

Beyond Individual Complications: Textbook Outcome in Elective Minimally Invasive Cholecystectomy and the Role of Robotic Approach

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Abstract

Background:

Textbook outcome (TO) combines multiple aspects of perioperative care to provide an overall assessment of surgical quality, but its application in cholecystectomy remains limited. Evidence comparing robotic cholecystectomy (RC) and laparoscopic cholecystectomy (LC) has focused predominantly on isolated perioperative outcomes. This study evaluated TO in elective minimally invasive cholecystectomy and the association of the robotic approach with perioperative quality and postoperative recovery.

Methods:

We retrospectively analyzed consecutive patients who underwent elective minimally invasive cholecystectomy from January 2024 through December 2025 at a single institution. TO was achieved when patients completed the perioperative course without postoperative complications, subtotal cholecystectomy, unplanned imaging or therapeutic intervention, ICU admission, readmission, or hospitalization extending to postoperative day 2 or later. Multivariable logistic regression was used to determine independent predictors of TO achievement and discharge before postoperative day 2.

Results:

The analysis included 257 patients, with 119 undergoing RC and 138 LC. RC was associated with fewer postoperative complications and higher TO achievement. Lower Charlson comorbidity index, index-admission cholecystectomy, and RC were independently associated with TO achievement. Prolonged postoperative recovery was the major contributor to TO failure. RC remained independently associated with timely postoperative recovery. Perioperative outcomes were comparable between approaches in the acute cholecystitis subgroup.

Conclusions:

TO provides a comprehensive assessment of perioperative quality in elective minimally invasive cholecystectomy. RC was associated with higher TO achievement and improved postoperative recovery in the elective setting, although these advantages were not observed in acute cholecystitis.

Introduction

Surgical management of benign gallbladder disease is now largely based on Laparoscopic cholecystectomy (LC), which has become a routine procedure across surgical centers worldwide. [1] Despite its broad use and generally favorable outcomes, surgical quality after cholecystectomy is still primarily evaluated using individual perioperative measures, including postoperative complications, bile duct injury, and conversion to open approach. [2] However, these events are relatively uncommon and may not fully capture the overall perioperative course or the patient-centered recovery experience.

Rather than relying on isolated postoperative endpoints, Textbook outcome (TO) evaluates surgical quality by considering multiple aspects of the perioperative course together. [3] Initially introduced in hepatobiliary and pancreatic surgery, TO generally encompasses the absence of postoperative complications, reinterventions, readmissions, mortality, and prolonged hospitalization, offering a more comprehensive assessment of surgical care quality. [4] Previous studies have suggested that TO may provide a more comprehensive assessment of variations in perioperative performance and healthcare delivery than individual adverse outcomes alone. [5,4,6]

While TO has been increasingly adopted in complex gastrointestinal surgery, its application in cholecystectomy remains limited. This may partly reflect the historically low rates of major adverse events following minimally invasive cholecystectomy, as well as the traditional emphasis on procedure-specific complications rather than recovery-oriented outcomes. [7] More recently, Lucocq et al. proposed a TO framework for elective LC that incorporates postoperative recovery and healthcare utilization as key components of surgical quality assessment. [8]

In parallel, robotic cholecystectomy (RC) has become increasingly adopted over the past decade. However, evidence regarding its potential advantages over LC remains inconclusive. Although some studies have reported improved perioperative outcomes with the robotic approach, others have found comparable or less favorable outcomes relative to conventional laparoscopy. [9-11] Furthermore, advances in robotic technology, including the introduction of single-port platforms, may further shape the evaluation of outcomes in minimally invasive cholecystectomy. [12] Evidence comparing surgical approaches has largely been derived from separate endpoints such as operative duration, complications, and hospital stay, leaving the overall course of care and recovery less well characterized. [8]

We examined TO in elective minimally invasive cholecystectomy to determine its clinical predictors and assess whether the surgical approach influenced the likelihood of achieving an optimal perioperative course. We further sought to characterize the main contributors to TO failure and determine whether deviations from expected postoperative recovery, rather than major complications alone, were the predominant drivers of suboptimal outcomes.

We hypothesized that RC would be associated with greater TO achievement, potentially reflecting improved perioperative recovery and overall quality of care, while TO failure would be attributable primarily to deviations in postoperative recovery rather than major adverse events.

Materials and Methods

Study design and patient population

Patients who underwent minimally invasive cholecystectomy at Far Eastern Memorial Hospital from January 2024 through December 2025 were consecutively identified and retrospectively analyzed. The manuscript was prepared with reference to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations.

The choice between laparoscopic and robotic cholecystectomy was based on routine clinical practice rather than prespecified indications or institutional selection criteria. Robotic procedures were performed with the da Vinci Xi Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). The robotic program was implemented only after institutional credentialing requirements had been fulfilled, and the study cohort did not include cases from the early adoption or learning phase. Operative management and perioperative care were otherwise standardized across both surgical approaches during the study period.

The analysis was restricted to elective LC and RC performed for benign gallbladder conditions. Patients were not considered for inclusion if they had cirrhosis, underwent gallbladder surgery in the setting of malignancy, were hospitalized primarily for a nonbiliary condition, received another operation during the same procedure, or were scheduled for open cholecystectomy from the outset.

Construction of the of TO

The components selected for TO were informed by earlier studies evaluating composite outcomes in elective cholecystectomy and hepatobiliary surgery. [8] Achievement of TO required the simultaneous fulfillment of all predefined criteria listed below:

1. No intraoperative or postoperative complications
2. No subtotal cholecystectomy
3. No prolonged postoperative recovery, defined as discharge on or beyond postoperative day 2
4. No unplanned postoperative reintervention or imaging
5. No intensive care unit (ICU) admission or hospital readmission

Postoperative imaging or therapeutic intervention was classified as unplanned when it was performed during the index hospitalization in response to a clinical concern and was not included in the standard perioperative care pathway. Readmission referred to any unplanned hospitalization within 30 postoperative days. Intraoperative complications encompassed any unexpected adverse event arising during the procedure, such as hemorrhage necessitating additional hemostatic measures, injury to the bile duct, bowel, or vascular structures, and anesthesia-related complications.

Events disrupting the expected course of recovery during the first 30 postoperative days were captured as complications and assigned a severity grade using the Clavien–Dindo system.

TO was achieved only when every predefined component was satisfied.

Data collection and study variables

Information was obtained retrospectively from the hospital electronic medical records. Variables analyzed at the patient level were age, sex, body mass index (BMI), Charlson comorbidity index (CCI), anticoagulant use, and history of biliary disease. Surgical data consisted of the indication for

cholecystectomy, operative approach (RC or LC), procedure duration, estimated blood loss, drain use, and conversion. Complications, ICU admission, readmission, reintervention, and length of stay (LOS) were evaluated as postoperative measures.

Early cholecystectomy referred to surgery undertaken during the index hospitalization.

Statistical analysis

Continuous variables were described by the median and interquartile range (IQR), and distributions between groups were compared with the Mann–Whitney U test. For categorical variables, frequencies and percentages were provided, with group comparisons based on either the chi-square or Fisher’s exact test according to data distribution. Variables associated with TO or discharge before postoperative day 2 on univariable screening were subsequently entered into separate logistic regression models for each endpoint. Model results are expressed as odds ratios (ORs) and 95% confidence intervals (CIs). All statistical testing was two-sided, with $p < 0.05$ indicating statistical significance. Missingness was assessed for each variable before analysis. Because missing observations were infrequent, only records with complete information for the variables required in each analysis were used, and no missing values were imputed.

The authors conducted all analyses with SPSS version 25 (IBM Corp., Armonk, NY, USA) and R version 4.3.1 (R Core Team), implemented through RStudio version 2023.06.1 (RStudio, PBC, Boston, MA, USA).

Results

Study population

A total of 367 minimally invasive cholecystectomies were performed during the study period. Following application of the predefined exclusion criteria, 344 patients remained in the final cohort. Of these, 257 (74.7%) underwent elective surgery, whereas the remaining 87 (25.3%) received cholecystectomy during the index admission for acute cholecystitis (AC). **Figure 1** illustrates the study flow and provides an overview of perioperative outcomes.

Baseline characteristics and perioperative outcomes according to surgical approach in elective cholecystectomy group

Table 1 presents the baseline characteristics of the population. Patients treated with RC were younger than those treated with LC (47.5 ± 15.5 vs 55.9 ± 14.4 years, $p < 0.001$), had a lower CCI (1.03 ± 1.46 vs 1.98 ± 2.07 , $p < 0.001$), and were less likely to receive anticoagulant therapy (5.9% vs 14.5%, $p = 0.026$). The distribution of surgical indications also differed between approaches: biliary colic was more prevalent among patients undergoing RC, whereas cholecystitis and biliary pancreatitis/cholangitis were more frequently encountered among those undergoing LC. In contrast, BMI, previous biliary disease, and the proportion of early cholecystectomy were comparable between the two groups.

Table 1. Comparison of characteristics of patients undergoing elective robotic cholecystectomy and laparoscopic cholecystectomy. (N = 257)

Variables	Robotic Cholecystectomy (N = 119)	Laparoscopic Cholecystectomy (N = 138)	p-value
Male (N, %)	78 (65.5)	67 (48.6)	0.008 [†]
Age (year)	46.0 (36.0-58.0)	56.0 (44.0-68.0)	<0.001 [*]
BMI	25.1 (22.8-28.3)	25.7 (22.7-29.4)	0.685 [*]
Anticoagulant usage (N, %)	7 (5.9)	20 (14.5)	0.026 [†]
History of biliary disease (N, %)	2 (1.7)	8 (5.8)	0.112 [†]
Operative indication (N, %)			0.032 [†]
Biliary colic	83 (69.7)	73 (52.9)	
Cholecystitis	23 (19.3)	40 (29.0)	
Biliary pancreatitis/ cholangitis	7 (5.9)	18 (13.0)	
Other (eg. polyps, biliary dyskinesia)	6 (5.0)	7 (5.1)	
CCI	0.0 (0.0-2.0)	2.0 (0.0-3.0)	<0.001 [*]
Early cholecystectomy (N, %)	111 (93.3)	119 (86.2)	0.070 [†]
LOS (day)	3.0 (3.0-3.0)	3.0 (3.0-4.0)	0.413 [*]
POD (day)	1 (1-2)	1 (1-2)	0.007 [*]
ICU stay (N, %)	0 (0.0)	10 (7.2)	0.002 [†]
OP time (min)	60.0 (40.0-100.0)	90.0 (60.0-120.0)	<0.001 [*]
Blood loss (ml)	5.0 (3.0-15.0)	5.0 (3.0-20.0)	0.235 [*]
Drainage placement (N, %)	13 (10.9)	38 (27.5)	0.001 [†]
CBD injury (N, %)	1 (0.8)	0 (0.0)	0.463 [†]
Conversion [#] (N, %)	0 (0.0)	0 (0.0)	-
Post-operative complication (N, %)	1 (0.8)	14 (10.1)	0.001 [†]

Post-operative bile leakage (N, %)	0 (0.0)	2 (1.4)	0.501 [†]
Textbook outcome achievement (N, %)	109 (91.6)	102 (73.9)	<0.001 [†]

Numerical data: median (interquartile range, IQR); Nominal data: N (percentage)

* Mann–Whitney U test; † Chi-square test; # Conversion to laparoscopic or open cholecystectomy; BMI: Body mass index; CCI: Charlson comorbidity index; LOS: Length of stay; POD: Post-operative days; ICU: Intensive care unit; OP: Operation; CBD: Common bile duct.

Perioperative outcomes are summarized in **Table 1**. Compared with LC, RC was associated with fewer ICU admissions (0% vs 7.2%, $p = 0.002$), shorter operative time (83.6 ± 61.7 vs 100.8 ± 46.5 minutes, $p < 0.001$), and less frequent drain placement (10.9% vs 27.5%, $p = 0.001$). Postoperative complications were also less frequent following RC (0.8% vs 10.1%, $p = 0.001$), while TO was achieved more often (91.6% vs 73.9%, $p < 0.001$). Blood loss, bile duct injury, conversion, and postoperative bile leakage did not differ significantly between the two approaches.

Predictors of TO achievement

Factors associated with TO achievement on univariable and multivariable analyses are summarized in **Table 2**. Univariable analysis identified younger age, lower CCI, early cholecystectomy, absence of anticoagulant use, and RC as significant predictors of TO achievement. After multivariable adjustment, lower CCI (OR 0.614, 95% CI 0.392–0.963, $p = 0.034$), early cholecystectomy (OR 7.676, 95% CI 2.788–21.137, $p < 0.001$), and RC (OR 2.771, 95% CI 1.170–6.563, $p = 0.020$) remained independently predictive of achieving TO.

Contributors to TO failure

The individual components of TO failure are detailed in **Table 3**. Delayed postoperative recovery beyond postoperative day 2 was the predominant contributor, accounting for 73.9% of all TO failures. Other causes, including postoperative complications, unplanned imaging, readmission, and reintervention, occurred less frequently, with major complications being uncommon. No deaths or conversions to open surgery occurred during the study period.

Table 2. Univariate and multivariate analyses of factors associated with textbook outcome achievement in patients undergoing elective minimal-invasive cholecystectomy. (N = 257)

Variables	Univariate analysis*		Multivariate analysis†	
	Odds ratio with 95% confidence interval	p-value	Odds ratio with 95% confidence interval	p-value
Male	0.903 (0.476-1.714)	0.754	-	-
Age (year)	0.935 (0.911-0.958)	<0.001	1.001 (0.952-1.053)	0.957
BMI	0.932 (0.860-1.010)	0.086	-	-
Anticoagulant usage	0.261 (0.112-0.609)	0.002	0.903 (0.292-2.795)	0.860
History of biliary disease	0.867 (0.178-4.224)	0.860		
CCI	0.538 (0.438-0.660)	<0.001	0.614 (0.392-0.963)	0.034
Early cholecystectomy	14.429 (5.911-35.211)	<0.001	7.676 (2.788-21.137)	<0.001
Robotic cholecystectomy	3.847 (1.816-8.151)	<0.001	2.771 (1.170-6.563)	0.020

BMI: Body mass index; CCI: Charlson comorbidity.

Table 3. Adverse outcomes for patients undergoing elective minimal-invasive cholecystectomy. (N = 257)

Outcome	No. (%) of. patients		
	All (N = 257)	Contribution to TO Failure (N = 46)	Single Contributor to TO Failure (N = 46)
Conversion [#]	0 (0.0)	0 (0.0)	0 (0.0)
Subtotal cholecystectomy	9 (3.5)	9 (19.6)	5 (10.9)
Intra-operative complications	1 (0.4)	1 (2.1)	0 (0.0)
Post-operative complications (Clavien-Dindo classification ≥ 1)	9 (3.5)	9 (19.6)	3 (6.5)
Post-operative imaging	11 (4.3)	11 (23.9)	3 (6.5)
Post-operative intervention	5 (1.9)	5 (10.9)	0 (0.0)
Prolonged postoperative recovery (discharge on or beyond POD 2)	34 (13.2)	34 (73.9)	23 (50.0)
Readmission (within 30 days)	9 (3.5)	9 (19.6)	3 (6.5)
Mortality	0 (0.0)	0 (0.0)	0 (0.0)

Conversion to laparoscopic or open cholecystectomy;

TO: Textbook outcome; POD: Postoperative day

Factors associated with timely postoperative recovery

Table 4 summarizes the analysis of timely postoperative recovery, defined as discharge before postoperative day 2. After multivariable adjustment, RC was independently associated with a greater likelihood of timely recovery (OR 2.418, 95% CI 1.516–3.855, $p < 0.001$), while age, CCI, and early cholecystectomy did not retain statistical significance.

AC subgroup analysis

Table 5 presents the subgroup analysis of patients who underwent index-admission cholecystectomy for AC. The RC and LC groups were similar with respect to baseline characteristics, including age, BMI, CCI, anticoagulant use, and disease severity according to the Tokyo Guidelines. Perioperative outcomes were likewise comparable between the two approaches, with no significant differences in length of stay, ICU admission, operative time, blood loss, drain placement, conversion, or postoperative complications.

Table 4. Univariate and multivariate analyses of factors associated with timely postoperative recovery (discharge before postoperative day 2) achievement in patients undergoing elective minimal-invasive cholecystectomy. (N = 257)

Variables	Univariate analysis [*]		Multivariate analysis [†]	
	Odds ratio with 95% confidence interval	p-value	Odds ratio with 95% confidence interval	p-value
Male	0.983 (0.639-1.511)	0.937	-	-
Age (year)	0.966 (0.952-0.980)	<0.001	0.983 (0.955-1.102)	0.248
BMI	1.004 (0.954-1.057)	0.883	-	-
Anticoagulant usage	0.741 (0.361-1.520)	0.414	-	-
History of biliary disease	0.568 (0.177-1.825)	0.342	-	-
CCI	0.736 (0.645-0.840)	<0.001	0.890 (0.691-1.147)	0.370
Early cholecystectomy	2.687 (1.218-5.928)	<0.014	1.598 (0.679-3.759)	0.283
Robotic cholecystectomy	2.837 (1.807-4.454)	<0.001	2.418 (1.516-3.855)	<0.001

BMI: Body mass index; CCI: Charlson comorbidity index.

Table 5. Comparison of characteristics of patients with acute cholecystitis undergoing index-admission robotic and laparoscopic cholecystectomy. (N = 87)

Variables	Robotic Cholecystectomy (N = 26)	Laparoscopic Cholecystectomy (N = 61)	p- value
Male (N, %)	14 (53.8)	39 (63.9)	0.473 [†]
Age (year)	56.1 (14.6)	54.9 (16.6)	0.763 [*]
BMI	25.5 (3.8)	26.6 (3.9)	0.262 [*]
Anticoagulant usage (N, %)	2 (7.7)	4 (6.6)	1.000 [†]
History of biliary disease (N, %)	0 (0.0)	2 (3.3)	1.000 [†]
CCI	1.88 (1.86)	1.84 (1.79)	0.875 [*]
Grading by Tokyo Guideline 2018			0.088 [†]
Mild	15 (57.7)	21 (34.4)	
Moderate	10 (38.5)	39 (63.9)	
Severe	1 (3.8)	1 (1.6)	
Early cholecystectomy (N, %)	1 (3.8)	2 (3.3)	1.000 [†]
LOS (day)	4.00 (2.22)	4.97 (8.18)	0.743 [*]
POD (day)	2.38 (2.28)	4.03 (8.13)	0.054 [*]
ICU stay (N, %)	2 (7.7)	4 (6.6)	1.000 [†]
OP time (min)	122.2 (60.3)	106.1 (33.6)	0.197 [*]
Blood loss (ml)	82.9 (131.9)	63.8 (106.3)	0.478 [*]
Drainage placement (N, %)	9 (34.6)	32 (52.5)	0.162 [†]
CBD injury (N, %)	1 (3.8)	0 (0.0)	0.299 [†]
Conversion [#] (N, %)	1 (3.8)	1 (1.6)	0.511 [†]
Post-operative complication (N, %)	3 (11.5)	9 (14.8)	1.000 [†]
Post-operative bile leakage (N, %)	0 (0.0)	0 (0.0)	-

Numerical data: mean ± standard deviation; Nominal data: N (percentage)

* Mann–Whitney U test; † Chi-square test; # Conversion to laparoscopic or open cholecystectomy; BMI: Body mass index; CCI: Charlson comorbidity index; LOS: Length of stay; POD: Post-operative days; ICU: Intensive care unit; OP: Operation; CBD: Common bile duct.

Discussion

In this retrospective cohort of patients undergoing elective minimally invasive cholecystectomy, TO offered a broader measure of perioperative quality by integrating multiple aspects of surgical care and postoperative recovery. RC was associated with more favorable perioperative outcomes and remained an independent predictor of TO achievement after adjustment for potential confounders. Notably, failure to achieve TO was largely attributable to prolonged hospitalization rather than major adverse events, underscoring the contribution of postoperative recovery to overall surgical quality. However, the advantages associated with RC in elective procedures were not evident among patients undergoing index-admission cholecystectomy for acute cholecystitis.

TO may provide a comprehensive assessment of perioperative quality in minimally invasive cholecystectomy

Since its initial introduction in colorectal cancer surgery [13], the concept of TO has expanded to a broad range of surgical fields, including vascular, hepatobiliary, and transplant surgery, where it serves as an integrated measure of perioperative care quality. [4,14,15]

Quality assessment in minimally invasive cholecystectomy has traditionally relied on individual perioperative outcomes. [2,16] However, the low frequency of major adverse events and the narrow scope of individual metrics may limit their ability to capture the overall quality of perioperative care. [17]

In a large multicenter analysis, Lucocq et al. established the potential utility of TO as an integrated measure of perioperative quality following elective laparoscopic cholecystectomy. [8] By integrating multiple aspects of perioperative care and postoperative recovery, TO provides a broader perspective on surgical performance than individual outcome measures, which may have limited discriminatory value when adverse events are uncommon. Given the methodological robustness and clinical applicability of this framework, we adopted a similar TO definition to evaluate outcomes following minimally invasive cholecystectomy.

Our findings further support the applicability of TO as a quality measure in minimally invasive cholecystectomy. As robotic and other advanced minimally invasive techniques continue to evolve, a composite framework such as TO may provide a broader assessment of perioperative performance by capturing aspects of care and recovery that are not fully represented by conventional individual outcomes.

Favorable perioperative outcomes were observed in the robotic group

The more favorable baseline characteristics of patients selected for elective RC, particularly younger age and lower comorbidity burden, raise concerns regarding potential selection bias. Nevertheless, the

association between RC and TO achievement persisted after multivariable adjustment for measured confounders, suggesting that baseline differences alone may not fully explain the observed benefit. Residual confounding remains possible, however, and the independent effect of surgical approach should therefore be interpreted with caution.

Prior studies using individual perioperative endpoints have also suggested potential benefits of RC. Gangemi et al. reported lower rates of conversion and postoperative complications following RC than LC, with these differences being particularly evident in technically challenging cases. [18] Propensity-matched studies have likewise reported shorter hospital stays and fewer readmissions after RC than after LC. [19] Complementing these findings, a prospective study by Vidovszky et al. showed that robotic single-site cholecystectomy was associated with favorable postoperative recovery and patient satisfaction while maintaining a perioperative safety profile comparable to conventional approaches. [20]

Nevertheless, previous comparisons have largely focused on individual perioperative endpoints rather than composite measures encompassing the overall surgical course. To our knowledge, this is the first study to compare RC and LC using TO as an integrated measure of perioperative quality. Our findings suggest that the potential advantages of RC may extend across multiple domains of care and become more apparent when assessed collectively rather than through isolated outcomes. Further investigation is warranted to clarify the mechanisms and perioperative factors contributing to this association.

Timely postoperative recovery was associated with TO achievement and more frequently observed following RC

Extended postoperative hospitalization may impose a greater burden on healthcare resources while also delaying recovery and negatively affecting the patient experience. [21] Delayed postoperative recovery was the predominant reason for failure to achieve TO in our cohort, a finding consistent with that of Lucocq et al., [8] who similarly identified extended LOS as a major factor limiting TO achievement after elective LC. Evidence from previous studies, including a recent meta-analysis of ERAS protocols, has linked longer postoperative stays to higher complication and readmission rates, slower recovery, and greater healthcare resource utilization, supporting LOS as a clinically relevant measure of perioperative recovery. [22]

Notably, RC remained independently associated with timely postoperative recovery in our cohort, raising the possibility that the robotic approach may facilitate earlier discharge. Several mechanisms could potentially account for this finding. One proposed advantage is reduced postoperative pain, which may result from greater instrument dexterity, improved operative precision, and less abdominal wall disruption, [23] particularly when single-site or reduced-port robotic techniques are employed. [12,24] Beyond its technical advantages, RC may also be integrated into more standardized perioperative care and recovery protocols, which could facilitate postoperative recovery and earlier discharge.

Advantages Observed in the Elective Setting Were Not Clearly Demonstrated in the Acute Setting

The clinical value of RC in acute care settings remains uncertain, as previous studies have yielded inconsistent results. [25-27] More recently, a large multicenter study published in *JAMA Surgery* found that robotic-assisted cholecystectomy for acute conditions was associated with higher postoperative morbidity, longer hospitalization, and greater drain utilization than LC, without evidence of a clear clinical advantage. [10] In contrast, these unfavorable outcomes were not observed in our AC subgroup, although the relatively small sample size limits definitive conclusions.

One possible explanation for this discrepancy is the difference in study populations: the *JAMA Surgery* cohort encompassed a broader spectrum of gallstone-related complications, including acute cholangitis and biliary pancreatitis, whereas our analysis was restricted to AC. Differences in patient selection, institutional practice, surgeon experience, and residual confounding may also have contributed to the divergent findings. Larger multicenter studies with standardized outcome definitions are needed to better define the role of RC in AC.

Limitations

Several limitations should be acknowledged. First, the retrospective, single-center design carries inherent risks of selection bias and residual confounding. Patients undergoing RC were younger and had a lower comorbidity burden, potentially contributing to the observed differences in perioperative outcomes. Although multivariable adjustment was performed, unmeasured confounding cannot be excluded, and the association between RC and TO should therefore be interpreted cautiously. Given the cohort size and limited number of outcome events, propensity score matching was not performed because matching could have further reduced the effective sample size and statistical power. Instead, multivariable regression using the full cohort was employed to adjust for measured confounders while preserving available information. Nevertheless, residual and unmeasured confounding cannot be excluded, and the observed association between RC and TO should therefore be interpreted cautiously.

Second, perioperative outcomes may reflect surgeon experience, institutional expertise, and established recovery protocols, potentially limiting the external validity of our findings. Moreover, a standardized definition of TO for cholecystectomy has yet to be established, and differences in its individual components may hinder comparisons across studies. In addition, prolonged hospitalization is inherently dependent on institutional discharge policies and healthcare system characteristics, which should be considered when interpreting the LOS-related component of TO.

Third, the observed association between RC and higher TO achievement may not be attributable to the surgical platform alone, as differences in perioperative workflow and postoperative care may also have contributed to improved outcomes.

Finally, the subgroup analysis of patients with AC was limited by its relatively small sample size, which may have reduced the statistical power to detect differences between RC and LC in the acute setting.

Conclusions

In conclusion, TO provides a comprehensive framework for evaluating perioperative quality after elective minimally invasive cholecystectomy. RC was associated with more favorable perioperative outcomes and a greater likelihood of achieving TO, with postoperative recovery emerging as a key determinant of overall performance. These associations, however, were not evident in the acute setting, highlighting the need for larger prospective studies to further define the role of RC across different clinical settings.

Abbreviations

LC - Laparoscopic cholecystectomy

TO - Textbook outcome

RC - Robotic cholecystectomy

ICU - Intensive care unit

LOS - Length of stay

BMI - Body mass index

CCI - Charlson comorbidity index

OR - Odds ratio

CI - Confidence Interval

AC - Acute cholecystitis

Declarations

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Competing Interests

The authors declare that they have no financial relationships or other competing interests relevant to this study.

Author Contributions

Y.-R.C., C.-H.H., and H.-F.L. contributed to the conception and methodological development of the study. Y.-R.C., C.-H.H., T.-F.S., and C.-L.K. participated in the investigation and data curation. Formal analyses were performed by Y.-R.C., C.-H.H., and K.-L.L. Y.-R.C. and C.-H.H. prepared the initial manuscript, while

K.-L.L., T.-F.S., C.-L.K., and H.-F.L. contributed to its critical review and revision. H.-F.L. supervised the study. The final version of the manuscript was reviewed and approved by all authors.

Ethics approval

Ethical clearance for this retrospective investigation was granted by the Research Ethics Review Committee of Far Eastern Memorial Hospital (IRB No. 114253-E). All study procedures complied with the Declaration of Helsinki. Because the analysis relied exclusively on previously collected, de-identified clinical information, the committee waived the need to obtain individual informed consent.

Consent to participate

Individual consent to participate was not required, as approved by the institutional review board.

Consent to publish

Publication consent was not required because no identifiable participant information or materials are presented.

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Disclosures

Yau-Ren Chang has no conflicts of interest to disclose.

Chih-Ho Hsu has no conflicts of interest to disclose.

Tiing Foong Siow has no conflicts of interest to disclose.

Chia-Ling Kuo has no conflicts of interest to disclose.

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Figures

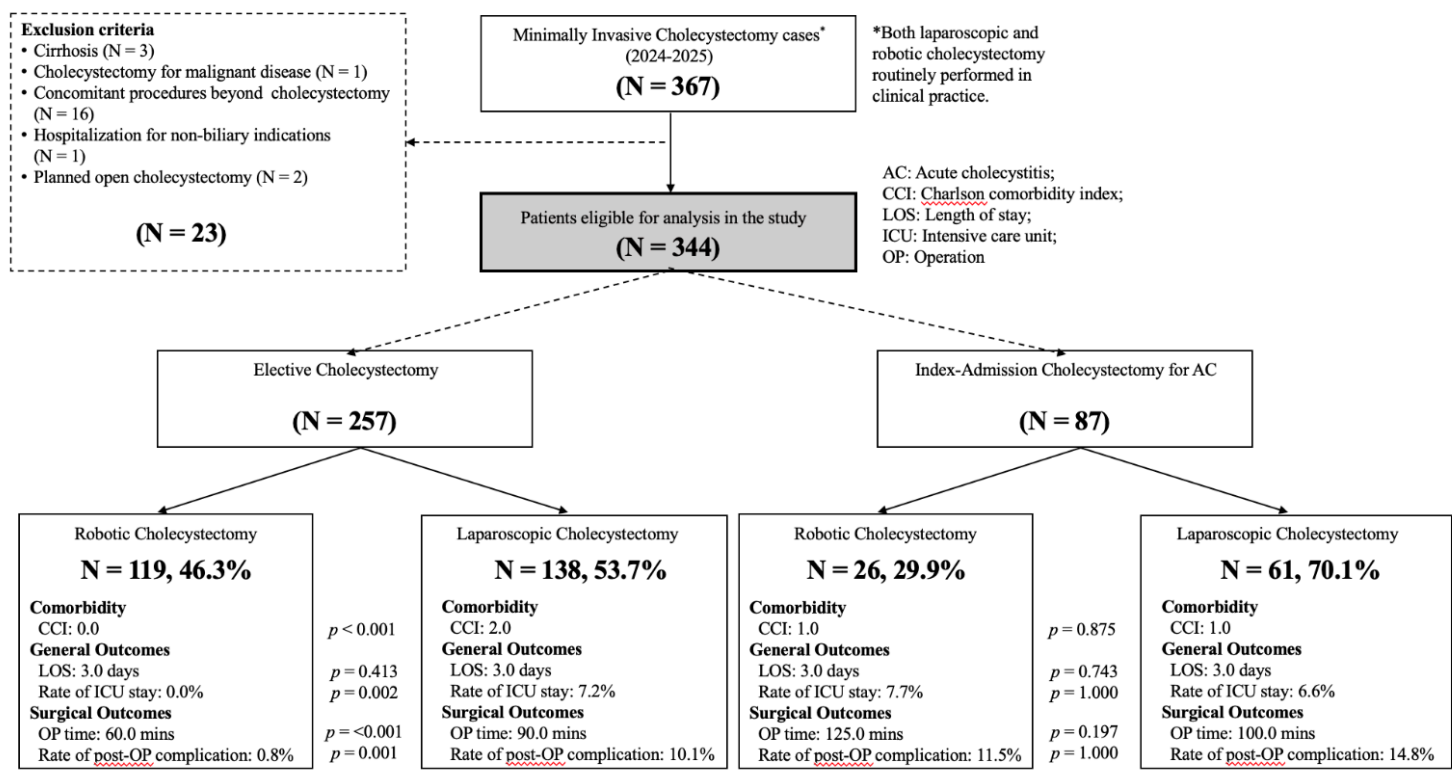


Figure 1

Study flow diagram and overview of perioperative outcomes in patients undergoing minimally invasive cholecystectomy.