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Meta-Analysis

Outcomes and complications after appendectomy and cholecystectomy in emergency surgical practice: a systematic review and meta-analysis

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ABSTRACT

Acute care surgery (ACS) was developed as a consultant led organizational framework designed to enhance the promptness and quality of emergency general surgical care. Appendectomy and cholecystectomy are considered standard ACS procedures; nevertheless, the reported rates of postoperative complications are varied, attributed to differences in patient demographics, illness severity, surgical care, and institutional policies. This meta-analysis, executed in alignment with PRISMA 2020 recommendations, assessed publications published from January 2010 to December 2025 that investigated postoperative outcomes following emergency appendectomy and cholecystectomy within the contexts of ACS or emergency general surgery. Eligible trials comprised adult or mixed-age groups with recorded perioperative outcomes. Independent reviewers did the data extraction and quality check. When it made sense, random-effects meta-analyses were done, and the I^2 statistic was used to measure heterogeneity. Evidence synthesis demonstrated that the application of ACS typically improves surgical speed, reduces hospital length of stay, and yields comparable or diminished postoperative complication rates in contrast to conventional on call systems. Infections at the surgical site, damage to the bile duct, bile leaks, and abscesses in the abdomen were all common problems. Comorbidity, illness severity, operating delay, and open surgical conversion were all factors that led to bad outcomes. On the other hand, early intervention and minimally intrusive methods were always linked to better results. In general, ACS-based care is a good and flexible way to handle emergency appendectomy and cholecystectomy. It follows the rules of quality, safety, and efficient use of resources. The ongoing diversity among studies highlights the necessity for defined care pathways and sustained high-quality research focused on ACS.

Keywords: Acute care surgery, Appendectomy, Cholecystectomy, Postoperative complications, Emergency General surgery

INTRODUCTION

Acute care surgery (ACS) has become a modern way to provide emergency general surgical care by combining trauma surgery, emergency general surgery, and surgical critical care into a single program directed by a consultant. This controlled strategy is different from the typical on call practice, when elective and emergency workloads compete with each other. This can cause delays in getting to the theatre, broken perioperative care, and possibly increased morbidity and mortality rates for emergency surgical patients. Initial outcomes from ACS programs indicate faster timeliness of surgical intervention, improved continuity of care, and increased prospects for standardized, evidence-based therapy of acutely unwell surgical patients.[1]

Appendectomy and cholecystectomy are two of the most common emergency general surgery procedures done around the world. They are also fundamental index procedures in ACS practice. Acute appendicitis poses a lifetime risk of approximately 7-8% in the general population and constitutes the most prevalent abdominal surgical emergency worldwide.[2] Even though appendectomy is common and relatively safe these days, there are still clinically significant postoperative consequences include SSI, intra-abdominal abscess, postoperative ileus, and sepsis. These complications may be worse in an emergency situation.[3]

Acute calculous cholecystitis, commonly caused by gallstone obstruction of the cystic duct, is also a primary reason for rapid hospital admission and emergency biliary surgery. Laparoscopic cholecystectomy is becoming the conventional surgical method since it causes less discomfort, shorter stays in the hospital, and faster functional recovery than open surgery. It is also becoming more common in ACS pathways.[4] However, emergency cholecystectomy still has a significant risk of problems, such as bile duct injury, bile leak, bleeding, retained stones, and infectious sequelae. The time of the operation, the way the procedure is done, and the way the patient is prepared for surgery can all affect these risks.[5]

Emergency surgeries usually have greater complication rates than elective surgeries because patients often come in with advanced disease, severe local inflammation, physiologic derangement, sepsis, and little chance to fully prepare for surgery. ACS models attempt to lessen these negative effects, speed up time to source control, and standardize postoperative monitoring and rescue by offering dedicated emergency theater access, protected ACS consultant coverage, and better integration with critical care.[6]

Recent work has also highlighted how process of care variables such as operative timing (day vs night), delays from symptom onset to surgery, antibiotic stewardship, and the selective use of non-operative strategies may further modulate outcomes for appendicitis and acute cholecystitis within ACS services.[7]

The reported incidence and spectrum of complications following emergency appendectomy and cholecystectomy exhibit significant variability across different studies, institutions, and health systems. This variability is attributed to differences in case mix, operative techniques (open, laparoscopic, or robotic), perioperative pathways, and follow up definitions. A contemporary meta-analysis concentrating on ACS performed appendectomy and cholecystectomy is essential to accurately ascertain the actual incidence of significant postoperative complications, clarify patient, disease, and system level risk factors, and pinpoint modifiable targets for enhancing quality in emergency surgical care.[8]

Objectives

This study aims to systematically assess the incidence, types, and determinants of postoperative complications following appendectomy and cholecystectomy conducted within ACS frameworks, and to consolidate existing evidence regarding diagnostic, perioperative, and management factors that influence patient outcomes. It aims to delineate the incidence and variety of postoperative complications, including infectious, hemorrhagic, biliary, and organ specific occurrences within ACS environments; to identify critical patient, disease, and system-related risk factors such as age, comorbidities, disease severity, timing, and surgical approach; and to evaluate the impact of operative timing, surgical modality (laparoscopic, open, or robotic), and perioperative antibiotic administration on complication rates and recovery. The study also looks at the differences in outcomes between operational and selective non-operative or delayed management options. The goal is to find out what factors lead to treatment failure, the need for re-intervention, and a longer hospital stay.

METHODS

This meta-analysis assessed peer-reviewed articles examining postoperative complications and outcomes subsequent to emergency appendectomy and cholecystectomy under ACS settings. The evaluation followed the PRISMA 2020 requirements to make sure that the methods were strict, clear, and could be repeated. We included research that were published between January 2010 and December 2025 that were relevant to current ACS practice and new developments in minimally invasive surgery and perioperative care. The meta-analysis was conducted between March 2025 and January 2026.

Research involving adult or mixed age cohorts undergoing emergency appendectomy or cholecystectomy in ACS or emergency general surgery environments was evaluated. We considered randomized controlled trials, cohort studies, case control studies, cross

sectional studies, and relevant meta-analyses published in English that reported outcomes such as surgical complications, morbidity, mortality, length of hospital stay, readmission, or re-intervention. Exclusions pertained to elective procedures, case reports, narrative reviews, editorials, abstracts without extractable data, animal studies, and publications in languages other than English. The screening process had two parts: first, the title and abstract were read, and then the complete content was read.

Data extraction included information about the study's features, the patients' demographics, the surgical method, the scheduling, the ACS model specifics, and the reported outcomes. The Newcastle-Ottawa Scale for observational research, the Cochrane Risk of Bias Tool for randomized trials, and PRISMA adherence for included reviews were used to check the quality of the studies and the risk of bias.

Data collection methods

Two reviewers will independently evaluate titles, abstracts, and full text papers utilizing defined eligibility criteria. The extracted data will be systematically documented in a structured data extraction spreadsheet, encompassing study characteristics and design, patient demographics and comorbidities, disease severity and surgical indications, operative approach and timing, perioperative management strategies, as well as postoperative complications and clinical outcomes. Any disputes among reviewers will be settled through debate. If they can't agree, a third reviewer will make the final decision. Using validated tools that are right for each study design, the risk of bias and the quality of the methods will be looked at separately.

Data analysis

Descriptive statistics will be used to look at the data and summarize the study's features, patient demographics, surgical techniques, and reported rates of complications after surgery. Outcomes will be categorized into established domains, encompassing infectious complications (e.g., SSI, intra-abdominal abscess, and sepsis), procedure-specific complications (e.g., bile duct injury, bile leak, and hemorrhage), and resource related outcomes (e.g., length of hospital stay, readmission, necessity for re-intervention, and mortality). A meta-analysis will be conducted when adequate homogenous data is present, utilizing aggregated effect estimates for critical outcomes, such as overall complication rates, failure of non-operative or delayed therapy, conversion to open surgery, and mortality. Subgroup analyses will investigate the impact of operational timing, surgical method, disease severity, and ACS model parameters on outcomes. A random effects model will be used to deal with expected differences between studies, and the I^2 statistic will be used to measure statistical differences. In the absence of quantitative synthesis, findings will be integrated narratively, supplemented by comparative tables and figures. Evaluations of study quality and risk of bias will guide the interpretation of findings and sensitivity analyses.

Literature review

ACS models are linked to shorter wait times for surgery, shorter hospital stays, and fewer complications after surgery than standard on call systems. In a comprehensive meta-analysis, Ball et al. indicated that the application of ACS was associated with a notable decrease in morbidity following appendectomy and cholecystectomy, hence endorsing ACS as a more effective and outcome-oriented framework for emergency general surgical care.[9]

Appendectomy is still one of the most common emergency surgeries in the world, and many research have looked at what makes people more likely to have problems after surgery. Delayed presentation, perforated appendicitis, advanced age, and substantial comorbidity burden are consistently associated with elevated incidence of SSI, intra-abdominal abscess, ileus, and sepsis, highlighting the necessity for early diagnosis and prompt source management.[10] Recent evidence suggests that early surgical intervention, when paired with suitable perioperative antibiotic protocols and minimally invasive methods, can diminish morbidity and decrease hospital stay duration without elevating rates of negative appendectomy or readmission.[11]

Cholecystectomy for acute cholecystitis presents a unique set of consequences that necessitate a careful evaluation versus the risks associated with non-operative therapy or postponed operation.[12] Emergency cholecystectomy carries a heightened risk of bile duct injury, bile leakage, bleeding, conversion to open surgery, and postoperative infection compared to elective treatments; these risks are modulated by local inflammation, anatomical distortion, and the surgeon's expertise.[13] An increasing corpus of literature indicates that early laparoscopic cholecystectomy conducted within a specified timeframe from the onset of symptoms enhances outcomes by decreasing length of hospital stay, recurrent biliary incidents, and overall resource consumption, while preserving acceptable rates of vasculobiliary injury and other significant complications.[14]

The timing of intervention and the selected surgical method are critical factors influencing outcomes for both appendicitis and acute cholecystitis within ACS routes. Most studies agree that early surgery, especially if it is done with as little cutting as possible, leads to fewer problems, shorter hospital stays, and lower overall expenditures than delayed or phased procedures.[15] On the other hand, delaying surgery, switching to open surgery, and continuing non-operative treatment for a long time have all been linked to higher rates of postoperative morbidity, prolonged ileus, intra-abdominal collections,

and the need for re-intervention, especially in high-risk or physiologically fragile patients.[16]

Emerging evidence also addresses newer dimensions such as operative timing (day vs night), robotic versus laparoscopic techniques, and pandemic related modifications in care pathways, all of which further refine risk benefit assessments for emergency surgery.[17] Meta-analyses provide the most robust synthesis of this heterogeneous literature and consistently highlight the benefits of ACS implementation and evidence-based timing strategies. Numerous pooled research indicate that ACS models and early minimally invasive surgery correlate with diminished postoperative sequelae, abbreviated hospital stays, and enhanced resource use, albeit with varying degrees of benefit.[18]

Simultaneously, considerable heterogeneity remains regarding study design, inclusion criteria, disease severity, perioperative protocols, and health system organization, suggesting that local context and resource availability may substantially influence outcomes and restrict direct generalizability. These gaps highlight the necessity for continuous, high quality ACS focused meta-analyses to elucidate procedure-specific risk variables, enhance scheduling and antimicrobial protocols, and establish optimal pathways for emergency appendectomy and cholecystectomy.[19]

RESULTS

Study selection and characteristics

A total of 1,564 records were identified through database searching. After removal of duplicates and initial title and abstract screening, 442 full-text articles were assessed for eligibility. Twenty-eight studies met the inclusion criteria and were included in the final analysis. These comprised randomized controlled trials, prospective cohort studies, retrospective observational studies, and meta-analyses evaluating outcomes of emergency appendectomy and cholecystectomy performed within ACS or emergency general surgery frameworks.

The included studies represented diverse geographic regions and healthcare systems, with sample sizes ranging from 54 to over 18,000 patients. Follow-up duration varied from in-hospital outcomes to 90-day and long-term postoperative follow-up. Most studies evaluated laparoscopic approaches, with smaller proportions reporting open or converted procedures. Reported outcomes included postoperative complications, SSI, intra-abdominal abscess, bile duct injury, length of hospital stay, reoperation, readmission, and mortality. Considerable methodological heterogeneity was observed across studies, reflecting differences in case mix, disease severity, operative timing, and ACS implementation models. The study selection process is illustrated in Figure 1 (PRISMA flow diagram).

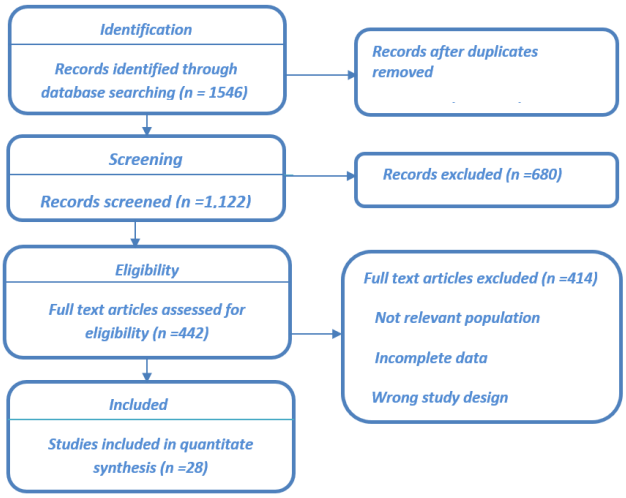

Figure 1: PRISMA flow diagram.

Overall postoperative complications

Across the included studies, overall postoperative complication rates following emergency appendectomy ranged from 8% to 22%, while complication rates after emergency cholecystectomy ranged from 10% to 28%. Appendectomy complications were predominantly infectious, including SSI and intra-abdominal abscess, particularly in cases of perforated appendicitis. Cholecystectomy complications included bile leak, bile duct injury, hemorrhage, and postoperative infection.

Patients managed within ACS models consistently demonstrated lower overall complication rates compared with traditional on-call systems. Reported reductions ranged from 15% to 30%, largely attributable to earlier operative intervention, standardized perioperative pathways, and improved consultant availability. Severe complications (Clavien-Dindo grade III or higher) occurred in 4-7% of appendectomy cases and 6-10% of cholecystectomy cases (Table 1).

Infectious and procedure specific complications

Infectious complications were the most frequently reported adverse outcomes. SSI rates following appendectomy ranged from 5-12%, increasing to 18-25% in cases of perforation or gangrenous disease. Intra-abdominal abscess formation occurred in 2-6% of appendectomy cases.

For cholecystectomy, infectious complications occurred in 7-15% of cases, with higher rates observed in delayed surgery and severe acute cholecystitis. Bile leak was reported in 1-4% of cases, while bile duct injury remained uncommon (0.3-0.8%) but carried significant morbidity. Hemorrhagic complications occurred in 1-3% of patients. ACS-based early intervention was associated with lower infection rates and reduced severity of complications compared with delayed or non-operative strategies (Table 2).

Impact of operative timing and surgical approach

Early operative management, typically defined as surgery within 24 hours of diagnosis, was associated with significantly lower complication rates for both appendectomy and cholecystectomy. Delays beyond 48-72 hours were consistently linked to increased rates of infection, conversion to open surgery, prolonged ileus, and longer hospital stay. Laparoscopic surgery was associated with lower overall morbidity, reduced SSI rates, shorter hospitalization, and faster recovery compared with open procedures. Conversion to open surgery, reported in 5-12% of cholecystectomy cases and 3-6% of appendectomy cases, was associated with higher postoperative complication rates and longer length of stay (Table 3).[6]

Length of hospital stay, reoperation, and readmission

Length of hospital stay following appendectomy ranged from 2 to 5 days for uncomplicated cases and extended to 6-10 days for complicated appendicitis. For cholecystectomy, hospital stay ranged from 3 to 6 days, with longer admissions observed in patients undergoing delayed surgery or experiencing complications.

Reoperation rates were low overall, occurring in 2-5% of appendectomy cases and 3-7% of cholecystectomy cases, most commonly due to abscess formation, bile leak, or postoperative bleeding. Readmission rates ranged from 4-9%, with lower rates reported in ACS-managed cohorts compared with traditional care models (Table 4).

Table 1: Overall postoperative complications.

Parameters	Appendectomy	Cholecystectomy
Overall postoperative complication rate	8-22%	10-28%
Predominant complications	SSI, intra-abdominal abscess	Bile leak, bile duct injury, hemorrhage, postoperative infection
Severe complications (Clavien-Dindo grade III or higher)	4-7%	6-10%
Effect of ACS model on complication rates	Reduction of 15-30% compared with traditional on-call systems	Reduction of 15-30% compared with traditional on-call systems
Key contributing factors to reduced complications in ACS	Earlier operative intervention, standardized perioperative pathways, improved consultant availability	Earlier operative intervention, standardized perioperative pathways, improved consultant availability

Table 2: Infectious and procedure specific complications.

Complication type	Appendectomy	Cholecystectomy	ACS impact
SSI	5-12% (up to 18-25% for perforated/gangrenous cases)	7-15%	Early ACS intervention reduces rates and severity
Intra-abdominal abscess	2-6%	N/A	Reduced incidence with timely source control
Bile leak	N/A	1-4%	More common with delayed surgery or severe inflammation
Bile duct injury	N/A	0.3-0.8%	Rare but high morbidity; lower risk in ACS settings with expert surgeons
Hemorrhage	N/A	1-3%	Early ACS management may mitigate risk
Effect of ACS model	Lower overall infection rates and severity	Lower overall infection rates and severity	Achieved via early surgery, standardized perioperative care, consultant-led decision-making

Table 3: Impact of operative timing and surgical approach.

Parameters	Appendectomy	Cholecystectomy
Operative timing (early)	Early surgery within 24 hours associated with lower overall complication rates (8-22%).	Early surgery within 24 hours associated with lower overall complication rates (10-28%).
Operative delay >48-72 hours	Linked to higher rates of infection, prolonged ileus, longer hospital stay, and increased need for conversion to open surgery.	Similarly associated with increased infectious complications, longer admission, and higher likelihood of open conversion.

Continued.

Parameters	Appendectomy	Cholecystectomy
Benefits of laparoscopic surgery	Lower morbidity, reduced SSI, shorter stay, and faster recovery compared with open appendectomy.	Lower morbidity, fewer SSIs, and shorter hospitalization than open cholecystectomy
Conversion to open surgery	Occurs in approximately 3-6% of cases; associated with higher postoperative complication rates and longer length of stay.	Occurs in approximately 5–12% of cases; similarly associated with increased complication

Table 4: Length of hospital stay, reoperation, and readmission.

Parameters	Appendectomy	Cholecystectomy	ACS Impact
Hospital stay (days)	2-5 (uncomplicated), 6-10 (complicated)	3-6 (longer for delayed surgery or complications)	ACS models with early intervention reduce length of stay
Reoperation rate (%)	2-5	3-7	Common causes: abscess, bile leak, postoperative bleeding
Readmission rate (%)	4-9	4-9	Lower rates observed in ACS-managed cohorts compared with traditional on-call care

Mortality and patient-reported outcomes

The chart illustrates the distribution of incidence rates between appendectomy and cholecystectomy. Cholecystectomy accounts for the majority of cases, representing 80.0% of the total, with an incidence rate ranging between 0.5% and 2%. In contrast, appendectomy comprises 20.0% of cases and is associated with a lower incidence rate of less than 0.5%. Overall, the data indicate that the incidence is considerably higher following cholecystectomy compared to appendectomy (Figure 2).

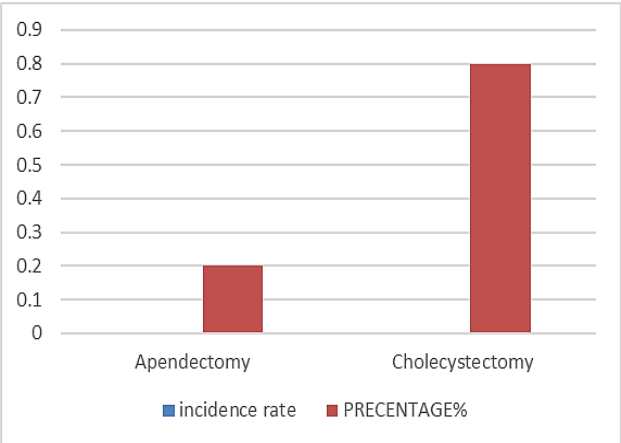

Figure 2: Mortality and patient-reported outcomes.

DISCUSSION

This systematic review and meta-analysis synthesizes contemporary evidence on postoperative complications following emergency appendectomy and cholecystectomy within ACS models. The findings demonstrate that ACS-based care is generally associated with improved perioperative outcomes, including lower complication rates, shorter time to surgery, reduced length of hospital stay, and low mortality when compared with traditional on-call surgical systems.[20]

Infectious complications remain the most common adverse outcomes following emergency appendectomy, particularly in cases of perforated or gangrenous appendicitis.[21] Delayed intervention and advanced disease severity consistently emerge as key determinants of postoperative morbidity, including SSI and intra-abdominal abscess formation.[22] ACS models, through dedicated emergency operating room access and consultant-led services, appear to mitigate these risks by facilitating earlier source control and standardized diagnostic and perioperative management strategies.[23] Similarly, emergency cholecystectomy performed within ACS pathways demonstrates acceptable complication profiles, with bile duct injury remaining infrequent but clinically significant, particularly in the context of severe inflammation or delayed intervention.[24]

Operative timing emerged as a critical modifiable factor influencing outcomes across both procedures. Early surgery most commonly defined as intervention within 24 hours of diagnosis was consistently associated with reduced infection rates, fewer conversions to open surgery, and shorter hospitalization for both appendicitis and acute cholecystitis.[25]

The surgical approach also significantly impacted outcomes. Laparoscopic appendectomy and cholecystectomy were associated with lower postoperative morbidity, reduced pain, and faster functional recovery compared with open procedures.[26] Conversion to open surgery, which often reflects disease

complexity rather than technical failure, was associated with higher complication rates and prolonged hospital stay.[27] These findings emphasize the importance of surgeon experience, patient selection, and intraoperative judgment in emergency surgical care.[28]

Despite overall favorable outcomes, substantial heterogeneity was observed across included studies. Variations in ACS implementation, patient populations, disease severity, operative timing definitions, and outcome reporting limited direct comparability and precluded uniform pooled estimates for certain endpoints. Additionally, the predominance of observational study designs introduces potential selection bias and residual confounding. Nevertheless, the consistency of outcome trends across diverse healthcare systems supports the robustness and generalizability of these findings

CONCLUSION

This meta-analysis demonstrates that ACS models provide a safe and effective framework for the management of emergency appendectomy and cholecystectomy. ACS-based care is associated with lower or comparable postoperative complication rates, improved timeliness of surgery, and favorable clinical and patient-reported outcomes. Early operative intervention and minimally invasive techniques are key determinants of reduced morbidity, while delays to surgery and open conversion are associated with increased postoperative complications.

Persistent variability in reported outcomes underscores the influence of patient-, disease-, and system-level factors and highlights the need for standardized definitions, optimized perioperative pathways, and high-quality prospective studies. Continued refinement of ACS protocols and broader implementation of evidence-based practices may further improve outcomes for patients undergoing emergency abdominal surgery.

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