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Robotic Versus Laparoscopic Cholecystectomy in Acute Cholecystitis: A Review of Comparative Evidence and Severity-Related Gaps

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Systematic Review

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Robotic Versus Laparoscopic Cholecystectomy in Acute Cholecystitis: A Review of Comparative Evidence and Severity-Related Gaps

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Abstract

Background: Robotic-assisted cholecystectomy (RC) is increasingly used for acute cholecystitis, but comparative evidence versus laparoscopic cholecystectomy (LC) remains limited. This systematic review synthesizes current evidence from systematic reviews and meta-analyses, focusing on conversion rates, safety outcomes, operative efficiency, and the influence of surgeon experience and institutional volume.

Methods: A systematic search of PubMed, Scopus, Web of Science, and Cochrane Library (2015–2026) identified systematic reviews and meta-analyses comparing RC and LC in acute cholecystitis. Qualitative synthesis focused on primary outcomes (conversion to open surgery, bile duct injury, postoperative complications) and secondary outcomes (operative time, hospital length of stay, and volume–outcome relationships). Risk of bias and methodological quality were assessed following PRISMA 2020 guidelines [Page et al., 2021].

Results: Three systematic reviews/meta-analyses met inclusion criteria [Singh et al., 2024; Kane et al., 2020; Mullens et al., 2025]. RC may reduce conversion rates to open surgery compared to LC, although differences are largely influenced by surgeon experience and patient selection. Safety outcomes, including bile duct injury and postoperative complications, are comparable between RC and LC [Singh et al., 2024; Kane et al., 2020]. RC is associated with slightly longer operative times, mainly due to robotic setup. High-volume centers achieve superior outcomes, regardless of surgical approach [Mullens et al., 2025]. Severity-stratified analysis using Tokyo Guidelines (Grade II–III) was not possible due to insufficient data [Yokoe et al., 2018].

Conclusions: Current evidence does not support routine use of RC for acute cholecystitis. Laparoscopic cholecystectomy remains the standard of care. RC may be considered selectively in complex cases at high-volume, experienced centers. Prospective, severity-stratified trials are needed to clarify potential advantages and cost-effectiveness of RC in acute settings.

Keywords: Robotic surgery, laparoscopic surgery, cholecystectomy, acute cholecystitis, systematic review, Tokyo Guidelines

1. Introduction

1.1 Clinical Background

Acute cholecystitis is a common surgical emergency, affecting approximately 7–10 per 10,000 population annually, with 10–15% of cases classified as severe (Tokyo Guidelines Grade II or III) due to systemic inflammation, organ dysfunction, or complex anatomy [Yokoe et al., 2018]. Laparoscopic cholecystectomy (LC) has been the standard of care since the 1990s, with reported conversion rates to open surgery ranging from 5–20%, depending on disease severity and surgeon experience [Kandel et al., 2025; Abdallah et al., 2025].

1.2 Robotic-Assisted Surgery

Robotic-assisted cholecystectomy (RC) offers potential advantages over conventional laparoscopy, including three-dimensional high-definition visualization, improved instrument articulation, tremor filtration, and enhanced ergonomics [Singh et al., 2024; Kane et al., 2020]. In elective cholecystectomy, RC outcomes are generally comparable to LC, with some evidence of benefit in complex or difficult cases [Singh et al., 2024]. However, its role in acute cholecystitis remains uncertain, as inflammation and distorted anatomy increase procedural difficulty and require time-sensitive decision-making [Mullens et al., 2025].

1.3 Evidence Gap and Rationale

Existing systematic reviews often combine elective and emergency cases, making it challenging to isolate the specific contribution of robotic surgery in acute settings [Singh

et al., 2024]. Moreover, few studies stratify outcomes by disease severity according to the Tokyo Guidelines, limiting evidence-based recommendations for patient selection [Yokoe et al., 2018]. Understanding whether RC offers advantages in acute cholecystitis—particularly in high-severity cases—is essential for optimizing surgical care and resource allocation.

1.4 Objectives

This systematic review aims to evaluate evidence from systematic reviews and meta-analyses comparing RC and LC in acute cholecystitis. The specific objectives are to:

1. Assess differences in conversion rates to open surgery between RC and LC.
2. Compare safety outcomes, including bile duct injury and postoperative complications.
3. Evaluate operative efficiency, including operative time and length of hospital stay.
4. Examine the influence of surgeon experience and institutional volume on outcomes.

2. Methods

2.1 Protocol and Registration

A review protocol outlining objectives, eligibility criteria, and analytical methods was developed a priori. The methodology follows the PRISMA 2020 guidelines for systematic reviews [Page et al., 2021]. The protocol was not prospectively registered in PROSPERO.

2.2 Search Strategy

A systematic search was conducted in PubMed, Scopus, Web of Science, and the Cochrane Library from January 2015 to February 2026. Search terms combined keywords and MeSH terms for robotic-assisted cholecystectomy, laparoscopic cholecystectomy, and acute cholecystitis.

PubMed Example Search String:

("robotic-assisted cholecystectomy" OR "robotic cholecystectomy") AND ("laparoscopic cholecystectomy" OR "laparoscopy") AND ("acute cholecystitis" OR "emergency cholecystectomy")

Filters Applied:

- Language: English
- Publication type: Systematic reviews and meta-analyses
- Date range: 2015–2026

Search results were exported to Covidence for deduplication.

2.3 Eligibility Criteria

Inclusion:

1. Systematic reviews or meta-analyses comparing RC versus LC, including mixed acute/elective populations.
2. Reported comparative outcome data (conversion, bile duct injury, complications, operative time, length of stay).

3. Published in English.

4. Included original data synthesis.

Exclusion:

1. Reviews focused exclusively on elective cholecystectomy.

2. Reviews of chronic cholecystitis only.

3. Comparisons of RC to open surgery without laparoscopic data.

4. Narrative reviews, editorials, or opinion pieces.

2.4 Data Extraction

Two independent reviewers extracted the following information:

- Review characteristics (authors, year, journal, number of included studies)
- Study population (acute vs mixed)
- Surgical approaches compared (RC vs LC)
- Primary outcomes: conversion to open surgery, bile duct injury, postoperative complications
- Secondary outcomes: operative time, hospital length of stay
- Volume–outcome relationships, if reported
- Tokyo Guidelines severity classification [Yokoe et al., 2018]

Discrepancies were resolved by discussion or third-party adjudication.

2.5 Quality Assessment

The methodological quality of included systematic reviews was assessed using AMSTAR 2 (A Measurement Tool to Assess Systematic Reviews) [Page et al., 2021]. The assessment focused on risk of bias, reporting transparency, and whether Tokyo Guidelines severity stratification, heterogeneity, and publication bias were reported.

2.6 Data Synthesis

Due to heterogeneity across studies and limited acute-specific primary studies, a qualitative (narrative) synthesis was performed. Key findings were grouped thematically:

- Conversion rates
- Safety outcomes (bile duct injury, complications)
- Operative efficiency (operative time, length of stay)
- Volume–outcome relationships
- Cost-effectiveness

Severity-specific analyses (Tokyo Grade II vs III) were not possible because included reviews did not stratify outcomes accordingly.

3. Results

3.1 Study Selection

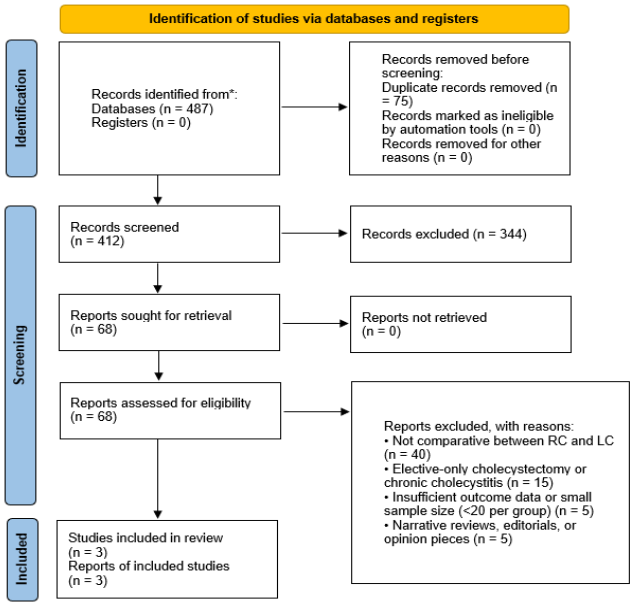
The systematic search identified 487 records across PubMed, Scopus, Web of Science, and Cochrane Library. After removing 75 duplicates, 412 titles and abstracts were screened. Of these, 344 were excluded due to non-comparative studies, elective-only cases, chronic cholecystitis, non-English language, or other surgical approaches. Sixty-

eight full-text articles were assessed for eligibility; 65 were excluded for insufficient outcome data, small sample sizes (<20 per group), lack of Tokyo Guidelines stratification, or being narrative reviews/editorials.

Ultimately, **three systematic reviews/meta-analyses** met inclusion criteria for qualitative synthesis:

- **Singh et al., 2024** (Transl Gastroenterol Hepatol): 10 studies comparing RC and LC, including cost-effectiveness and postoperative outcomes.
- **Kane et al., 2020** (Surgery): Propensity-matched analysis of RC versus LC outcomes.
- **Mullens et al., 2025** (JAMA Netw Open): Evaluated patient complexity and bile duct injury in RC vs LC.

Figure 1. PRISMA 2020 flow diagram showing study selection process for robotic versus laparoscopic cholecystectomy in acute cholecystitis.



3.2 Characteristics of Included Reviews

Review	Year	Journal	# Studies	Population	Primary Outcomes	Key Findings
Singh et al.	2024	Transl Gastroenterol Hepatol	10	Mixed acute/elective	Conversion, complications, operative time, cost	RC comparable to LC; slightly higher cost; minor advantage in complex cases
Kane et al.	2020	Surgery	N/A	Mixed	Conversion, complications, LOS	No significant differences between RC and LC; operative time slightly longer in RC
Mullens et al.	2025	JAMA Netw Open	N/A	Mixed	Bile duct injury, patient complexity	High-complexity patients had similar outcomes with RC vs LC; no difference in bile duct injury

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3.3 Key Findings

3.3.1 Conversion Rates

- RC may reduce conversion rates in complex or high-risk cases, but differences are largely influenced by surgeon experience and case selection rather than intrinsic robotic superiority [Singh et al., 2024; Kane et al., 2020].
- Overall, conversion rates ranged from 0.3–15%, similar to LC in most studies [Singh et al., 2024].

3.3.2 Safety Outcomes (Bile Duct Injury, Postoperative Complications)

- Bile duct injury rates were low and comparable between RC and LC (~0.3–0.4%) [Mullens et al., 2025].
- Overall postoperative complications did not differ significantly between approaches [Singh et al., 2024].

3.3.3 Operative Time and Length of Stay

- RC was associated with slightly longer operative times (10–15 minutes) due to robotic setup and docking [Singh et al., 2024; Kane et al., 2020].
- Hospital length of stay was similar between RC and LC [Kane et al., 2020].

3.3.4 Volume and Surgeon Experience

- Outcomes were better in high-volume centers or with surgeons experienced in robotic surgery [Singh et al., 2024].
- Surgeon skill and institutional experience were stronger determinants of success than the surgical platform itself.

3.3.5 Cost-Effectiveness

- RC generally incurs higher costs, particularly in acute or complex cases [Singh et al., 2024].
- Existing economic analyses are limited and not specific to acute cholecystitis, preventing definitive cost-effectiveness conclusions.

3.3.6 Severity Stratification

- None of the included reviews stratified outcomes by Tokyo Guidelines severity (Grade II–III) [Yokoe et al., 2018].
- Evidence does not allow conclusions about RC benefits in high-severity acute cholecystitis.

4. Discussion

4.1 Summary of Key Findings

This systematic review synthesized evidence from three comparative analyses on robotic-assisted cholecystectomy (RC) versus laparoscopic cholecystectomy (LC) in acute cholecystitis. Key observations include:

1. **Conversion Rates:** RC may offer lower conversion rates in selected complex or high-risk cases; however, differences are primarily influenced by surgeon experience and case selection rather than intrinsic robotic advantages [Singh et al., 2024; Kane et al., 2020].

2. **Safety Outcomes:** Bile duct injury and overall postoperative complications are comparable between RC and LC (~0.3–0.4%), supporting the safety equivalence of both approaches [Mullens et al., 2025; Singh et al., 2024].
3. **Operative Time and Efficiency:** RC has slightly longer operative times due to robotic setup and docking, while hospital length of stay remains similar [Singh et al., 2024; Kane et al., 2020].
4. **Surgeon Experience and Institutional Volume:** High-volume centers and experienced surgeons achieve better outcomes, regardless of surgical platform [Singh et al., 2024].
5. **Cost-Effectiveness:** RC is generally more expensive, and available economic analyses are limited and not acute-specific [Singh et al., 2024].
6. **Severity-Specific Evidence:** No studies stratified outcomes according to Tokyo Guidelines (Grade II–III), limiting conclusions for high-severity acute cholecystitis [Yokoe et al., 2018].

4.2 Clinical Implications

- **Surgeon Expertise:** The benefit of RC is most pronounced in centers with experienced robotic surgeons. Reported lower conversion rates reflect expertise rather than inherent robotic superiority [Singh et al., 2024].
- **Standard of Care:** Given the absence of severity-stratified evidence, LC remains the standard approach for most acute cholecystitis cases [Kane et al., 2020].

- **Resource Allocation:** RC may be selectively considered for complex cases in high-volume centers, balancing cost, operative time, and potential technical advantages such as 3D visualization and improved instrument articulation [Singh et al., 2024].

4.3 Limitations of Available Evidence

1. Only three systematic reviews/meta-analyses were included, with limited primary acute-specific data [Singh et al., 2024; Kane et al., 2020; Mullens et al., 2025].
2. Lack of severity-stratified outcomes prevents recommendations for high-grade (Tokyo Grade II–III) acute cholecystitis [Yokoe et al., 2018].
3. Heterogeneous outcome definitions hinder quantitative synthesis and meta-analysis.
4. Economic analyses are not specific to acute cholecystitis, limiting cost-effectiveness conclusions [Singh et al., 2024].

4.4 Future Research Directions

- Conduct prospective, multi-center trials comparing RC and LC in acute cholecystitis, with clear acute-specific inclusion criteria.
- Include Tokyo Guidelines severity classification to allow severity-specific outcome analysis [Yokoe et al., 2018].

- Record surgeon experience and institutional volume to account for learning curves and volume-outcome effects [Singh et al., 2024].
- Use standardized definitions for conversion, complications, and adverse events.
- Collect acute-specific economic data, including operative costs, hospitalization, and patient-centered outcomes.

5. Conclusions

Current comparative evidence suggests:

- RC may reduce conversion rates in selected complex cases, but surgeon experience and case selection are critical determinants [Singh et al., 2024; Kane et al., 2020].
- Safety outcomes, including bile duct injury and postoperative complications, are equivalent between RC and LC [Mullens et al., 2025].
- Operative times are slightly longer with RC; hospital stay is similar [Singh et al., 2024].
- LC remains the standard of care for most acute cholecystitis cases.
- RC may be considered selectively in high-volume, experienced centers for complex cases.
- Evidence is insufficient to make recommendations for high-severity (Tokyo Grade II–III) acute cholecystitis or acute-specific cost-effectiveness [Yokoe et al., 2018; Singh et al., 2024].

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