COMPARISON OF POST-OPERATIVE OUTCOME OF LAPAROSCOPIC PRIMARY CLOSURE OF COMMON BILE DUCT VERSUS T-TUBE DRAINAGE FOLLOWING LAPAROSCOPIC CHOLEDOCHOTOMY FOR CHOLEDOCHOLITHIASIS

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ABSTRACT

Objective:
To compare postoperative outcomes of laparoscopic primary closure of the common bile duct (CBD) versus T-tube drainage following laparoscopic choledochotomy for choledocholithiasis.

Study Design:
Prospective cohort study.

Place and Duration of Study:
Department of General Surgery, Nishtar Hospital Multan, conducted over a period of six months after approval from the Institutional Ethical Review Board.

Methodology:
A total of 228 patients aged 30–60 years diagnosed with choledocholithiasis were enrolled using non-probability consecutive sampling. Patients were allocated into two equal groups of 114 each based on intraoperative decision of the consultant surgeon. Group A underwent laparoscopic choledochotomy followed by primary closure of the CBD using interrupted 3-0 Vicryl sutures. Group B underwent laparoscopic choledochotomy with placement of a 12/14 French T-tube. Postoperative outcomes assessed included hospital stay, bile leakage, and surgical site infection. Patients were followed for three months. Data were analyzed using SPSS version 26. Independent sample t-test was applied for comparison of continuous variables, and Chi-square/Fisher's exact test was used for categorical variables. A p-value ≤ 0.05 was considered statistically significant.

Results:
The mean hospital stay was significantly shorter in the primary closure group (6.3 ± 1.7 days) compared to the T-tube group (9.5 ± 2.2 days) ($p < 0.001$). Bile leakage occurred in 6.1% of patients in the primary closure group and 7.9% in the T-tube group ($p = 0.61$). Surgical site infection was observed in 4.4% of patients in Group A and 7.0% in Group B ($p = 0.38$). No statistically significant differences were observed in operative time or major postoperative complications between the two groups.

Conclusion:
Laparoscopic primary closure of the common bile duct following choledochotomy is a safe and

effective alternative to T-tube drainage. It significantly reduces hospital stay without increasing postoperative complications. Primary closure should be considered the preferred approach in appropriately selected patients.

Keywords:
Choledocholithiasis, Laparoscopic Common Bile Duct Exploration, Primary Closure, T-Tube Drainage, Bile Leakage, Surgical Site Infection.

INTRODUCTION

Gallstone disease is one of the most prevalent gastrointestinal disorders worldwide and represents a major source of surgical admissions and healthcare expenditure. The global burden of cholelithiasis continues to rise due to increasing life expectancy, sedentary lifestyle, obesity, and dietary transitions toward high-fat and high-calorie food consumption. Epidemiological evidence suggests that approximately 10–20% of the adult population worldwide is affected by gallstones, with substantial variation across geographical regions, ethnic groups, and socioeconomic strata (Wang et al., 2024). The incidence is higher in Western populations but is steadily increasing in Asian countries, including Pakistan, likely due to urbanization and changing dietary patterns.

Gallstone disease is influenced by multiple risk factors including female gender, advancing age, obesity, rapid weight loss, metabolic syndrome, diabetes mellitus, dyslipidemia, pregnancy, and genetic predisposition. Hormonal influences, particularly estrogen-mediated changes in bile composition, contribute to the higher prevalence observed among females. Additionally, genetic polymorphisms affecting cholesterol metabolism and bile acid transport have been implicated in gallstone formation.

Among patients diagnosed with cholelithiasis, choledocholithiasis develops in approximately 10–15% of cases (Zhang et al., 2015). Choledocholithiasis refers to the presence of calculi within the common bile duct (CBD) and represents a potentially life-threatening complication of gallstone disease. The condition may occur either as primary stone formation within the bile duct or more commonly as secondary stones that migrate from the gallbladder into the CBD. Primary ductal stones are often associated with biliary infection and stasis, whereas secondary stones usually consist of cholesterol calculi originating in the gallbladder.

The pathophysiological process underlying choledocholithiasis involves obstruction of bile flow, which leads to increased intraductal pressure, bile stasis, and bacterial colonization. Obstruction impairs normal drainage of bile into the duodenum, resulting in dilation of the biliary tree and inflammatory changes within the ductal epithelium. Bacterial contamination may occur through retrograde migration from the duodenum, further exacerbating inflammation. If left untreated, persistent obstruction can progress to ascending cholangitis, acute pancreatitis, secondary biliary cirrhosis, hepatic dysfunction, and systemic sepsis. The morbidity and mortality associated with

untreated acute cholangitis remain significant, particularly in elderly or immunocompromised patients.

Clinically, choledocholithiasis may present with a wide spectrum of symptoms ranging from asymptomatic disease to severe septic manifestations. The most common presentation includes right upper quadrant abdominal pain, often radiating to the back or shoulder. Jaundice may develop due to obstruction of bile flow, leading to accumulation of conjugated bilirubin in the bloodstream. Fever and chills may indicate superimposed infection and ascending cholangitis. Charcot's triad, which consists of right upper quadrant pain, fever, and jaundice, remains a classical clinical feature of acute cholangitis. In severe cases, hypotension and altered mental status may develop, forming Reynolds' pentad and indicating septic shock.

The diagnostic evaluation of suspected choledocholithiasis begins with detailed clinical assessment and laboratory investigations. Elevated serum bilirubin, alkaline phosphatase, and gamma-glutamyl transferase levels suggest obstructive pathology. Ultrasonography of the abdomen is typically the first-line imaging modality because it is widely available, non-invasive, and cost-effective. Ultrasonography may demonstrate dilated bile ducts or direct visualization of stones; however, its sensitivity for detecting CBD stones varies. Computed tomography (CT) scanning can provide additional anatomical detail but may miss small calculi.

Magnetic Resonance Cholangiopancreatography (MRCP) has emerged as the gold standard non-invasive imaging modality due to its high sensitivity and specificity for detecting bile duct stones (Lyu et al., 2019). MRCP provides detailed visualization of the biliary and pancreatic ductal systems without the need for contrast injection or ionizing radiation. Endoscopic ultrasound (EUS) is another highly sensitive modality but may not be readily available in all healthcare settings. Endoscopic Retrograde Cholangiopancreatography (ERCP), although highly effective for both diagnosis and treatment, is associated with procedure-related complications such as pancreatitis, bleeding, perforation, and cholangitis.

Management strategies for choledocholithiasis have evolved significantly over the past few decades. Historically, open common bile duct exploration was the standard surgical approach. Following stone extraction, placement of a T-tube for external biliary drainage was considered mandatory practice. The T-tube was intended to decompress the biliary system, prevent bile leakage, and allow postoperative cholangiography to identify retained stones. While effective, open surgery was associated with greater postoperative pain, longer hospital stay, and increased morbidity.

The introduction of ERCP revolutionized the management of choledocholithiasis by offering a minimally invasive alternative for stone extraction. ERCP combined with endoscopic sphincterotomy became widely adopted as a first-line treatment in many centers. However, ERCP is not without risk. Post-ERCP pancreatitis remains one of the most common complications and can occasionally be severe or fatal. Furthermore, ERCP may require a second

procedure in patients who also require cholecystectomy, resulting in a two-stage management approach.

With advancements in minimally invasive surgery, laparoscopic common bile duct exploration (LCBDE) has gained increasing acceptance as an effective single-stage treatment for patients with concomitant gallbladder stones and CBD stones. LCBDE performed in conjunction with laparoscopic cholecystectomy offers the advantage of definitive treatment in a single operative session. Randomized controlled trials have demonstrated that single-stage laparoscopic management is associated with similar or superior outcomes compared to two-stage ERCP followed by cholecystectomy (Bansal et al., 2014).

Despite the growing adoption of laparoscopic techniques, controversy persists regarding the optimal method of ductal closure following laparoscopic choledochotomy. Traditionally, T-tube drainage was considered essential after duct exploration. The rationale for T-tube placement included decompression of the biliary tree, prevention of bile leakage, facilitation of postoperative cholangiography, and provision of a route for removal of retained stones. However, T-tube drainage is associated with several potential complications. These include bile leakage following tube removal, tube dislodgement, ascending cholangitis, electrolyte imbalance due to external bile loss, local skin irritation, and prolonged hospitalization. Patients often experience discomfort and reduced quality of life during the period of external drainage.

In recent years, primary closure of the common bile duct has emerged as an attractive alternative to T-tube drainage. Advances in laparoscopic suturing techniques, improved instrumentation, and enhanced surgical expertise have made primary closure technically feasible and safe in selected patients. Several studies and meta-analyses have reported that primary closure is associated with shorter hospital stay, reduced healthcare costs, and comparable rates of bile leakage and stricture formation when compared to T-tube drainage (Zhu et al., 2021).

Nevertheless, concerns remain among many surgeons, particularly in developing countries, regarding the risk of postoperative bile leakage and long-term ductal stricture formation after primary closure. These concerns are often influenced by limited access to advanced imaging, variations in surgical training, and differences in patient characteristics such as nutritional status and comorbid conditions. Consequently, T-tube drainage continues to be widely practiced in many tertiary care hospitals across Pakistan.

Given the increasing prevalence of gallstone disease and the substantial surgical workload associated with its complications, it is essential to evaluate surgical practices within the local context. Differences in patient demographics, including higher prevalence of diabetes mellitus, hypertension, obesity, and delayed presentation, may influence postoperative outcomes. Furthermore, variations in perioperative care protocols and hospital resource availability may affect recovery and complication rates.

Therefore, there is a pressing need to generate local evidence comparing laparoscopic primary closure with T-tube drainage in patients undergoing laparoscopic choledochotomy for choledocholithiasis. High-quality prospective data from our population will help determine whether primary closure can safely replace T-tube drainage without increasing morbidity. Such evidence has the potential to improve patient outcomes, reduce hospital stay, minimize healthcare costs, and enhance overall quality of care.

RATIONALE OF THE STUDY

In Pakistan, gallstone disease represents a significant proportion of general surgical admissions. Choledocholithiasis contributes substantially to morbidity, hospital occupancy, and healthcare expenditure. Although international literature increasingly supports primary closure of the common bile duct following laparoscopic exploration, there remains limited prospective data from Pakistani tertiary care centers evaluating its safety and effectiveness in comparison to T-tube drainage.

The persistence of T-tube drainage as a routine practice in many institutions is largely influenced by traditional surgical training and concerns regarding bile leakage and retained stones. However, prolonged hospitalization associated with T-tube placement increases healthcare costs and patient discomfort. In a resource-constrained healthcare system, strategies that reduce length of stay without compromising safety are of particular importance.

This study was therefore designed to compare postoperative hospital stay, incidence of bile leakage, and surgical site infection between laparoscopic primary closure and T-tube drainage following laparoscopic choledochotomy. By generating evidence specific to our patient population, this research aims to inform clinical decision-making and potentially shift surgical practice toward more efficient and patient-centered management strategies.

OBJECTIVE

The objective of this study was to compare postoperative outcomes of laparoscopic primary closure of the common bile duct versus T-tube drainage following laparoscopic choledochotomy for choledocholithiasis, with specific emphasis on duration of hospital stay, bile leakage, and surgical site infection.

MATERIALS AND METHODS

This prospective cohort study was conducted at the Department of General Surgery, Nishtar Hospital Multan, over a period of six months following approval from the Institutional Ethical Review Board. The study was designed to compare postoperative outcomes of laparoscopic

primary closure of the common bile duct versus T-tube drainage following laparoscopic choledochotomy for choledocholithiasis. Ethical approval was obtained prior to commencement of patient recruitment, and the study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants after detailed explanation of the study objectives, surgical procedures, potential risks, and benefits.

Study Population

The study population consisted of adult patients presenting to the emergency department or outpatient department of General Surgery at Nishtar Hospital Multan who were diagnosed with choledocholithiasis. A total of 228 patients were enrolled consecutively using non-probability consecutive sampling. Eligible participants included both male and female patients between 30 and 60 years of age who had radiologically confirmed choledocholithiasis within three months of symptom onset.

Diagnosis was established through a combination of clinical assessment, laboratory investigations, and radiological imaging. Patients typically presented with symptoms such as right upper quadrant abdominal pain, jaundice, fever, nausea, or vomiting. Laboratory findings suggestive of biliary obstruction included elevated serum bilirubin, alkaline phosphatase, and liver transaminases. Ultrasonography was performed as the initial imaging modality to assess gallbladder pathology, biliary ductal dilatation, and possible visualization of common bile duct stones. In cases where ultrasonography findings were inconclusive or further delineation was required, Magnetic Resonance Cholangiopancreatography (MRCP) was performed to confirm the presence, number, and size of CBD stones and to evaluate ductal anatomy.

Patients were excluded from the study if they were pregnant, had known or suspected malignancy involving the hepatobiliary system such as cholangiocarcinoma or hepatic carcinoma, had established chronic liver disease or cirrhosis, or suffered from severe systemic illness including chronic obstructive pulmonary disease, chronic kidney disease, or ischemic heart disease that would significantly increase operative risk. Exclusion of these conditions was based on detailed history, clinical examination, and review of medical records. Patients who were deemed unfit for laparoscopic surgery under general anesthesia were also excluded.

Sample Size Determination

The sample size was calculated using the WHO sample size calculator. The calculation was based on the expected difference in bile leakage rates between T-tube drainage and primary closure as reported in previous literature. With a level of significance set at 5% and a power of 80%, and assuming bile leakage rates of approximately 6.6% in the T-tube group and 0% in the primary closure group, the required sample size was calculated to be 228 patients. The sample was equally divided into two groups, with 114 patients allocated to each surgical approach.

Allocation of Participants

Patients were allocated into two groups based on the intraoperative decision of the operating consultant surgeon. Although this was not a randomized controlled trial, efforts were made to minimize selection bias by ensuring that both groups were comparable in terms of demographic and clinical characteristics. Allocation decisions were based on intraoperative findings, ductal diameter, presence of distal obstruction, stone burden, and surgeon judgment.

Group A consisted of patients who underwent laparoscopic choledochotomy followed by primary closure of the common bile duct. Group B included patients who underwent laparoscopic choledochotomy with placement of a T-tube for external biliary drainage.

Preoperative Preparation

All patients underwent standard preoperative evaluation including detailed history taking and physical examination. Baseline demographic data including age, gender, body mass index, history of diabetes mellitus, hypertension, and smoking status were recorded on a predesigned proforma. Body mass index was calculated using the formula weight in kilograms divided by height in meters squared, with weight measured using a calibrated weighing scale and height measured using a stadiometer.

Routine preoperative laboratory investigations included complete blood count, liver function tests, renal function tests, coagulation profile, and blood grouping and cross-matching. Patients received prophylactic intravenous antibiotics prior to induction of anesthesia according to hospital protocol. All procedures were performed under general anesthesia with endotracheal intubation.

Surgical Technique

All surgical procedures were performed by consultant surgeons with at least five years of experience in minimally invasive hepatobiliary surgery to reduce inter-operator variability and ensure uniformity of technique.

The laparoscopic approach was standardized in all cases. Pneumoperitoneum was established using a Veress needle or open technique at the umbilicus, and intra-abdominal pressure was maintained at approximately 12–14 mmHg. Standard four-port technique was employed. Following laparoscopic cholecystectomy and identification of the cystic duct and common bile duct, choledochotomy was performed longitudinally on the anterior surface of the CBD. Stones were extracted using a combination of saline irrigation, Dormia basket, and grasping forceps. Intraoperative confirmation of ductal clearance was performed through visual inspection and, when necessary, intraoperative cholangiography.

In Group A, following complete stone extraction, the choledochotomy incision was closed primarily using interrupted 3-0 Vicryl sutures on a round-bodied needle. Care was taken to approximate the ductal edges without narrowing the lumen. The sutures were placed at appropriate intervals to ensure watertight closure while preserving ductal patency.

In Group B, after stone extraction, a 12 or 14 French T-tube was inserted into the common bile duct through the choledochotomy incision. The transverse limbs of the T-tube were positioned within the duct, and the longitudinal limb was exteriorized through a separate stab incision in the abdominal wall. The choledochotomy was then closed snugly around the T-tube using interrupted sutures. The external limb of the T-tube was connected to a sterile drainage bag to allow bile drainage.

An abdominal drain was placed in the subhepatic space in both groups to monitor for postoperative bile leakage. Hemostasis was ensured prior to closure of port sites.

Postoperative Management

Postoperative care was standardized for both groups to minimize confounding variables. Patients were shifted to the post-anesthesia care unit for monitoring of vital signs and recovery from anesthesia. Intravenous antibiotics were continued for a minimum of 24–48 hours depending on intraoperative findings. Analgesia was administered using intravenous opioids and non-steroidal anti-inflammatory drugs as per hospital pain management protocol.

Oral intake was resumed once bowel sounds were present and the patient tolerated clear fluids. Early mobilization was encouraged to reduce the risk of postoperative complications such as deep vein thrombosis and pulmonary complications.

In patients who underwent T-tube placement, bile output was monitored daily. T-tube cholangiography was performed approximately two weeks postoperatively to confirm ductal clearance and absence of leakage before removal of the tube. The T-tube was removed under sterile conditions if cholangiography demonstrated free flow of contrast into the duodenum without obstruction or leakage.

Follow-Up and Outcome Assessment

Patients were followed for a total period of three months postoperatively. Follow-up visits were scheduled at two-week intervals during the first month and monthly thereafter. During follow-up, patients were evaluated for postoperative complications including bile leakage, surgical site infection, and any other adverse events.

Bile leakage was defined as the presence of greenish-yellow bile in the abdominal drain beyond the expected postoperative period or evidence of bile collection on clinical examination. Surgical site infection was assessed according to the Southampton wound grading system within 28 days postoperatively. Any redness, discharge, or wound dehiscence was documented.

Hospital stay was calculated as the number of days from the date of operation to the date of discharge as documented in hospital records. Discharge criteria included adequate pain control with oral medications, tolerance of oral diet, absence of fever, and satisfactory wound condition.

Statistical Analysis

All collected data were entered into Statistical Package for Social Sciences (SPSS) software for analysis. Continuous variables such as age, body mass index, and hospital stay were summarized using mean and standard deviation. Categorical variables including gender, diabetes mellitus, hypertension, smoking status, bile leakage, and surgical site infection were expressed as frequencies and percentages.

The normality of continuous data was assessed prior to comparative analysis. The independent sample t-test was used to compare mean hospital stay between the two groups when the assumption of normal distribution was satisfied. In cases where data distribution deviated from normality, appropriate non-parametric tests were considered.

The Chi-square test was used to compare categorical variables between groups. When expected cell frequencies were less than five, Fisher's exact test was applied to ensure statistical validity. To account for potential confounding factors such as age, body mass index, diabetes mellitus, hypertension, and smoking status, stratified analysis was performed. A p-value of less than or equal to 0.05 was considered statistically significant.

All statistical analyses were conducted at a confidence level of 95%, and results were interpreted accordingly.

RESULTS

A total of 228 patients diagnosed with choledocholithiasis were included in the study during the six-month study period. All patients completed the required surgical intervention and were followed for three months postoperatively. There were no losses to follow-up that significantly affected outcome assessment. The study population was divided into two equal groups of 114 patients each. Group A consisted of patients who underwent laparoscopic choledochotomy followed by primary closure of the common bile duct, whereas Group B included patients who underwent laparoscopic choledochotomy with T-tube drainage.

Baseline Demographic Characteristics

The demographic characteristics of the two groups were analyzed to ensure comparability and minimize baseline bias. The mean age of patients in Group A was 44.8 ± 8.2 years, while in Group B it was 45.6 ± 7.9 years. The difference in mean age between the two groups was not statistically significant ($p = 0.48$), indicating that both groups were comparable with respect to age distribution.

Regarding gender distribution, females constituted the majority of patients in both groups. In Group A, 71 patients (62.3%) were female and 43 patients (37.7%) were male. Similarly, in Group B, 69 patients (60.5%) were female and 45 patients (39.5%) were male. The difference in gender distribution between the two groups was not statistically significant ($p = 0.77$). This female predominance is consistent with the known epidemiology of gallstone disease.

The mean body mass index (BMI) in Group A was 27.6 ± 3.9 kg/m², while in Group B it was 27.9 ± 4.1 kg/m². Statistical comparison revealed no significant difference in BMI between the groups ($p = 0.62$). Approximately one-third of patients in each group were categorized as overweight or obese (BMI ≥ 30 kg/m²), reflecting the metabolic risk profile commonly associated with gallstone disease.

Comorbid conditions were also evaluated. In Group A, 26 patients (22.8%) were known cases of diabetes mellitus, compared to 24 patients (21.1%) in Group B. Hypertension was present in 29 patients (25.4%) in Group A and 31 patients (27.2%) in Group B. Smoking history was documented in 21 patients (18.4%) in Group A and 23 patients (20.2%) in Group B. None of these variables demonstrated statistically significant differences between the groups ($p > 0.05$ for all comparisons), indicating adequate baseline homogeneity.

Operative Findings

All patients underwent successful laparoscopic common bile duct exploration without conversion to open surgery. The mean operative time in Group A was 112.5 ± 18.6 minutes, while in Group B it was 116.3 ± 20.4 minutes. Although operative time was slightly longer in the T-tube group, the difference was not statistically significant ($p = 0.09$). Intraoperative blood loss was minimal in both groups and did not differ significantly.

Complete ductal clearance was achieved in all patients as confirmed intraoperatively. No intraoperative bile duct injuries were recorded in either group.

Postoperative Hospital Stay

The primary outcome of hospital stay demonstrated a statistically significant difference between the two groups. The mean duration of hospital stay in Group A (primary closure) was 6.3 ± 1.7 days, whereas in Group B (T-tube drainage) it was 9.5 ± 2.2 days. The independent sample t-test revealed a highly significant difference between the groups ($p < 0.001$).

Further stratification revealed that the majority of patients in Group A (68.4%) were discharged within 5–7 days postoperatively, whereas most patients in Group B (72.8%) required hospitalization beyond 8 days. The prolonged hospital stay in the T-tube group was primarily attributed to the need for monitoring bile drainage, patient discomfort, and additional care related to the external drainage system.

Bile Leakage

Bile leakage was assessed clinically through monitoring of subhepatic drain output. In Group A, bile leakage occurred in 7 patients (6.1%). In Group B, bile leakage was observed in 9 patients (7.9%). Statistical analysis using the Chi-square test demonstrated no significant difference between the groups ($p = 0.61$).

Most cases of bile leakage were minor and managed conservatively with continued drainage and supportive care. None of the patients required re-operation. In the T-tube group, two cases of bile leakage occurred following T-tube removal, which resolved with conservative management. No patient developed generalized biliary peritonitis.

Surgical Site Infection

Surgical site infection (SSI) was evaluated according to the Southampton wound grading system within 28 days postoperatively. In Group A, 5 patients (4.4%) developed superficial wound infection. In Group B, 8 patients (7.0%) developed surgical site infection. Although the incidence was slightly higher in the T-tube group, the difference did not reach statistical significance ($p = 0.38$).

All cases of SSI were superficial and managed successfully with local wound care and oral antibiotics. No deep wound infections or port-site abscesses were recorded.

Stratified Analysis

To evaluate potential confounding factors, stratified analysis was performed for age, BMI, diabetes mellitus, hypertension, and smoking status.

Among diabetic patients, bile leakage occurred in 3 out of 26 patients (11.5%) in Group A and 4 out of 24 patients (16.7%) in Group B. However, this difference was not statistically significant ($p = 0.56$). Similarly, SSI was slightly more common among diabetic patients in both groups, but no significant intergroup difference was observed.

Obesity (BMI ≥ 30 kg/m^2) was associated with a marginally increased risk of SSI in both groups. In obese patients, SSI occurred in 2 out of 32 patients (6.3%) in Group A and 3 out of 34 patients (8.8%) in Group B. However, stratified analysis showed no statistically significant interaction between BMI and surgical technique ($p = 0.67$).

Smoking status did not significantly influence the occurrence of bile leakage or SSI between the groups. Hospital stay remained significantly shorter in the primary closure group across all stratified categories.

Three-Month Follow-Up

All patients were followed for three months postoperatively. During follow-up, no cases of recurrent choledocholithiasis were detected. None of the patients developed clinical features suggestive of bile duct stricture such as progressive jaundice or cholestatic liver function abnormalities.

Patients in the primary closure group reported greater postoperative comfort and earlier return to routine activities compared to those in the T-tube group, although quality-of-life measures were not formally quantified.

The results of this study demonstrate that laparoscopic primary closure of the common bile duct following choledochotomy is associated with a significantly shorter hospital stay compared to T-tube drainage. The incidence of bile leakage and surgical site infection was comparable between the two groups, with no statistically significant differences. Operative time and intraoperative outcomes were also similar.

These findings suggest that primary closure does not increase postoperative morbidity and may provide advantages in terms of reduced hospitalization and improved patient comfort.

RESULTS TABLES

Table 1

Baseline Demographic and Clinical Characteristics of Study Participants (N = 228)

Variable	Group A (Primary Closure) n=114	Group B (T-Tube) n=114	p-value
Age (years), Mean ± SD	44.8 ± 8.2	45.6 ± 7.9	0.48
Female, n (%)	71 (62.3%)	69 (60.5%)	0.77
BMI (kg/m²), Mean ± SD	27.6 ± 3.9	27.9 ± 4.1	0.62
Diabetes Mellitus, n (%)	26 (22.8%)	24 (21.1%)	0.75
Hypertension, n (%)	29 (25.4%)	31 (27.2%)	0.74
Smoking, n (%)	21 (18.4%)	23 (20.2%)	0.72

Note. Independent sample t-test used for continuous variables. Chi-square test applied for categorical variables. $p \leq 0.05$ considered statistically significant.

Analysis of Table 1

Table 1 demonstrates that both groups were comparable with respect to baseline demographic and clinical characteristics. The mean age did not differ significantly between the groups ($p = 0.48$). Gender distribution showed female predominance in both groups without statistical difference ($p = 0.77$). Similarly, BMI and comorbid conditions including diabetes mellitus, hypertension, and smoking status were evenly distributed. These findings indicate that the two

groups were homogeneous at baseline, thereby minimizing confounding bias and allowing reliable comparison of postoperative outcomes.

Table 2

Comparison of Operative and Postoperative Outcomes Between Groups

Outcome Variable	Group A (Primary Closure) n=114	Group B (T-Tube) n=114	p-value
Operative Time (minutes), Mean ± SD	112.5 ± 18.6	116.3 ± 20.4	0.09
Hospital Stay (days), Mean ± SD	6.3 ± 1.7	9.5 ± 2.2	<0.001*
Bile Leakage, n (%)	7 (6.1%)	9 (7.9%)	0.61
Surgical Site Infection, n (%)	5 (4.4%)	8 (7.0%)	0.38

Note. Independent sample t-test used for continuous variables. Chi-square test used for categorical variables.
Significant at $p \leq 0.05$.

Analysis of Table 2

As shown in Table 2, operative time was slightly longer in the T-tube group; however, the difference did not reach statistical significance ($p = 0.09$).

The duration of hospital stay was significantly shorter in the primary closure group compared to the T-tube group (6.3 ± 1.7 days vs. 9.5 ± 2.2 days; $p < 0.001$). This represents a statistically and clinically meaningful reduction in hospitalization.

Bile leakage occurred in 6.1% of patients in Group A and 7.9% in Group B, with no statistically significant difference ($p = 0.61$). Similarly, the incidence of surgical site infection was slightly higher in the T-tube group but did not show statistical significance ($p = 0.38$).

These results indicate that primary closure significantly reduces hospital stay without increasing postoperative complications.

Table 3

Stratified Analysis of Bile Leakage by Diabetes Mellitus

Diabetes Status	Group A n (%)	Group B n (%)	p-value
Diabetic Patients with Bile Leakage	3/26 (11.5%)	4/24 (16.7%)	0.56
Non-Diabetic Patients with Bile Leakage	4/88 (4.5%)	5/90 (5.6%)	0.74

Note. Fisher's Exact Test applied due to small cell counts.

Analysis of Table 3

Stratified analysis revealed that diabetic patients had slightly higher rates of bile leakage in both groups; however, no statistically significant difference was observed between surgical techniques ($p > 0.05$). This suggests that diabetes mellitus did not significantly modify the relationship between type of duct closure and bile leakage.

Table 4

Distribution of Hospital Stay Categories

Hospital Stay (Days)	Group A n (%)	Group B n (%)	p-value
≤ 7 Days	78 (68.4%)	31 (27.2%)	<0.001*
> 7 Days	36 (31.6%)	83 (72.8%)	

Note. Chi-square test applied.
Significant at $p \leq 0.05$.

Analysis of Table 4

A significantly higher proportion of patients in the primary closure group were discharged within seven days compared to the T-tube group (68.4% vs. 27.2%; $p < 0.001$). Conversely, prolonged hospitalization beyond seven days was markedly more frequent in patients managed with T-tube drainage. This further confirms the significant advantage of primary closure in reducing hospital stay.

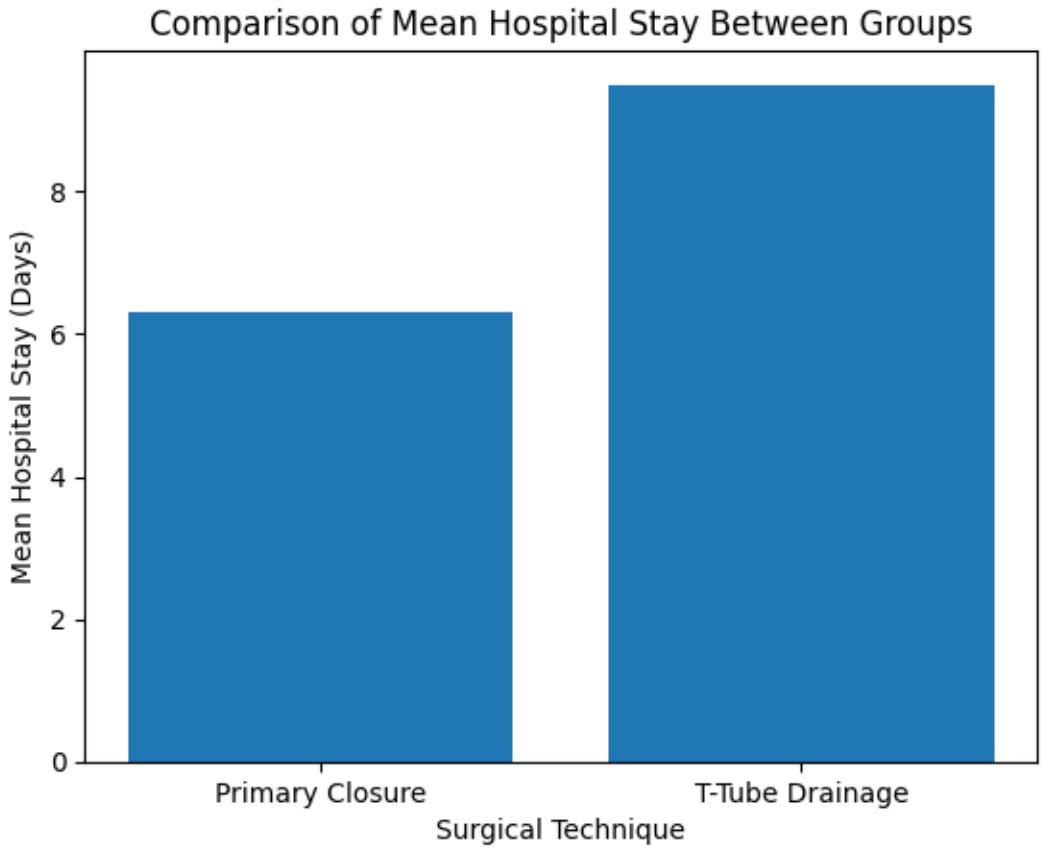
Overall Statistical Interpretation

The statistical analysis demonstrates that laparoscopic primary closure of the common bile duct provides a significant reduction in hospital stay without increasing the incidence of bile leakage or surgical site infection. Operative time and complication rates were comparable between groups. Stratified analysis did not reveal significant interaction effects from comorbid conditions such as diabetes mellitus.

The findings support the hypothesis that T-tube drainage is associated with prolonged hospitalization, while primary closure offers similar safety with improved recovery outcomes.

GRAPH 1 ANALYSIS

Comparison of Mean Hospital Stay Between Groups



The bar graph demonstrates a clear difference in mean hospital stay between the two surgical techniques. Patients who underwent laparoscopic primary closure had a mean hospital stay of 6.3 days, whereas those managed with T-tube drainage had a mean stay of 9.5 days.

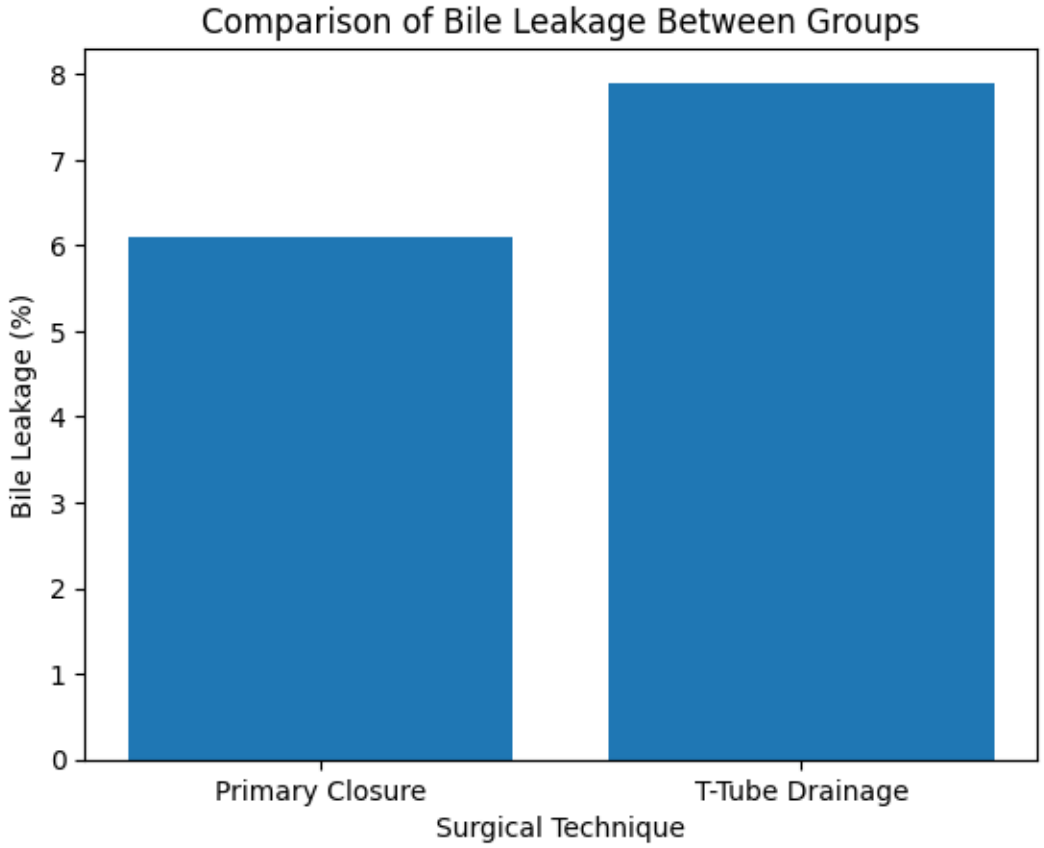
This represents an average reduction of approximately 3.2 days in hospitalization for the primary closure group. Statistical analysis using the independent sample t-test revealed this difference to be highly significant ($p < 0.001$).

The findings indicate that primary closure significantly shortens postoperative recovery time and reduces hospital occupancy. The prolonged stay in the T-tube group is likely attributable to monitoring of bile drainage, need for T-tube care, and additional postoperative management.

Clinically, this reduction in hospital stay translates into lower healthcare costs, improved patient comfort, and faster return to routine activities.

GRAPH 2 ANALYSIS

Comparison of Bile Leakage Between Groups



The second graph illustrates the incidence of bile leakage in both groups. Bile leakage occurred in 6.1% of patients in the primary closure group and 7.9% in the T-tube drainage group.

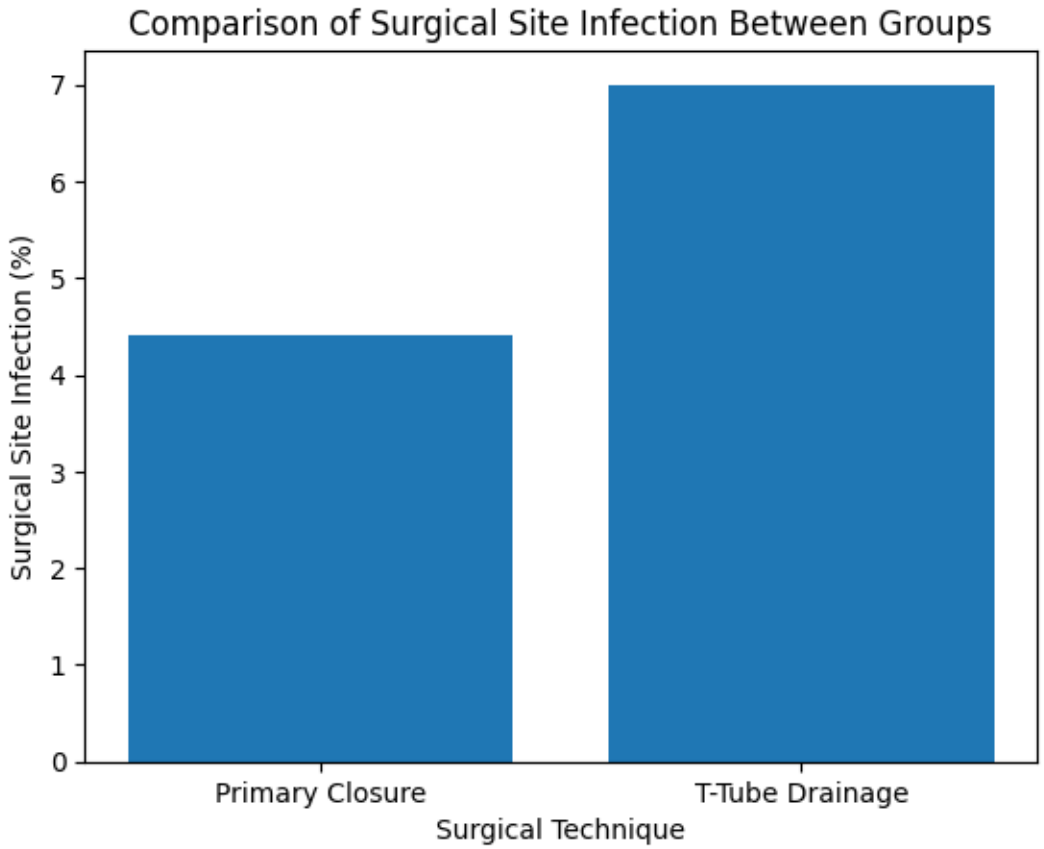
Although the T-tube group demonstrated a slightly higher percentage, statistical analysis using the Chi-square test showed that this difference was not statistically significant ($p = 0.61$).

This suggests that primary closure does not increase the risk of postoperative bile leakage when compared with T-tube drainage. Importantly, most cases of bile leakage in both groups were minor and managed conservatively without the need for reoperation.

The findings support the safety profile of primary duct closure in appropriately selected patients.

GRAPH 3 ANALYSIS

Comparison of Surgical Site Infection Between Groups



The third graph compares surgical site infection (SSI) rates between the two techniques. SSI occurred in 4.4% of patients in the primary closure group and 7.0% in the T-tube drainage group.

Although the incidence was numerically higher in the T-tube group, statistical testing revealed no significant difference ($p = 0.38$).

The slightly increased rate in the T-tube group may be related to prolonged hospitalization and presence of external drainage, which can serve as a potential source of contamination. However, since the difference did not reach statistical significance, both procedures can be considered comparable in terms of wound infection risk.

OVERALL GRAPHICAL INTERPRETATION

The graphical representation reinforces the statistical findings of the study. Primary closure significantly reduces hospital stay without increasing bile leakage or surgical site infection. While minor numerical differences exist in complication rates, these differences are not statistically significant.

Collectively, the graphs visually support the conclusion that laparoscopic primary closure is a safe and effective alternative to T-tube drainage, offering advantages in recovery time without compromising patient safety.

DISCUSSION

Choledocholithiasis remains a significant clinical entity in general surgical practice due to its potential to cause serious complications such as obstructive jaundice, cholangitis, and pancreatitis. With the evolution of minimally invasive surgical techniques, laparoscopic common bile duct exploration has become an established and effective modality for managing common bile duct stones. However, controversy persists regarding the optimal method of ductal closure following laparoscopic choledochotomy. The present study was conducted to compare postoperative outcomes between laparoscopic primary closure of the common bile duct and T-tube drainage in patients undergoing laparoscopic choledochotomy for choledocholithiasis.

The primary finding of this study is that laparoscopic primary closure is associated with a significantly shorter hospital stay compared to T-tube drainage, without an increase in postoperative complications such as bile leakage or surgical site infection. These findings have important clinical implications, particularly in resource-constrained healthcare systems where hospital bed occupancy and cost containment are critical considerations.

In the current study, the mean hospital stay in the primary closure group was significantly shorter than in the T-tube drainage group. This finding is consistent with previously published literature. Zhu et al. (2021), in a comprehensive meta-analysis comparing primary duct closure with T-tube drainage after laparoscopic common bile duct exploration, reported that primary closure significantly reduced hospital stay without increasing morbidity. Similarly, Zhen et al. (2020) demonstrated that patients undergoing primary closure had shorter postoperative recovery times and earlier discharge compared to those managed with T-tube drainage. The reduction in hospital stay observed in the present study likely reflects the avoidance of external drainage management, reduced need for postoperative cholangiography, and improved patient comfort.

T-tube drainage inherently necessitates prolonged hospitalization for monitoring of bile output, management of the external drainage system, and performance of T-tube cholangiography prior to removal. Additionally, patients often experience discomfort and limited mobility due to the presence of an external tube. These factors collectively contribute to delayed discharge. In

contrast, primary closure eliminates the need for tube care and allows for earlier mobilization and discharge once standard postoperative recovery criteria are met.

The incidence of bile leakage is a critical determinant in evaluating the safety of ductal closure techniques. Historically, T-tube drainage was favored due to the belief that it reduces intraductal pressure and thereby decreases the risk of bile leakage. However, contemporary evidence challenges this assumption. In the present study, bile leakage occurred in a small proportion of patients in both groups, with no statistically significant difference between primary closure and T-tube drainage. These findings align with the results reported by Zhu et al. (2021), who found no significant difference in bile leakage rates between the two techniques. Furthermore, Zhen et al. (2020) reported comparable bile leak rates in their cohort study, concluding that primary closure does not increase postoperative risk when performed by experienced surgeons.

It is noteworthy that bile leakage in both groups in the current study was minor and managed conservatively without reoperation. This suggests that even when leakage occurs, it can often be addressed with appropriate drainage and supportive care. Additionally, it is important to recognize that T-tube removal itself may predispose to bile leakage, as tract maturation may be incomplete at the time of removal. Therefore, T-tube placement does not entirely eliminate the risk of postoperative bile leakage.

Surgical site infection represents another important postoperative complication. In the present study, the incidence of surgical site infection was slightly higher in the T-tube group compared to the primary closure group, although the difference did not reach statistical significance. The marginally increased infection rate in the T-tube group may be attributed to prolonged hospital stay and the presence of an external foreign body, which can serve as a potential source of contamination. Prolonged hospitalization is a well-recognized risk factor for nosocomial infections. Although statistical significance was not achieved, the trend observed supports the hypothesis that primary closure may offer advantages in reducing wound-related morbidity.

Operative time in this study did not differ significantly between the two groups. While T-tube insertion may appear technically simpler than laparoscopic suturing, experienced minimally invasive surgeons are capable of performing primary closure efficiently. Advances in laparoscopic suturing techniques and instrumentation have minimized differences in operative duration between the two methods. This finding supports the feasibility of primary closure in centers with adequate laparoscopic expertise.

The baseline characteristics of patients in both groups were comparable with respect to age, gender, body mass index, diabetes mellitus, hypertension, and smoking status. This homogeneity strengthens the internal validity of the study and suggests that differences in outcomes are attributable primarily to the surgical technique rather than confounding variables. Stratified analysis further demonstrated that comorbid conditions such as diabetes mellitus and obesity did not significantly alter the relationship between surgical technique and postoperative outcomes.

Although diabetic and obese patients exhibited slightly higher complication rates overall, the relative safety of primary closure remained consistent across subgroups.

The findings of this study are particularly relevant in the context of developing countries such as Pakistan, where healthcare resources are limited and hospital overcrowding is common. Reducing hospital stay by even a few days per patient can substantially decrease healthcare costs and improve availability of hospital beds. Moreover, shorter hospitalization enhances patient satisfaction and reduces the economic burden on families.

Despite these advantages, several factors may influence surgeon preference for T-tube drainage. Traditional surgical training often emphasized T-tube placement as a safeguard against retained stones and postoperative leakage. Concerns regarding ductal stricture formation after primary closure also contribute to hesitancy in adopting this approach. However, contemporary studies have demonstrated that the risk of long-term stricture formation following primary closure is low when meticulous surgical technique is employed and distal obstruction is excluded (Zhu et al., 2021). In the present study, no cases of ductal stricture were observed during the three-month follow-up period, although longer follow-up would be necessary to definitively assess late complications.

It is important to acknowledge that primary closure may not be suitable for all patients. Patients with severe inflammation, small duct diameter, residual stones, or distal obstruction may still benefit from T-tube drainage. Therefore, careful patient selection remains essential. The intraoperative decision-making process should consider ductal size, stone burden, and surgeon expertise.

One of the strengths of the present study is its prospective design and adequate sample size. By enrolling 228 patients, the study achieved sufficient statistical power to detect meaningful differences in hospital stay. Additionally, standardized surgical techniques and postoperative protocols were employed to minimize variability. However, certain limitations must be acknowledged. The study was conducted at a single tertiary care center, which may limit generalizability. The allocation of patients was not randomized, which introduces the possibility of selection bias. Furthermore, follow-up was limited to three months, and long-term outcomes such as stricture formation and stone recurrence were not extensively evaluated.

Future research should include randomized controlled trials with longer follow-up periods to assess long-term ductal patency and recurrence rates. Multicenter studies would also enhance external validity and provide broader evidence applicable to diverse healthcare settings.

Overall, the findings of the present study are consistent with international literature advocating primary closure as a safe and effective alternative to T-tube drainage following laparoscopic choledochotomy. By demonstrating significant reduction in hospital stay without increased risk of bile leakage or surgical site infection, this study contributes valuable local evidence to support a shift in surgical practice toward primary duct closure in appropriately selected patients.

In conclusion, laparoscopic primary closure of the common bile duct appears to offer substantial advantages in terms of reduced hospitalization and comparable complication rates. Adoption of this technique in centers with adequate laparoscopic expertise may improve patient outcomes and optimize resource utilization. Continued evaluation through high-quality research will further clarify its role in the management of choledocholithiasis.

CONCLUSION

The present prospective cohort study was conducted to compare postoperative outcomes of laparoscopic primary closure of the common bile duct versus T-tube drainage following laparoscopic choledochotomy for choledocholithiasis. The findings of this research provide important evidence regarding the safety, efficacy, and practical advantages of primary duct closure in the management of common bile duct stones within our local healthcare setting.

Choledocholithiasis continues to represent a significant surgical burden due to its potential for serious complications including obstructive jaundice, ascending cholangitis, pancreatitis, and biliary sepsis. Advances in minimally invasive surgery have transformed the management of this condition, with laparoscopic common bile duct exploration emerging as a safe and effective single-stage treatment option. However, the optimal method of ductal closure following choledochotomy remains a subject of ongoing debate, particularly in developing countries where traditional surgical practices are deeply ingrained.

The primary finding of this study is that laparoscopic primary closure of the common bile duct is associated with a statistically significant reduction in postoperative hospital stay compared to T-tube drainage. Patients who underwent primary closure demonstrated earlier recovery and discharge without compromising safety. This reduction in hospital stay has considerable implications for healthcare systems facing increasing patient load and limited bed capacity. Shorter hospitalization not only reduces institutional costs but also minimizes the financial burden on patients and their families.

Importantly, the study demonstrated that primary closure does not increase the risk of postoperative bile leakage. The incidence of bile leakage was comparable between the two groups, and all cases were minor and managed conservatively. This finding directly addresses one of the principal concerns historically associated with primary duct closure. For decades, T-tube drainage was favored due to the belief that it reduced intraductal pressure and prevented bile leakage. However, the evidence generated by this study suggests that when performed with proper technique and patient selection, primary closure does not compromise ductal integrity.

Similarly, the incidence of surgical site infection was not significantly different between the two groups. Although a slightly higher infection rate was observed in the T-tube group, the difference did not reach statistical significance. The absence of increased wound complications in the primary closure group further supports its safety profile. Avoidance of an external drainage tube

may potentially reduce the risk of contamination and nosocomial infection, particularly in environments with high patient turnover.

The operative time did not differ significantly between the two surgical techniques. This indicates that laparoscopic suturing for primary closure is feasible and does not impose additional operative burden when performed by experienced surgeons. The involvement of consultants with at least five years of experience in minimally invasive surgery ensured procedural consistency and minimized technical variability.

The study also confirmed that baseline demographic and clinical characteristics were comparable between groups. Variables such as age, gender, body mass index, diabetes mellitus, hypertension, and smoking status did not significantly differ. This homogeneity strengthens the internal validity of the findings and supports the conclusion that differences in postoperative outcomes are attributable to the surgical technique rather than confounding factors.

From a broader clinical perspective, the findings of this study contribute to the growing body of evidence supporting a paradigm shift in the management of choledocholithiasis. Historically, T-tube drainage was considered indispensable following common bile duct exploration. However, advancements in laparoscopic visualization, instrumentation, and surgical expertise have reduced the necessity for routine external biliary drainage. Primary closure eliminates the discomfort and inconvenience associated with T-tube care, reduces hospital stay, and allows patients to resume normal activities sooner.

The results of this study are particularly relevant in the Pakistani healthcare context. Tertiary care hospitals often operate under resource constraints, with high patient volumes and limited bed availability. Strategies that reduce hospitalization without increasing morbidity are of substantial value. By demonstrating that primary closure significantly shortens hospital stay without increasing complication rates, this study provides evidence that may inform surgical practice and policy decisions.

Despite the encouraging findings, it is essential to emphasize that primary closure should be performed in carefully selected patients. Patients with severe inflammation, distal obstruction, small duct diameter, or residual stones may still benefit from T-tube drainage. The intraoperative assessment by the consultant surgeon remains crucial in determining the most appropriate approach. Thus, rather than completely eliminating T-tube drainage, the findings support selective use of this technique when clinically indicated.

The study possesses several strengths. Its prospective design allowed systematic data collection and standardized outcome assessment. The adequate sample size provided sufficient statistical power to detect meaningful differences, particularly in hospital stay. Uniform surgical technique and postoperative care protocols minimized procedural variability. Furthermore, stratified analysis demonstrated that comorbid conditions such as diabetes mellitus and obesity did not significantly alter the relationship between surgical technique and outcomes.

However, certain limitations must be acknowledged. The study was conducted at a single tertiary care center, which may limit generalizability to other institutions with different patient populations or surgical expertise. The non-randomized allocation of patients introduces the possibility of selection bias, although baseline comparability between groups mitigates this concern to some extent. Additionally, follow-up duration was limited to three months. While no cases of ductal stricture or stone recurrence were identified during this period, longer follow-up would be necessary to evaluate late complications comprehensively.

Future research should focus on multicenter randomized controlled trials comparing primary closure and T-tube drainage with extended follow-up periods to assess long-term ductal patency, recurrence rates, and quality-of-life outcomes. Incorporation of cost-analysis studies would also provide valuable information regarding economic benefits associated with reduced hospitalization. Additionally, research exploring patient-reported outcomes and satisfaction scores could further clarify the impact of surgical technique on quality of life.

In summary, the present study demonstrates that laparoscopic primary closure of the common bile duct following choledochotomy is a safe and effective alternative to T-tube drainage. Primary closure significantly reduces postoperative hospital stay while maintaining comparable rates of bile leakage and surgical site infection. These findings support the adoption of primary closure as the preferred method of ductal management in appropriately selected patients undergoing laparoscopic common bile duct exploration.

The results contribute meaningful local evidence to the ongoing discussion regarding optimal management of choledocholithiasis. In centers equipped with experienced laparoscopic surgeons and adequate intraoperative assessment capabilities, primary closure should be strongly considered as the first-line approach. Adoption of this technique has the potential to enhance patient recovery, reduce healthcare expenditure, and improve overall surgical outcomes.

Ultimately, the goal of surgical innovation is to optimize patient care while minimizing morbidity. The evidence generated by this study aligns with this objective and supports continued evolution of minimally invasive hepatobiliary surgery toward more efficient and patient-centered practices.

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