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Review

Biliary Preservation Surgery vs. Cholecystectomy: A Re-Evaluation of the Era of Precision Medicine

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Abstract: In the management of biliary diseases, gallbladder-preserving surgery and cholecystectomy are two primary surgical strategies that have attracted considerable attention. With the advent of precision medicine, the development of advanced diagnostic tools and personalized treatment approaches necessitates a re-evaluation of their clinical applications. Gallbladder-preserving surgery, including procedures such as partial cholecystectomy and gallbladder-preserving lithotomy, aims to remove pathological lesions while retaining as much functional gallbladder tissue as possible, whereas cholecystectomy involves complete removal of the diseased gallbladder to prevent recurrence. Each approach has distinct advantages and limitations: gallbladder-preserving surgery maintains gallbladder function and supports normal biliary physiology, while cholecystectomy provides definitive resolution of gallbladder pathology with a lower recurrence risk. However, gallbladder-preserving procedures carry the potential for disease recurrence, and cholecystectomy may result in loss of gallbladder function and associated complications. Recent studies have explored the indications, surgical outcomes, and long-term prognosis of these procedures across diverse patient populations. Guided by precision medicine, the integration of genetic testing, advanced imaging modalities, and biomarker assessments enables more accurate risk stratification and individualized treatment planning, enhancing both surgical safety and efficacy. This article systematically reviews recent literature on gallbladder-preserving surgery and cholecystectomy, providing a comprehensive evaluation of indications, therapeutic effects, complications, and postoperative recovery, with the aim of offering clinicians evidence-based guidance for selecting the most appropriate surgical approach for each patient.

Keywords: gallbladder-preserving surgery; cholecystectomy; precision medicine; personalized treatment; surgical assessment

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1. Introduction

1.1. Background and Definition of Gallbladder-preserving Surgery

The primary indications for gallbladder-preserving surgery include gallstones, cholecystitis, and, in certain cases, pancreatitis. Compared to cholecystectomy, this procedure is associated with lower postoperative complication rates and faster recovery. Patients undergoing gallbladder-preserving surgery generally require shorter hospital stays, typically 3-5 days, compared to 5-7 days for cholecystectomy. In many cases, the gallbladder remains in a reversible pathological state, where the risks of extensive surgical intervention may outweigh the benefits, contributing to the growing recognition and adoption of gallbladder-preserving techniques [1].

Clinical practice employs various gallbladder-preserving surgical methods, with percutaneous cholecystostomy and endoscopic retrograde cholangiopancreatography (ERCP) among the most common. ERCP, in particular, achieves a clinical success rate exceeding 85%, which is critical for managing acute cholecystitis. For high-risk patients

with comorbidities such as diabetes or cardiovascular disease, gallbladder-preserving surgery can significantly reduce surgical risks [2].

In the era of precision medicine, personalized treatment strategies have become increasingly integral to biliary surgery. Clinicians make decisions based on patients' specific conditions, physical status, and risk assessments to develop optimal treatment plans. Customized surgical approaches that account for individual biliary anatomy not only enhance therapeutic outcomes but also substantially improve patients' quality of life [3-8].

Cholecystectomy is not suitable for all patients, and a thorough evaluation of gallbladder function, gallstone characteristics, and comorbidities is essential. Overall, gallbladder-preserving surgery and cholecystectomy offer complementary approaches for managing biliary diseases, with the former preserving function and the latter providing definitive resolution. With ongoing advancements in medical technology and deepening research, both approaches are expected to see broader and more precise applications.

1.2. History and Development of Cholecystectomy

The history of cholecystectomy dates back to the early 19th century, with the first surgical procedures performed in the 1830s. Subsequent developments in anesthesia and surgical techniques gradually transformed cholecystectomy into a standard procedure. By the mid-20th century, open cholecystectomy had become the primary approach, accompanied by significant improvements in surgical safety and effectiveness. Research during this period focused on surgical risk assessment, postoperative infection control, and recovery strategies [4-10].

The introduction of laparoscopic cholecystectomy in 1985 represented a major milestone in gallbladder surgery. This minimally invasive technique reduced surgical trauma, shortened hospital stays, and decreased postoperative complications. Laparoscopic recovery typically requires 1-3 days, representing a 70% reduction compared to traditional open surgery.

In recent years, precision medicine has increasingly influenced biliary surgery. Patient-specific variations in gallstone formation, complications, and postoperative recovery have highlighted the importance of personalized surgical planning. Physicians exercise particular caution when selecting surgical approaches for high-risk patients, including elderly individuals and those with comorbidities. Advancements in preoperative imaging, especially ultrasound and CT technologies, have enhanced diagnostic accuracy and informed surgical decision-making.

Compared with cholecystectomy, gallbladder-preserving procedures, such as laparoscopic bile duct exploration, have received increasing attention, especially for patients with high recurrence rates of gallstones. These approaches reduce the need for gallbladder removal while preserving functional capacity. However, the indications remain limited, requiring careful patient selection and evaluation. The ongoing evolution of cholecystectomy continues to focus on improving surgical safety and efficacy. Integrating precision medicine into patient selection, surgical approaches, and postoperative management is expected to further enhance clinical outcomes [11,12].

1.3. The Rise of Precision Medicine and Its Impact on Gallbladder Surgery

The emergence of precision medicine represents a paradigm shift toward personalized and targeted healthcare, with significant implications for biliary surgery. This model leverages genomic, proteomic, and metabolomic analyses to gain detailed insights into patients' biological characteristics, enabling customized treatment strategies. For example, molecular biomarker detection can help predict the pathological status of cholecystitis, supporting the selection of optimal surgical approaches [13].

In the context of precision medicine, the comparison between gallbladder-preserving surgery and traditional cholecystectomy has become increasingly relevant. Genomic analyses have demonstrated that certain patients tolerate functional changes from gallbladder-preserving surgery better and recover more quickly. Additionally, correlations between specific genotypes, the severity of gallbladder inflammation, and bile composition suggest that precision medicine can provide valuable evidence for individualized treatment planning [14-20].

Recent research indicates that cholecystectomy indications are no longer determined solely by clinical presentation but also by genetic profiles and biomarkers. Patients with particular lipid metabolism disorders, for example, exhibit higher postoperative complication risks after gallbladder removal. Gene expression profiling further enhances the precision of prognosis assessments. Implementation of precision medicine strategies has been associated with a 20-30% reduction in postoperative complications.

Even in the era of minimally invasive surgery, precision medicine offers new guidance for surgical approach selection. By integrating imaging technologies with patient-specific characteristics, surgeons can better assess procedural complexity and develop rational treatment plans. Clinical evidence demonstrates that gallbladder-preserving surgeries guided by precision medicine achieve superior outcomes compared to conventional approaches, with shorter recovery times and approximately a 3-day reduction in hospital stays [21,22].

Despite these advantages, challenges remain, particularly regarding treatment costs and patient acceptance. Although the cost of genetic testing and related technologies is decreasing, economically disadvantaged patients may still face barriers to access. Further evidence-based research is necessary to establish the long-term effectiveness and safety of precision medicine in gallbladder surgery. Overall, precision medicine has profound implications for biliary surgery, offering the potential for improved clinical outcomes and enhanced quality of life [23,24].

2. State of Research

2.1. Current Status and Trends of Gallbladder-preserving Surgery Worldwide

Statistical data from multiple large-scale retrospective studies conducted in 2019 indicate that the success rate of gallbladder-preserving surgery ranges between 80% and 90%. Medical institutions in several countries have established standardized treatment protocols and surgical guidelines for these procedures. In France and Germany, for example, clinical trials on gallbladder-preserving treatments for gallstones have explored the integration of small-incision techniques with laparoscopic surgery. The results demonstrate that patients undergoing laparoscopic gallbladder-preserving surgery experience a 2–3-day reduction in average hospital stays compared to traditional cholecystectomy, which typically requires 5-7 days of hospitalization [25-30].

Technological advancements, including endoscopic ultrasound (EUS) and magnetic resonance cholangiopancreatography (MRCP), have improved the early detection and precise treatment of gallbladder diseases. When combined with traditional open and laparoscopic surgery, these imaging modalities have progressively optimized postoperative recovery. With further developments in imaging technology, the scope of gallbladder-preserving surgery is expected to expand significantly.

Pathological studies of gallbladder tissue after gallbladder-preserving surgery indicate that such procedures can partially maintain physiological function, which is crucial for biliary health. The integration of personalized medicine, particularly genomic and proteomic analyses, could facilitate more precise surgical planning, thereby further improving success rates [31].

Despite its advantages, gallbladder-preserving surgery still faces implementation challenges. Postoperative biliary complications and the potential risk of gallbladder malignancy require careful monitoring. Rigorous patient selection-considering age, body

mass index, comorbidities, and psychological status-is essential to avoid inappropriate gallbladder preservation. Overall, gallbladder-preserving surgery is increasingly recognized for its role in treating gallbladder lesions, but ongoing research and technological innovation are needed to address clinical challenges and maximize patient benefits [32].

2.2. Current Application and Technological Advancements of Cholecystectomy

As the primary surgical approach for treating gallstones and related conditions, cholecystectomy has experienced continuous advancements in both technique and clinical application. The procedure is mainly divided into open cholecystectomy and laparoscopic cholecystectomy, with laparoscopic surgery now preferred due to its minimal invasiveness, faster recovery, and shorter hospital stays.

According to international guidelines, laparoscopic cholecystectomy has seen an average annual growth rate of 20% in recent years. Its indications have expanded to include acute cholecystitis, gallbladder polyps, and even early screening for gallbladder cancer. Approximately 90% of patients undergoing laparoscopic cholecystectomy can be discharged within 24 hours, significantly enhancing postoperative quality of life.

Technological developments have improved the feasibility and safety of cholecystectomy. Single-incision laparoscopic surgery (SILS) allows operations through a small incision, reducing postoperative pain and complications, while achieving comparable safety and effectiveness to conventional laparoscopic approaches. Robotic-assisted surgery is also gaining attention due to enhanced instrument flexibility and precision, enabling safer management of complex cases [33].

Continuous upgrades in surgical instruments, such as ultrasonic scalpels and electrosurgical units, have reduced intraoperative bleeding and promoted faster recovery. High-resolution 3D imaging provides clearer intraoperative visualization, minimizing the risk of injury to bile ducts and surrounding tissues [34].

Postoperative complication management remains a focus of current research. The incidence of biliary leakage and bile duct injury has declined to approximately 0.5-1%, and optimization of postoperative care has progressively reduced complications such as intestinal obstruction and infections after discharge. While technological advancements have enhanced surgical safety, personalized treatment strategies tailored to individual patient conditions remain essential. Future research will emphasize integrating precision medicine, particularly through genomic and systems biology approaches, to further improve surgical outcomes and patient safety [35].

2.3. Comparison of Biliary Preservation Surgery and Cholecystectomy in the Management of Complications

Traditional cholecystectomy, which removes the gallbladder entirely, may alter bile flow patterns, increasing the risk of postoperative biliary complications. Patients often require long-term digestive enzyme supplementation to compensate for reduced gallbladder function. Studies indicate that approximately 25% of patients experience postoperative symptoms such as indigestion, which can significantly impact quality of life. In contrast, gallbladder-preserving surgery substantially reduces this complication rate by maintaining organ function [36].

Management strategies for postoperative complications differ between the two surgical approaches. For patients undergoing gallbladder-preserving surgery who develop biliary tract infections or common bile duct stones, endoscopic treatment is an effective option with relatively low recurrence rates. Endoscopic retrograde cholangiopancreatography (ERCP) can successfully remove gallstones, with most patients achieving satisfactory outcomes. Additionally, gallbladder-preserving surgery maintains normal bile flow, supporting the body's natural defenses against infections.

In contrast, postoperative care following cholecystectomy often requires more complex management and multiple follow-ups, increasing healthcare resource consumption and patient discomfort. Imaging studies indicate that patients who undergo gallbladder-preserving surgery generally maintain normal liver function indicators, such as bilirubin levels. Those who undergo cholecystectomy may experience liver dysfunction due to altered bile flow, necessitating close monitoring. Therefore, gallbladder-preserving procedures not only reduce complication rates but also contribute to improved postoperative quality of life. This comparison underscores the importance of personalized treatment strategies in the era of precision medicine, demonstrating the flexibility and effectiveness of postoperative complication management [37].

3. Indications for Surgery

3.1. Indications and Contraindications for Gallbladder-preserving Surgery

Gallbladder-preserving surgery is generally not recommended for patients with acute cholecystitis, significant gallbladder atrophy, or gallbladder adenomyosis. The presence of gallbladder cancer is a critical contraindication, requiring rigorous clinical evaluation. Severe comorbidities, such as hepatic dysfunction or systemic diseases, may also compromise surgical suitability. For elderly patients and those with multiple organ dysfunction, comprehensive risk assessment is essential to ensure safe surgical decisions.

Ultrasound is widely used for initial diagnosis and follow-up of gallbladder diseases. High-resolution imaging modalities such as CT and MRI effectively identify gallbladder lesions and their characteristics, providing crucial information for determining surgical indications. With the development of minimally invasive techniques, laparoscopic gallbladder-preserving surgery has gradually become a standard alternative to conventional cholecystolithotomy. Its safety and effectiveness are increasingly recognized, although stricter requirements for surgical skills and case selection raise the bar for physicians' technical proficiency [38-42].

Clinical studies indicate that in properly screened patients, the success rate of gallbladder-preserving surgery exceeds 85%, with postoperative biliary complications occurring in less than 5% of cases. Comprehensive evaluation of individual conditions, lifestyle factors, and future functional needs is critical to achieving optimal outcomes and improving postoperative quality of life.

3.2. Indications and Contraindications for Cholecystectomy

Cholecystectomy is commonly indicated for gallstones, cholecystitis, gallbladder polyps, and gallbladder dysfunction. Symptomatic gallstones are the most frequent indication, with approximately 80-90% of patients requiring surgical intervention. Acute cholecystitis typically necessitates emergency surgery within 24-72 hours of onset to reduce complications, while chronic cholecystitis with recurrent symptoms may also warrant cholecystectomy. Gallbladder polyps larger than 1 cm present clear surgical indications due to potential malignancy, and gallbladder dysfunction identified through reduced contraction function on imaging is another important indication [43].

Contraindications for cholecystectomy include severe systemic diseases, such as heart disease or diabetes, requiring careful risk assessment. Patients with liver decompensation may face higher postoperative risks, necessitating thorough evaluation. Recent acute pancreatitis, severe coagulation disorders, and significant gastrointestinal conditions, including intestinal obstruction or extensive peritonitis, also contraindicate immediate surgery.

Definitive diagnosis is supported by imaging modalities such as ultrasound, CT, and MRCP. Preoperative assessments should include detailed patient history, physical examination, and laboratory tests to ensure safety and efficacy. For high-risk patients, biliary-preserving procedures may be preferred to maintain gallbladder function.

Precision medicine approaches are increasingly important in developing individualized surgical plans to optimize outcomes [44,45].

3.3. Clinical Criteria for Individualized Surgical Selection

Individualized surgical selection is based on multidimensional evaluations of disease stage, patient condition, and physiological characteristics to achieve optimal outcomes with minimal postoperative risk. Acute cholecystitis without additional complications generally warrants cholecystectomy to reduce recurrence and complication risks. In mild cases, such as asymptomatic gallstones or small polyps, gallbladder-preserving surgery may be more appropriate.

Imaging assessments, including ultrasound, should evaluate gallbladder size, wall thickness, and stone morphology. A wall thickness exceeding 3 mm indicates increased risk of inflammation or malignancy, favoring cholecystectomy. Age and comorbid conditions are critical factors; elderly patients or those with systemic diseases may benefit from gallbladder-preserving surgery to reduce postoperative complications. Surgical objectives, such as maintaining bile excretion and digestive function, also guide decision-making [46].

Selective dynamic cholecystography can predict gallbladder emptying function, providing individualized physiological feedback. Patients with normal emptying may prioritize gallbladder-preserving surgery, while those with impaired function may benefit from cholecystectomy. By integrating medical history, imaging, and laboratory tests, clinicians can develop personalized surgical plans.

Patient education regarding surgical options, expected outcomes, and potential risks is essential for enhancing involvement and satisfaction. Advanced intraoperative navigation, minimally invasive techniques, and postoperative monitoring further support the implementation of individualized surgical plans, ensuring alignment with both patient needs and clinical standards [47].

3.4. Surgical Selection Strategies for Different Patient Groups

Surgical strategies must be tailored to specific patient populations. In elderly patients, higher comorbidity and disease complexity make gallbladder-preserving procedures a viable option in selected cases. Postoperative complication rates for patients over 70 are approximately 30% after cholecystectomy, compared to around 15% with gallbladder-preserving surgery, although patient health status and stone characteristics must be considered.

Obese patients, particularly those with BMI over 30, are more likely to undergo cholecystectomy, though preoperative weight management may reduce surgical risks. Diabetic patients require careful blood glucose control, as levels below 6.5% significantly decrease postoperative infection rates and improve surgical safety.

For pregnant women with cholecystitis, the second trimester is the optimal time for surgery, achieving success rates exceeding 95%. Patients with liver disease, including cirrhosis, require individualized risk-benefit analyses. Those with preserved hepatic function may safely undergo cholecystectomy, while patients with severe impairment may benefit from gallbladder-preserving strategies.

In all patient groups, individualized surgical strategies, guided by precision medicine, optimize surgical success, reduce postoperative complications, and improve overall outcomes. Clinicians must carefully assess patient-specific factors, disease characteristics, and potential risks to develop tailored surgical plans that maximize both efficacy and safety [48].

4. Surgical Approach

4.1. Common Methods of Gallbladder Preservation Surgery and Their Technical Advantages and Disadvantages

Cholecystoplasty is indicated for patients with thickened gallbladder walls and functional impairment, aiming to restore gallbladder emptying capacity. This procedure involves local tissue reconstruction to achieve morphological and functional restoration. However, it requires advanced surgical expertise, and postoperative complications are relatively common. When performed by less experienced surgeons, issues such as biliary colic or cholecystitis may arise.

Cholangial drainage is primarily indicated for patients with biliary obstruction. It prevents gallbladder inflammation and bile duct infections by facilitating drainage through endoscopic or percutaneous approaches. This method offers lower invasiveness and fewer complications compared to traditional surgical procedures. Postoperative complication rates remain below 5%, while bile duct drainage efficiency is effectively enhanced [49].

When evaluating biliary-preserving surgical approaches, differences in long-term efficacy, postoperative dietary adaptation, and quality of life must be considered. Patients undergoing biliary-preserving surgery demonstrate improved biliary health outcomes compared to traditional cholecystectomy, including reduced gallstone recurrence and enhanced liver function protection. Emerging techniques, such as laparoscopic biliary-preserving procedures and robot-assisted surgeries, are gradually gaining prominence, offering potential improvements in surgical experience and prognosis [50].

Selecting the appropriate surgical approach requires holistic evaluation of the patient's medical history, physical condition, and individual needs. Understanding the technical strengths and limitations of various gallbladder-preserving surgeries is critical for personalized treatment in the era of precision medicine. With continued technological advancements, these procedures are expected to expand their indications and improve postoperative outcomes.

4.2. Analysis of Major Cholecystectomy Techniques (Traditional vs. Minimally Invasive)

Cholecystectomy, the standard procedure for treating gallstones and related conditions, can be categorized into traditional open cholecystectomy and minimally invasive approaches. Traditional open surgery typically requires a large abdominal incision (approximately 10-15 cm) and is suitable for large gallbladders or complex inflammatory conditions. It provides high visualization and clear anatomical access, facilitating management of complications such as bile duct injuries or extensive inflammation. However, open surgery is associated with slower recovery, longer hospital stays, and higher postoperative complication rates [51].

Minimally invasive cholecystectomy includes laparoscopic and robotic-assisted procedures, utilizing small incisions (typically 0.5-1.5 cm). These techniques offer reduced postoperative pain, shorter hospital stays (typically 24-48 hours), and lower complication rates. The conversion rate from minimally invasive to open surgery is approximately 2-5%. Intraoperative biliary imaging can further enhance surgical safety.

Both traditional and minimally invasive surgeries generally require general anesthesia, though local anesthesia may be used in select minimally invasive cases. Complication rates are below 3% for minimally invasive surgery, compared to approximately 15% for traditional open procedures. Treatment success rates are comparable (~95%), with minimally invasive approaches offering notable advantages for suitable patients, including those without severe obesity or prior abdominal surgery.

Future developments in cholecystectomy will focus on preoperative precision imaging, real-time intraoperative monitoring, and personalized postoperative rehabilitation. Integration of emerging technologies, including artificial intelligence, has

the potential to optimize surgical planning, intraoperative decisions, and overall clinical outcomes [52].

4.3. Comparison of Key Techniques in Surgical Procedures

Laparoscopic cholecystectomy (LC) is a safe, minimally invasive procedure providing rapid recovery and low infection risks. It has become the gold standard for gallbladder diseases due to excellent visualization and low complication rates. Key technical aspects include the use of carbon dioxide pneumoperitoneum to optimize the surgical view and integration of ultrasonic scalpels to reduce blood loss.

Gallbladder-preserving surgery is indicated for patients unable to tolerate total cholecystectomy, particularly those with chronic cardiopulmonary diseases or diabetes. This approach preserves gallbladder function, reducing postoperative gastrointestinal discomfort. Conversely, cholecystectomy is recommended for acute cholecystitis, gallbladder polyps, or gallstones, preventing complications associated with functional loss [53].

The precision of gallbladder-preserving surgery relies on imaging-assisted techniques. ERCP allows clear visualization and precise stone removal, minimizing damage to the common bile duct. Intracavitary ultrasound provides high-resolution imaging to assess stone size and location. Cholecystectomy employs electrosurgical instruments to minimize tissue damage and ensure shorter postoperative recovery.

Big data-driven surgical planning and precision medicine are increasingly guiding surgical strategy selection. Integration of biomarkers, imaging, and patient profiles enables optimal approach selection to enhance outcomes while minimizing adverse effects. Standardized quality control and multicenter trials are necessary to validate the long-term efficacy and cost-effectiveness of gallbladder-preserving surgery compared to cholecystectomy [54].

4.4. Innovation and Future Development Direction of Surgical Operations

Advancements in precision medicine are shaping surgical innovations and future directions. Technological progress in both gallbladder-preserving surgery and cholecystectomy allows surgeons to tailor approaches to individual patient conditions. Minimally invasive techniques, particularly laparoscopy, have significantly improved safety and recovery. Comparative studies show laparoscopic cholecystectomy has a complication rate of 2-5%, with hospital stays reduced to 1-3 days.

Robot-assisted surgery enables precise operations and enhanced visualization. Studies indicate robotic cholecystectomy reduces postoperative complications, lowers pain scores, and can shorten operation time by 20-30% [55].

Preoperative evaluation combined with personalized strategies further improves surgical success. Imaging techniques such as EUS and MRCP provide detailed views of biliary anatomy, supporting precise diagnosis. Preoperative biomarker testing aids in risk assessment. Postoperative rehabilitation strategies, including the ERAS concept and regional nerve blocks, enhance recovery, reduce pain, and shorten hospital stays.

High-throughput technologies, such as genomics and proteomics, deepen understanding of genetic susceptibility and disease mechanisms, allowing for tailored surgical approaches and postoperative care. Telemedicine and real-time monitoring improve postoperative follow-up and patient management.

The adoption of emerging technologies continues to enhance surgical outcomes, reduce complications, and improve patient experience. In this evolving landscape, innovation and future development in surgical operations will promote a more refined, personalized model of patient care [56].

5. Clinical Efficacy

5.1. Recovery Period and Long-Term Efficacy of Gallbladder-Preserving Surgery

Patients undergoing gallbladder-preserving surgery generally experience shorter hospital stays compared to those undergoing cholecystectomy. Hospitalization typically ranges from 3 to 5 days. The adoption of minimally invasive techniques has further facilitated postoperative recovery, allowing patients to resume eating within 24 hours and return to normal activities within 72 hours. Postoperative complications are relatively rare, generally below 5%, with biliary tract infections and bile leakage being the most common, though their incidence is significantly lower than in cholecystectomy.

Gallbladder-preserving surgery aims to reduce the incidence of biliary-related diseases. Studies indicate that, compared to cholecystectomy, it is more effective in preventing biliary complications such as diarrhea and infections associated with gallbladder removal. Prospective studies show that patients undergoing gallbladder-preserving surgery achieve higher quality-of-life scores, particularly in digestive function and mental health, with over 80% experiencing substantial symptom relief within two years post-surgery [57].

Long-term outcomes demonstrate sustained benefits, including improvements in liver function metrics and overall biliary health. Follow-up studies indicate that over 70% of patients maintain excellent quality of life without new biliary complications within five years. In contrast, a higher proportion of cholecystectomy patients experience persistent symptoms, including indigestion and abdominal discomfort, over extended periods.

With the development of precision medicine, treatment decisions now consider not only physical condition but also psychological factors, medical history, and patient expectations. Comprehensive evaluations enable individualized surgical planning, optimizing both recovery and long-term efficacy. While gallbladder-preserving surgery is not suitable for all biliary diseases, it demonstrates favorable clinical outcomes under clear indications.

5.2. Evaluation of Efficacy and Long-Term Prognosis of Cholecystectomy

Cholecystectomy is widely used to treat gallbladder disorders and can be performed laparoscopically or through open surgery. Laparoscopic cholecystectomy is preferred due to its minimally invasive nature and shorter recovery period. Complication rates for laparoscopic procedures range from 3% to 5%, with average postoperative hospital stays of 2-3 days, significantly shorter than the 5-7 days required for open surgery.

Efficacy evaluations focus on postoperative symptom improvement, quality of life, and recurrence rates. Studies involving large patient cohorts demonstrate that over 70% report complete symptom resolution, with approximately 80% remaining recurrence-free at 12 months. Meta-analyses indicate laparoscopic cholecystectomy achieves a clinical cure rate of up to 90% [58].

Long-term prognosis shows a reduced risk of biliary tract diseases. Cohort studies reveal a 60% decrease in biliary disease risk within five years post-surgery. The incidence of cholangiocarcinoma after cholecystectomy is low, approximately 0.1%. Some patients, however, may experience biliary drainage symptoms, with a prevalence of 5-10%. Quality-of-life assessments, including EQ-5D and SF-36, indicate improvements of 20-25 points within 6-12 months postoperatively, particularly in nutrient absorption and daily functioning.

Dynamic monitoring of postoperative complications is essential. Early complications such as bleeding and infection occur in less than 3% of cases, while late complications, including bile duct injuries, are estimated at 0.5-1%. Preoperative evaluation and individualized treatment planning are critical to optimize outcomes. Precision medicine approaches should further explore personalized management strategies, including dietary and lifestyle adjustments, particularly for patients with comorbidities such as

pancreatitis. Overall, cholecystectomy significantly improves both quality of life and long-term prognosis in patients with gallbladder diseases [59].

5.3. Comparison of Therapeutic Effects between Gallbladder-Preserving Surgery and Cholecystectomy

Cholecystectomy remains the gold standard for treating gallbladder diseases, particularly in patients with recurrent cholecystitis. Laparoscopic cholecystectomy provides lower complication rates, faster recovery, and shorter hospital stays (1-3 days) compared to open surgery. Postoperative outcomes are evaluated using pain scores, quality-of-life measures, and complication rates. Pain typically scores 6-7 on the first postoperative day, dropping below 2 by day seven, accompanied by significant quality-of-life improvements.

From a health economics perspective, cost-benefit analyses are necessary. Gallbladder-preserving surgery may reduce initial medical expenses, but recurrence and subsequent surgical interventions can result in long-term costs exceeding those of cholecystectomy, potentially increasing by 20-30% over five years. Patient satisfaction surveys indicate that approximately 85% of cholecystectomy patients report favorable outcomes, compared to about 70% for gallbladder-preserving surgery.

Advancements in laparoscopic techniques have improved the safety and effectiveness of cholecystectomy. Nevertheless, gallbladder-preserving surgery remains valuable for specific populations, such as young women and high-risk surgical candidates. Personalized treatment strategies considering pathology, age, and overall health are crucial. For patients with chronic cholecystitis and gallstones, gallbladder-preserving surgery may be considered as first-line treatment under proper indications. Clinicians should weigh surgical risks against long-term outcomes to select the most appropriate approach.

Future clinical research should strengthen randomized controlled trials comparing these two surgical methods to clarify their indications and optimize therapeutic outcomes, providing robust evidence for personalized treatment strategies.

6. Surgical Risks and Complications

6.1. Common Complications of Gallbladder Surgery and Their Management

Late complications such as biliary strictures and gallbladder remnants are generally rare, but when they occur, they may require readmission or additional surgical intervention. Biliary strictures can result from biliary injury or postoperative scar tissue proliferation, and are commonly managed through endoscopic dilation or stent placement. Gallbladder remnants can be detected through imaging studies, and if residual tissue contains cholesterol stones or other lesions, further surgical removal may be necessary. The occurrence of gallbladder remnants is closely related to preoperative gallbladder function and intraoperative procedural assessment. Advanced imaging techniques can improve detection rates, particularly during postoperative follow-up.

Long-term outcomes after gallbladder-preserving surgery require ongoing evaluation, including assessment of gallbladder function recovery and its impact on quality of life. Modern approaches emphasize individual patient differences, utilizing precision medicine to comprehensively evaluate surgical indications, complication risks, and overall health status when developing personalized treatment plans. Clinicians must maintain up-to-date knowledge of common postoperative complications and their management and rigorously conduct follow-up care to improve patient outcomes and reduce the likelihood of reoperation.

6.2. Potential Risks and Management of Complications in Cholecystectomy

Cholecystectomy is a commonly performed surgical procedure for gallbladder diseases, with high success rates; however, potential risks and complications remain.

Postoperative bleeding occurs in approximately 0.5% to 2% of cases and can be mitigated through meticulous surgical technique and careful postoperative monitoring.

Biliary tract injury is one of the most serious complications, occurring in 0.3% to 0.5% of cases. Such injuries can result in postoperative bile leakage and bile duct stenosis. The use of ultrasound-guided localization and intraoperative cholangiography can effectively reduce the incidence of these injuries.

Postoperative infections represent another important risk, particularly in patients with underlying medical conditions. Infections often present as intra-abdominal abscesses or pulmonary complications. Strict aseptic technique and timely antibiotic administration are essential for reducing infection risks, while post-discharge monitoring and symptomatic treatment are critical for management.

Postoperative abdominal pain and functional dyspepsia are common, affecting 10% to 20% of patients. Early rehabilitation and nutritional guidance can alleviate symptoms and improve quality of life.

Given these potential risks, personalized surgical planning, comprehensive preoperative evaluation, and vigilant postoperative management are crucial. Factors such as overall health, gallbladder function, and comorbidities must be considered to design the most suitable treatment plan. Advances in precision medicine, including genomic profiling, can further optimize surgical planning, reduce complications, and enhance patient satisfaction. Effective management of cholecystectomy risks requires multidisciplinary collaboration and evidence-based practice to achieve the best clinical outcomes.

6.3. Different Strategies of Both Parties in Risk Management

Risk management strategies differ between gallbladder-preserving surgery and cholecystectomy. Gallbladder-preserving surgery aims to protect biliary anatomy, reducing postoperative complications such as biliary infections and the need for biliary reanastomosis. Complication rates for gallbladder-preserving surgery range from 5% to 8%, compared to up to 15% for cholecystectomy. Advanced endoscopic techniques, ultrasound guidance, and cholangiography facilitate precise localization and removal of gallstones while minimizing biliary tract injury.

Cholecystectomy, being more invasive, focuses on managing risks associated with postoperative complications. Bile duct injury occurs in 0.5% to 1% of cases, necessitating preoperative imaging, such as MRI or CT, to identify biliary abnormalities. Intraoperative strategies, including precise duct identification and careful incision planning, can reduce complication rates. Obese patients face higher postoperative risks, requiring specialized preoperative assessment and weight management protocols.

For high-risk patients, gallbladder-preserving surgery offers flexible indications, enabling personalized strategies to balance risks and benefits. Precision medicine tools, including genetic testing and advanced imaging, aid in identifying high-risk individuals and selecting safer surgical approaches. Postoperative management for patients with chronic conditions, such as obesity and diabetes, requires comprehensive evaluation to address potential risks effectively.

The minimally invasive nature of gallbladder-preserving surgery allows faster recovery, with hospital stays typically lasting 2-3 days compared to 4-5 days for cholecystectomy. Postoperative quality-of-life assessments indicate higher satisfaction during the first month following gallbladder-preserving procedures. These differences highlight the importance of tailored risk management strategies between the two surgical approaches. In the era of precision medicine, optimizing the coordination of surgical strategies with individual patient conditions will remain a key focus for future research.

7. Conclusion

7.1. Overall Comparison of Biliary Preservation Surgery and Cholecystectomy

Gallbladder-preserving surgery is indicated for patients with functional or non-functional gallbladder disorders, particularly in cases of gallstones, achieving a 65-80% removal rate. In contrast, cholecystectomy has broader indications, including acute or chronic cholecystitis and intrahepatic bile duct stones. The postoperative complication rate for cholecystectomy ranges from 5% to 10%, whereas gallbladder-preserving surgery generally demonstrates significantly lower complication rates, typically below 2%.

Postoperative gallstone recurrence rates indicate differences between the two approaches. Cholecystectomy recurrence rates are 15-30%, while gallbladder-preserving surgery recurrence typically remains below 10%. Although gallbladder function is maintained, regular postoperative monitoring remains essential to prevent recurrence.

Clinical studies suggest that gallbladder-preserving surgery provides superior improvements in quality of life. Patient outcomes demonstrate more normalized bile acid metabolism and a marked reduction in postoperative symptoms such as diarrhea and indigestion. Data indicate an average improvement of approximately 20 points in postoperative quality-of-life scores for patients undergoing gallbladder-preserving surgery.

It is important to note that gallbladder-preserving surgery requires advanced technical expertise, with surgeons needing strong endoscopic skills and continuous visual monitoring to minimize the risk of biliary tract injury. Large gallstones present additional challenges, increasing the risk of complications.

In summary, both gallbladder-preserving surgery and cholecystectomy have distinct advantages and limitations. Individualized evaluation based on patient-specific conditions is essential. The advancement of precision medicine necessitates redefining surgical indications and prognosis assessment through big data analysis and randomized clinical trials.

7.2. Recommendations for Surgical Selection under the Guidance of Precision Medicine

In the era of precision medicine, selecting between gallbladder-preserving surgery and cholecystectomy requires comprehensive preoperative evaluation, considering individual patient variations such as medical history, imaging findings, age, comorbidities, and genetic susceptibility. Advances in genomics and proteomics provide new insights for clinical decision-making. For example, certain genetic mutations may influence cancer risk and guide the timing and extent of surgical intervention.

Identifying suitable candidates for gallbladder-preserving surgery is particularly important. Patients without gallbladder inflammation, small gallstones (diameter <1 cm), and no complications are better suited for this approach, as it minimizes postoperative complications and enhances quality of life. In contrast, cholecystectomy significantly reduces recurrence rates in cases of recurrent pancreatitis or cholecystitis.

Imaging plays a pivotal role in preoperative planning. Diagnostic modalities, including ultrasound, CT, and MRCP, enable precise evaluation of biliary anatomy, stone localization, and size, providing critical information for surgical planning. Differentiating benign from malignant lesions and assessing potential biliary complications are essential, especially in patients with biliary tumors, where comprehensive strategies may involve combined surgery and adjuvant therapies.

The design of clinical pathways should incorporate multidisciplinary collaboration across preoperative, intraoperative, and postoperative phases. Minimally invasive techniques, such as laparoscopic cholecystectomy, are preferred due to shorter recovery times and reduced hospital stays. Postoperative monitoring and follow-up care remain essential, particularly for high-risk patients, who require regular imaging assessments to ensure disease-free outcomes.

Clinicians should base surgical decisions on a comprehensive assessment of individual patient conditions. Precision medicine emphasizes individualized treatment, informed by accurate diagnostics, to improve overall efficacy and ensure that surgical choices are scientifically justified.

7.3. Future Research Directions and Clinical Application Prospects

Future research comparing gallbladder-preserving surgery and cholecystectomy should integrate precision medicine and personalized treatment strategies. Genomic studies offer new perspectives on the pathogenesis of biliary diseases. Investigating correlations between specific gene mutations and gallbladder disease prognosis through large-scale case-control studies could identify biomarkers that guide clinical decision-making.

Advances in imaging technologies, particularly MRI and CT, provide precise evidence for surgical strategy selection. Future studies could develop imaging-based models to predict the relative advantages of gallbladder-preserving surgery versus cholecystectomy, enhancing clinical outcome predictability. Recent evidence suggests that CT image feature extraction can effectively differentiate patients suitable for each procedure, improving the success rate of surgical approach selection.

Optimizing perioperative management is also critical. Given the unique characteristics and potential complications of gallbladder-preserving surgery, research should focus on how anesthesia techniques and pain management protocols affect recovery. Systematic evaluation of these factors will inform safer and more effective surgical decisions.

Technological innovations, such as robot-assisted surgery, may enhance precision and safety in biliary procedures. Further exploration of robotic applications in gallbladder-preserving surgeries represents a key research direction. Comparative studies on the effectiveness of various surgical instruments and techniques for biliary tract lesion resection can provide evidence-based guidance and potentially improve postoperative patient satisfaction and quality of life.

Postoperative management can benefit from remote monitoring and nursing strategies. Wearable devices, such as smart wristbands, allow real-time monitoring of physiological indicators, providing timely feedback to clinicians and reducing complication rates.

Patient education and preoperative psychological interventions are important for improving surgical outcomes. Future studies should investigate patient cognition and understanding of gallbladder-preserving surgery versus cholecystectomy through surveys and interviews, supporting informed decision-making and effective doctor-patient communication.

Finally, evaluating national and regional disparities in surgical indications and outcomes is essential. Socioeconomic factors influencing surgical choices should be assessed to inform public health policy. Integrating findings from these multidimensional studies will advance the application of precision medicine in biliary tract surgeries.

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