain scores, and rescue opioid requirements. **Results:** Baseline demographics, BMI, comorbidities, and indications were statistically comparable between groups ($p > 0.05$). Mean total procedure time was numerically shorter in the LC group without reaching statistical significance (24.56 ± 3.57 vs. 25.38 ± 4.16; $p = 0.293$). There were zero conversions, bile duct injuries, or 30-day readmissions/mortality in either cohort. SSI rates were statistically equivalent (RC: 2.0% vs. LC: 8.0%; $p = 0.362$). The RC cohort demonstrated significantly lower 24-hour NRS pain scores (2.76 ± 1.19 vs. 4.48 ± 1.18; $p < 0.001$) and a marked reduction in rescue opioid requirement (28.0% vs. 74.0%; $p < 0.001$). **Conclusion:** Robotic cholecystectomy is a safe, reproducible alternative to standard laparoscopy in benign gallbladder disease. Beyond procedural equivalence, RC confers a significant opioid-sparing advantage by attenuating early postoperative pain.

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INTRODUCTION

Cholecystectomy constitutes one of the most routinely conducted abdominal interventions across global healthcare systems [1]. Since its adoption in the 1990s, laparoscopic cholecystectomy (LC) has remained the gold standard, conferring favorable outcomes with respect to perioperative morbidity, mortality, and duration of hospital stay compared with open resection [2]. From the early 2000s onward, robotic surgery has undergone gradual yet extensive clinical integration for both oncological and non-malignant indications. It addresses major ergonomic and dexterity-related limitations of conventional laparoscopy through endo-wristed instruments, tremor elimination, and stable, high-magnification stereoscopic imaging [3]. Evidence across several cohorts confirms that undergoing robotic cholecystectomy (RC) does not increase perioperative morbidity compared with laparoscopy, even during the early phase of the learning curve (the prerequisite case threshold and operative training needed to attain procedural mastery) [1,4,5]. Complication rates remained statistically indistinguishable across these cohorts. Moreover, for surgeons practicing beyond the procedural learning curve, recent meta-analytic data and systematic reviews demonstrate equivalence between RC and LC regarding both intraoperative performance and postoperative recovery [1,6]. Across these studies, outcomes including perioperative complications, blood loss, surgical site infection rates, and conversion to open or conventional approaches remained comparable. Operating room time, however, was prolonged among patients undergoing RC [1,6].

RC has been associated with significantly improved patient-reported outcomes, including cosmetic satisfaction, body image scores, and reduced postoperative pain, largely driven by greater operative precision, superior visualization, and faster convalescence [7,8]. The application of RC within the Indian clinical landscape is in its early developmental stages, leaving its comparative utility largely undefined.

To our knowledge, this study ranks among the initial comparative series from this region to assess RC alongside standard LC. In this work, we present our early institutional cohort, evaluating 30-day perioperative safety and clinical metrics between multiport RC and multiport LC. **Figure 1.** Comparative overview of robotic & laparoscopic cholecystectomy highlighting procedural features, perioperative outcomes, postoperative pain, recovery, and patient satisfaction in benign gallbladder disease.

To eliminate inter-operator variability, all operations across both cohorts were performed by a single experienced minimally invasive surgeon. Crucially, the surgeon had already navigated the procedural learning curve for RC, ensuring that this series represents stabilized, post-learning-curve technical performance.

MATERIALS & METHODS

Study Design and Setting

This retrospective cohort study was conducted at a tertiary care referral institute in Bengaluru, Karnataka, India. A comprehensive electronic medical record review was performed for consecutive adult patients who underwent elective, non-complex cholecystectomy for benign gallbladder disease between July 2024 and January 2026. The study protocol was reviewed and approved by the Institutional Ethics Committee, and the requirement for informed consent was waived due to the retrospective, anonymized nature of the chart review.

Inclusion and Exclusion Criteria

Eligible participants included all adult patients (age more than 18 years) who underwent elective, non-complex cholecystectomy using either a multiport laparoscopic cholecystectomy (LC) or multiport robotic cholecystectomy (RC) approach for symptomatic, benign gallbladder pathologies (e.g., symptomatic cholelithiasis, chronic cholecystitis, or gallbladder polyps). Patients with known or intraoperatively confirmed gallbladder

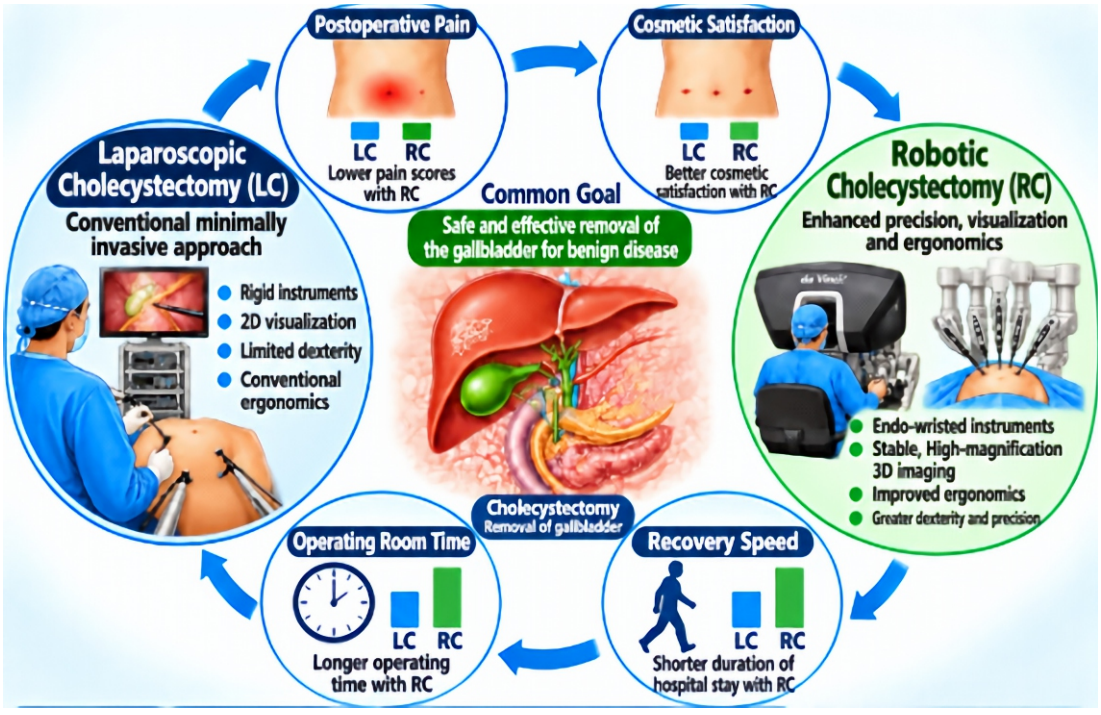


Figure 1. Comparison of robotic and laparoscopic cholecystectomy outcomes.

malignancies, preoperatively identified choledocholithiasis requiring concurrent common bile duct exploration, severe acute gangrenous or perforated cholecystitis, or conversions stemming from unexpected malignancy were systematically excluded from this analysis.

Surgical Technique and Surgeon Experience

All procedures (LC and RC) were performed by a single experienced, fellowship-trained minimally invasive surgeon adhering strictly to standardized clinical society operative guidelines. Crucially, the operating surgeon had previously surpassed the learning curve for RC-defined as exceeding 20 completed robotic procedures within a three-month interval-ensuring that all data gathered in this series reflect established, post-learning-curve technical consistency without early procedural acquisition bias.

Robotic Cholecystectomy (RC): Robotic procedures were executed using the da Vinci Xi Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) utilizing a standardized four-port configuration. The platform's integrated high-definition 3D stereoscopic vision and articulating EndoWrist instruments (providing seven degrees of freedom) were leveraged to perform precise anatomical dissection, achieve the Critical View of Safety (CVS), clip-ligate the cystic duct and cystic artery using *MIRUS™ Ligating Clip*, and dissect the gallbladder off the liver bed.

Laparoscopic Cholecystectomy (LC): Multiport LC was conducted using standard four-port laparoscopic access (umbilical, epigastric, and two right subcostal ports) with conventional rigid laparoscopic instrumentation, standard 2D/3D laparoscopy, and electrocautery, following identical operative safety principles (CVS identification) as in RC.

Specimens in both groups were retrieved within an endobag through the umbilical port site, and fascia and skin were closed using *Mitsu™ No. 1* and *Filapron™ 3-0 R/C* respectively under direct visualization.

Data Collection & Study Endpoints

Demographic and baseline characteristics extracted from medical records included age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status classification, and relevant systemic comorbidities.

Intraoperative Variables: Surgical approach (LC vs. RC), total operating room (OR) time (defined as time from skin incision to complete skin closure), estimated blood loss (EBL), need for conversion (to open surgery or conventional laparoscopy), and intraoperative complications (e.g., bile duct injury, excessive hemorrhage, or bowel perforation).

Postoperative Outcomes: Duration of hospital stay (LOS, recorded in hours/days), total postoperative analgesic requirements, surgical site infections (SSIs, defined according to Centers for Disease Control and Prevention criteria), general postoperative morbidity (graded using the Clavien-Dindo classification system), 30-day unplanned readmissions, and 30-day reoperations.

Pain Assessment: Postoperative pain severity was systematically measured at 24 hours post-surgery using an 11-point Numerical Rating Scale (NRS; scored from 0 to 10, where 0 represents "no pain" and 10 represents the "worst pain imaginable").

Statistical Analysis: Continuous variables were assessed for distributional normality using the Shapiro–Wilk test. Normally distributed continuous variables were expressed as mean ± standard deviation (SD) and compared between the LC and RC cohorts using an independent two-sample t-test. Non-normally distributed variables were reported as median with interquartile range (IQR) and compared using the Mann–Whitney U test. Categorical variables were presented as absolute frequencies and percentages (n, %) and evaluated using Pearson's chi-square test or Fisher's exact test when expected cell counts were < 5. All statistical tests were two-tailed, and a p-value < 0.05 was considered statistically significant. Data management and statistical computations were executed using Stata statistical software, version 16.0 (StataCorp LLC, College Station, TX, USA).

RESULTS

A total of 100 consecutive indicated noncomplex cholecystectomy cases were collected, 50 robotic cholecystectomy (RC) and 50 cases of LC. Age, Sex, BMI, and diagnosis requiring the procedure were not significantly different between the two groups. The mean age in the RC group was 47.08 ± 13.40 years, whereas in the LC group, the mean age was 47.28 ± 13.41. Females represented 68% (n = 34) of cases in the LC arm compared to 32% of males in this group, whereas female representation was 70% (n = 35) in the RC group, with 30% being males. The mean BMI in the RC group was 26.70 ± 3.40, whereas the mean BMI in the LC group was 26.71 ± 3.53. Indications for cholecystectomy included Symptomatic cholelithiasis (LC = 30 (60.0%) | RC = 29 (58.0%)), Chronic cholecystitis (LC = 15 (30.0%) | RC = 16 (32.0%)) and Gall bladder polyps (LC = 5 (10.0%) | RC = 5 (10.0%)) and was comparable between both groups. None of the patients in either group had a previous history of upper abdominal surgery. All 100 cases underwent noncomplex cholecystectomy for gallstone disease. All the baseline demographic and clinical characteristics are summarized in **Table 1**. Total procedure time was numerically less in the LC group but not statistically significant. However, this does not translate into any cost benefits as per the local healthcare practices. There were no conversions from the planned procedure to open cholecystectomy in either of the groups. There were no intraoperative complications such as bleeding or common bile duct injury. The rates of SSIs were numerically lower in the robotic group, 2% vs 8% (p = 0.3622). All the SSIs

were superficial type which was treated with conservative management. There were no postoperative complications in both groups. The mean length of hospital stay was comparable in both groups.

The mean pain score at 24 hours after the surgery was 2.76 ± 1.19 in the robotic group and 4.48 ± 1.18 in the laparo-scopic group which was statistically significant (p- value= <0.001. 28% of the patients required opioid analgesics in the robotic group whereas 74% of patients in the laparoscopic group needed at least one dose of opioid analgesics which was statistically significant (p-value= <0.001).

There were no reoperations in both groups. The 30-day mortality was nil in both groups. The intraoperative and postoperative outcomes are summarized in **Table 2**.

Table 1: Baseline Demographic and Clinical Characteristics of the Study Cohort (N = 100)

S. No.	Characteristic	LC (n= 50)	RC (n= 50)	p- value
1.	Age (years), Mean±SD	47.28 ± 13.41	47.08 ± 13.40	0.941
2.	Sex, n (%)			1.000
	Female	34 (68.0%)	35 (70.0%)	
	Male	16 (32.0%)	15 (30.0%)	
3.	BMI (kg/m^2), Mean±SD	26.71 ± 3.53	26.70 ± 3.40	0.872
4.	Primary Surgical Indication, n (%)			0.976
	Symptomatic cholelithiasis	30 (60.0%)	29 (58.0%)	
	Chronic cholecystitis	15 (30.0%)	16 (32.0%)	
	Gallbladder polyps	5 (10.0%)	5 (10.0%)	
5.	Comorbidities, n (%)	-	-	0.906
	None	23 (46.0%)	20 (40.0%)	-
	Hypertension (HTN)	11 (22.0%)	10 (20.0%)	
	Diabetes Mellitus (DM)	5 (10.0%)	8 (16.0%)	
	Hypothyroidism	6 (12.0%)	7 (14.0%)	
	HTN + DM	5 (10.0%)	5 (10.0%)	

Table 2: Perioperative outcomes

S. No.	Characteristic	RC (n= 50)	LC (n= 50)	p- value
1.	Total procedure time(mins), Mean±SD	25.38 ± 4.16	24.56 ± 3.57	0.293
2.	Conversion to open cholecystectomy, n (%)	0 (0)	0 (0)	-
3.	Intraoperative complications, n (%)	0 (0)	0 (0)	-
4.	Surgical site infection, n (%)	1 (2%)	4 (8%)	0.3622
5.	Postoperative complications, n (%)	0 (0)	0 (0)	-
6.	Length of hospital stay(days), Mean±SD	1.02 ± 0.14	1.12 ± 0.33	0.0507
7.	NRS at 24 hours post-surgery, mean ± SD	2.76 ± 1.19	4.48 ± 1.18	<0.001*
8.	Need for opioid analgesics, n (%)	14 (28%)	37 (74%)	<0.001*
9.	Readmission within 30 days after surgery, n (%)	0 (0)	0 (0)	-
10.	Reoperations, n (%)	0 (0)	0 (0)	-
11.	30-day mortality, n (%)	0 (0)	0 (0)	-

*p-value is significant (p- value= <0.005)

DISCUSSION

Over the last five years, robotic cholecystectomy (RC) has progressively integrated into Indian surgical practice. Herein, we report a retrospective comparative series of 100 consecutive non-complex cholecystectomies, comprising 50 robotic and 50 laparoscopic procedures, evaluating their 30-day perioperative safety profiles. Owing to the paucity of contemporary comparative literature from India, our findings are benchmarked against international multi-institutional cohorts to assess the reproducibility and clinical equivalence of RC in an emerging surgical landscape.

Regarding immediate perioperative outcomes, our series demonstrated comparable lengths of hospital stay, with no intraoperative adverse events, postoperative complications, or conversions to open surgery observed in either cohort. These findings closely mirror prevailing international benchmarks. Notably, a comprehensive 2023 systematic review and meta-analysis comparing multiport LC and multiport RC across 14 studies encompassing over 3,000 patients corroborates this equivalence [1]. The meta-analysis demonstrated no statistically significant differences in estimated intraoperative blood loss (weighted mean difference [WMD]: −6.73 mL; 95% CI: −16.31 to 2.84 mL; $p = 0.17$) or duration of hospitalization (WMD: −0.38 days; 95% CI: −0.87 to 0.12 days; $p = 0.13$) [1]. Furthermore, rates of overall postoperative morbidity remained statistically indistinguishable between approaches (weighted odds ratio [OR]: 1.21; 95% CI: 0.80 to 1.84; $p = 0.86$), with parity likewise observed in the incidence of common bile duct injuries ($p = 0.46$) [1]. A notable finding in our series was the significantly lower pain severity reported by the robotic cohort at 24 hours postoperatively. This reduction in acute postoperative discomfort likely stems from the biomechanical advantages of the robotic platform; the fixed pivot point at the abdominal wall (remote center of motion) substantially reduces torque, traction, and shear stress across the port-site musculature compared with the continuous levering forces exerted by rigid laparoscopic trocars. Our observations are consistent with the existing clinical literature. In an earlier study by Lee et al., patients undergoing RC demonstrated significantly reduced pain compared to those receiving LC at 6 hours, 24 hours, 2 days, and 1 week postoperatively [8]. However, that study evaluated single-port RC against conventional multiport LC, introducing confounding

incision-related variables [8]. More directly comparable to our four-port methodology is a 2022 Korean study comparing multiport RC to multiport LC, which established significantly attenuated pain trajectories in the robotic arm across early recovery intervals: 2, 4, and 8 hours postoperatively ($p = 0.04$, $p = 0.02$, and $p = 0.02$, respectively) [9]. Furthermore, their LC cohort required significantly higher postoperative analgesic consumption (mean 0.7± 0.9 doses) compared with the RC cohort (0.3 ± 0.5 doses; $p = 0.03$) [9]. This mirrors our institutional experience, where the superior pain control in the RC arm translated directly into a marked reduction in rescue opioid reliance, shielding robotic patients from opioid-related side effects such as nausea, sedation, and delayed bowel function.

Although we observed a trend toward fewer surgical site infections (SSIs) in the robotic cohort (2.0% vs. 8.0%), this numerical difference did not attain statistical significance ($p = 0.362$). This finding is broadly concordant with the published literature, where comparative studies have consistently failed to demonstrate significant disparities in wound infection rates between surgical modalities [7,10,11]. Kudsi et al. reported comparable SSI rates between approaches (2.4% for RC vs. 1.9% for LC; p = not significant) [7], while Grochola et al. observed identical SSI incidences of 3.3% across both the RC and LC arms [10]. Collectively, these data confirm that while robotic assistance maintains meticulous tissue handling, it offers wound-related safety outcomes entirely comparable to conventional laparoscopic surgery.

In our series, there were no conversions to open cholecystectomy in either the RC or LC cohort (0.0% vs. 0.0%). While our zero-conversion rate reflects our selection of elective, non-complex benign pathologies and a single surgeon's post-learning curve proficiency, broader clinical series have consistently identified a significantly lower risk of conversion associated with the robotic approach [1,12,13]. In a systematic review by Straatman et al., the pooled risk of open conversion was significantly attenuated in the robotic arm [1]. Similarly, in a comparative study of multiport RC ($n = 171$) versus multiport LC ($n = 441$) by Tao et al., the conversion rate was markedly lower following robotic intervention (0.6% vs. 6.6%, $p = 0.001$) [12]. Although that cohort predominantly comprised non-complex cases analogous to ours, their study population exhibited a higher mean age, greater BMI, and higher proportion of male patients [12]. Furthermore, one of the largest single-institution series evaluating conversion and bile duct injury across 965 patients (RC: $n = 676$; LC: $n = 289$) demonstrated a striking reduction in conversion favoring the robotic platform (0.15% vs. 4.5%, $p < 0.001$) [13]. Enhanced 3D stereoscopic visualization, articulation, and tremor filtration likely facilitate meticulous dissection within Calot's triangle, thereby mitigating technical failure that typically necessitates open conversion.

Prevention of iatrogenic bile duct injury (BDI) remains the paramount safety benchmark in minimally invasive cholecystectomy. In our series, no common bile duct or major biliary tract injuries occurred in either the RC or LC cohorts. The broader relationship between robotic assistance and BDI risk has recently become a subject of active debate following a 10-year analysis of US Medicare administrative claims data by Kalata et al. [14].

In that registry review, the authors reported a statistically higher risk of major BDI requiring operative reconstruction within one year in the robotic cohort ($n = 25,084$) relative to the laparoscopic cohort ($n = 1,001,004$). However, retrospective administrative database analyses inherently suffer from coding inaccuracies, lack anatomical granularities such as disease severity or inflammation grade, and frequently capture procedures performed during the early institutional learning curves of multiple non-specialist surgeons. In contrast, large multi-institutional comparative series and systematic reviews-including the meta-analysis by Straatman et al. [1] and high-volume institutional evaluations [13,15,16] have consistently demonstrated that post-learning curve RC yields equivalent or even lower BDI rates compared with conventional laparoscopy. When standardized dissection protocols and meticulous achievement of the Critical View of Safety (CVS) are maintained, robotic stereoscopic magnification and articulated instrumentation serve as effective safeguards rather than risk factors for biliary trauma.

Strengths and limitations of our study

To our knowledge, this investigation represents one of the initial comparative clinical series evaluating robotic cholecystectomy against conventional laparoscopic cholecystectomy from the Indian subcontinent. It also adds valuable real-world evidence to the limited global literature directly comparing multiport RC to multiport LC. A major strength of our study is that all procedures were conducted by a single experienced minimally invasive surgeon beyond their procedural learning curve, ensuring strict uniformity in operative technique, dissection principles, and perioperative care protocols.

Nevertheless, our findings must be interpreted within the context of several limitations. First, conducting the study within a single-surgeon practice may constrain the external generalizability of our operative durations and complication rates across diverse surgical teams with variable robotic experience. Second, the retrospective single-center architecture, combined with the lack of formal prospective sample size or power calculations, carries an inherent risk of bias selection and limits statistical power to detect rare surgical adverse events. Third, clinical surveillance was restricted to a 30-day perioperative window, precluding the assessment of medium- to long-term outcomes such as late biliary strictures or incisional port-site hernias. Finally, granular fiscal and billing data were unavailable, preventing a formal health economic or cost-effectiveness evaluation. Future prospective, multicenter registries with long-term follow-up and health economic analyses will be essential to establish the broader value proposition of robotic cholecystectomy in resource-sensitive healthcare environments.

CONCLUSION

In conclusion, this study provides one of the initial comparative clinical evaluations of robotic versus laparoscopic cholecystectomy from an Indian tertiary care setting. Our findings demonstrate that robotic cholecystectomy is a safe, reproducible, and effective

alternative to the gold-standard laparoscopic approach for benign, non-complex gallbladder disease, offering comparable peri-operative safety alongside significantly reduced early post-operative pain and opioid requirements. To substantiate these early real-world observations, future prospective, multi-institutional studies with larger sample sizes, formal health-economic analyses, and extended follow-up are warranted to definitively characterize the long-term clinical efficacy and value proposition of robotic surgery in India.

CLINICAL SIGNIFICANCE

The clinical significance of this study lies in its potential to bridge the gap between research findings and practical health-care, diagnosis, and treatment outcomes. By highlighting real-care applications. It emphasizes the importance of translating scientific observations into meaningful improvements in patient world relevance, the study contributes to evidence based medical practice and supports informed clinical decision making. Ultimately, the findings aim to enhance patient quality of life, optimize therapeutic strategies, and promote better disease management in clinical settings.

ABBREVIATIONS

BMI: Body Mass Index
LC: Laparoscopic Cholecystectomy
LOS: Length of Hospital Stay
NRS: Numerical Rating Scale
RC: Robotic Cholecystectomy
SSI: Surgical Site Infection

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AUTHOR CONTRIBUTIONS

All authors significantly contributed to the study conception and design, data acquisition, or data analysis and interpretation. They participated in drafting the manuscript or critically revising it for important intellectual content, consented to its submission to the current journal, provided final approval for the version to be published, and accepted responsibility for all aspects of the work. Additionally, all authors meet the authorship criteria outlined by the International Committee of Medical Journal Editors (ICMJE) guidelines.

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CONFLICT OF INTEREST

Authors declared that there is no conflict of interest.

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All necessary consent & approval was obtained by authors.

CONSENT FOR PUBLICATION

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DATA AVAILABILITY

All data generated and analyzed are included within this research article. The datasets utilized and/or analyzed in this study can be obtained from the corresponding author upon a reasonable request.

USE OF ARTIFICIAL INTELLIGENCE (AI) & LARGE LANGUAGE MODEL (LLM)

The authors confirm that no AI & LLM tools were used in the writing or editing of the manuscript, and no images were altered or manipulated using AI & LLM.

AUTHOR'S NOTE

This article serves as an important educational tool for the scientific community, offering insights that may inspire future research diretions. However, they should not be relied upon independently when making treatment decisions or developing public health policies.

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