DOI: https://doi.org/10.4038/gmj.v30i3.8273 **Review**

Cholecystectomy: A review of surgical approaches, complications, and outcomes

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ABSTRACT

Cholecystectomy, the surgical removal of the gallbladder, is a widely performed procedure for treating symptomatic gallstone disease, acute cholecystitis, and other biliary disorders. This review highlights the advantages, disadvantages, and clinical outcomes of several cholecystectomy approaches, including open and laparoscopic procedures. Because of its less invasive nature, decreased postoperative pain, and quicker recovery, laparoscopic cholecystectomy has emerged as the gold standard method. Open cholecystectomy, although less common, remains essential in complex cases with severe inflammation or anatomical challenges.

Even with improvements, cholecystectomy still has risks of complications such as bleeding, infection, bile duct injury, and post-cholecystectomy syndrome. It is particularly important to have the appropriate surgical technique, intraoperative imaging, and surgeon experience in order to reduce complications. Hospital stays and post-operative complications have decreased as a result of improved postoperative recovery brought about by Enhanced Recovery After Surgery (ERAS) procedures. The future of cholecystectomy is also being shaped by new technologies like robotic-assisted surgery and artificial intelligence, while more study is required to determine the long-term advantages and cost-effectiveness of these procedures.

This review underscores the need for continued advancements in surgical techniques, better training programmes, and multidisciplinary approaches to optimize patient outcomes and minimise complications. To further enhance the safety and effectiveness of cholecystectomy, future studies should investigate AI-driven decision-making tools, enhanced imaging methods, and robotic-assisted surgery improvement.

Keywords*:* *Bile duct Injury, Cholecystectomy, Gallstone disease, Laparoscopic surgery, Robotic surgery.*

Introduction

Cholecystectomy is a common surgical treatment which is mostly done for biliary diseases, acute cholecystitis, and symptomatic gallstone disease, in which gallbladder is removed surgically (1). Due to its shorter hospital stay, quicker recovery, and decreased postoperative pain, laparoscopic cholecystectomy has become the gold standard method as a result of improvements in minimally invasive procedures. Though its cost-effectiveness is still being assessed, robotic-assisted cholecys--tectomy has recently become popular and offers improved precision.

Despite these advancements, there are still complications associated with cholecystectomy, such as bleeding, infection, damage to the bile duct,

and long-term issues such post-cholecystectomy syndrome (2). The severity of the condition, the patient's characteristics, and the surgeon's experience all influence the surgical approach. Even though laparoscopic cholecystectomy is usually the preferable procedure, complicated circumstances requiring significant inflammation or anatomical changes still require open surgery.

This review explores the different surgical approaches to cholecystectomy, their benefits and risks, and clinical outcomes. By examining complications and long-term effects, this review aims to provide insights into optimizing surgical decision-making and patient care.

Surgical Approaches to Cholecystectomy

1. Open cholecystectomy

Previously, the most effective treatment for gallbladder disease was open cholecystectomy. To access and remove the gallbladder, an incision is made in the right upper quadrant (3). This method is especially applied in cases of cancer, gangrene, or severe gallbladder inflammation. Compared to less intrusive methods, open cholecystectomy is linked to longer hospital stays, more postoperative pain, and a higher risk of complications, despite its effectiveness (4). Because of these drawbacks, it is now mostly used in situations where laparoscopic cholecystectomy is not practical. Open cholecystectomy is an option in oncologic settings because it provides improved exposure in difficult cases, such as those with biliary tract malignancies.

Furthermore, open cholecystectomy remains the preferred choice in cases where patients present with severe coagulopathy or conditions that contraindicate pneumoperitoneum, such as significant cardiopulmonary disease. In these situations, open cholecystectomy is the safer option because laparoscopy does not result in elevated intra-abdominal pressure.

2. Laparoscopic cholecystectomy

Laparoscopic cholecystectomy (LC) has largely replaced open surgery as the preferred technique due to its minimally invasive nature, shorter recovery time, and reduced postoperative pain (6). In order to remove the gallbladder, a laparoscope and specialized tools are inserted through small incisions. LC has been associated with a quicker return to normal activities, shorter hospital stays, and less wound complications. Nevertheless, there are potential risks due to it, such as damage to the bile duct, intestinal perforation, and the need for open surgery in situations of complex gallbladder illness (6).

Several studies have explored the benefits of early versus delayed laparoscopic cholecystectomy in cases of acute cholecystitis. Early laparoscopic cholecystectomy which is performed within 72 hours of symptom onset, has been associated with lower morbidity, shorter hospital stays, and reduced rates of gallbladder-related complications (1). On the other side, if the inflammation is severe, a delayed laparoscopic cholecystectomy can be required, requiring antibiotic interval therapy and percutaneous cholecystostomy prior to definitive surgery.

3. Robotic-assisted cholecystectomy

Minimally invasive cholecystectomy has been significantly improved with the use of robotic-assisted surgery. According to Abu-Eshy, *et al.,* robotic cholecystectomy may lower the risk of complications because it provides increased surgeon control, improved visibility, and increased precision (7). In cases with challenging anatomy, significant inflammation, or previous abdominal procedures, robotic surgery is especially advantageous. However, because it requires specific training, is expensive, and takes longer to operate, its adoption is restricted (8).

Large-scale research is required to determine whether robotic cholecystectomy is more cost-effective than laparoscopic procedures, despite the procedure's growing popularity. According to some research, better visibility during robotic cholecystectomy may lower bile duct injury rates, although further randomized controlled trials are required to validate these results. Better ergonomics for the surgeon are also made possible by robotic-assisted procedures, which may lessen surgeon fatigue and increase surgical precision in long or complicated situations.

Complications of cholecystectomy

1. Bile duct injury

Bile duct injury (BDI) is one of the most serious complications of cholecystectomy, with an incidence rate of 0.3% to 0.7% in laparoscopic procedures (9). According to Brunt, *et al.* (2001), injuries might occur due to improper identification of biliary anatomy, overuse of electrocautery, or challenging dissection in inflammatory tissues. Bile leaks, strictures, and the requirement for complex surgical correction are among the effects of bile duct injury (10). The critical evaluation of safety approach and routine intraoperative cholangiography are two strategies to lower BDI. Surgeons with higher case volumes and more experience have significantly lower rates of BDI, underscoring the importance of structured training and mentorship programs for surgical trainees.

2. Haemorrhage and Infection

Bleeding during cholecystectomy can result from injury to the cystic artery, liver bed, or major vascular structures. Although postoperative bleeding is uncommon, it needs to be identified and treated immediately (12). Surgical site infections (SSIs) and intra-abdominal abscesses are additional complications, with risk factors including prolonged operative time, bile spillage, and immunosuppression (13). The risk of infections can be reduced with proper surgical technique and the use of prophylactic antibiotics. Percutaneous drainage may be necessary to manage sepsis in cases of abscess formation or infected bile collections.

Clinical outcomes and postoperative considerations

Patients who are undergoing laparoscopic cholecystectomy typically experience shorter hospital stays and quicker return to normal daily activities compared to those undergoing open cholecystectomy (2). Enhanced recovery after surgery (ERAS) protocols, including multimodal analgesia and early mobilization, found to have further improved patient outcomes. Robotic-assisted techniques may offer further advancements in recovery time and postoperative pain management, although more studies are needed to confirm these benefits (7).

Additionally, preoperative patient education regarding postoperative expectations and lifestyle modifications can enhance recovery and improve patient satisfaction regarding the surgery. Studies have shown that structured educational programmes regarding dietary modifications, pain management, and activity resumption significantly reduce patient anxiety and improve postoperative adherence to medical advice.

Discussion

The evolution of cholecystectomy techniques highlights the ongoing efforts to optimize surgical outcomes, minimise complications, and enhance recovery of the patients. While laparoscopic cholecystectomy remains the gold standard for the treatment due to its minimally invasive nature, robotic-assisted surgery is gaining traction, particularly for complex cases. However, the higher costs associated with robotic guided surgery pose a significant barrier to widespread adoption in each and every setting, necessitating further cost-effectiveness analyses and technological advancements to make it more accessible.

One of the key considerations in cholecystectomy is the risk of bile duct injury (BDI), a potentially serious complication with associated long-term consequences. Despite its low incidence rates, BDIs can lead to significant morbidity, requiring complex surgical repairs or endoscopic interventions. The implementation of intraoperative cholangiography (IOC) and near-infrared fluorescence imaging has shown promise in reducing misidentification of biliary structures, thereby improving patient safety during the surgery. Additionally, the incorporation of artificial intelligence (AI) in intraoperative decision-making may further refine surgical precision, potentially reducing associated complications.

Surgeon's experience remains a crucial determinant of cholecystectomy outcomes. Studies indicate that high-volume surgeons and specialized training programs contribute to lower rates of complications,

especially BDIs. Simulation-based training and structured mentorship programs can help connect the learning curve for laparoscopic and robotic-assisted techniques, ensuring that less-experienced surgeons can safely perform the procedure. The expansion of training programs focused on robotic-assisted techniques may also help integrate this approach more broadly into clinical practice.

Postoperative recovery protocols have also undergone significant improvements with the adoption of Enhanced Recovery After Surgery (ERAS) recent guidelines. These protocols emphasize multimodal analgesia, early mobilisation following surgery, and optimised nutritional support, collectively contributing to shorter hospital stays and improved patient satisfaction. Future research should focus on refining these protocols to further enhancing of patient outcomes, particularly in high-risk populations such as the elderly or those with significant comorbidities.

Furthermore, emerging research techniques are exploring the role of AI and machine learning in predicting surgical risks and guiding clinical decision-making. AI-driven modalities analysing patient data may aid in stratifying patients based on their risk profile, allowing for personalized surgical planning. While still in early development, these technologies hold the potential to improve surgical outcomes by optimising patient selection and predicting complications before they arise postoperatively.

The financial implications of cholecystectomy techniques must also be considered when selecting surgical modalities. While laparoscopic cholecystectomy is well established as the most cost-effective approach for most patients planned for surgery, the high upfront costs of robotic surgery continue to limit its adoption. However, as robotic modalities become more sophisticated and cost-efficient, their broader implementation may become more feasible. Large-scale studies comparing the long-term benefits of robotic versus laparoscopic cholecystectomy, particularly regarding complication rates and patient quality of life, are mandatory to determine its true value.

Conclusions

Cholecystectomy remains the definitive treatment for symptomatic gallbladder related diseases. While laparoscopic guided cholecystectomy is the current gold standard due to its superior outcomes compared to open surgery, robotic-assisted techniques continue to evolve. The risk of complications such as bile duct injury and postoperative infections underscores the significance of surgical expertise and careful patient selection. Future research should focus on advancing surgical techniques, reducing complications, and optimising patient recovery. Expanding the role of artificial intelligence and machine learning in making decisions related to surgeries and intraoperative guidance may enhance safety and improve patient outcomes.

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