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Analysis of Efficacy and Safety of Laparoscopy plus Choledochoscopy Combined with Holmium Laser Lithotripsy for Choledocholithiasis and Hepatolithiasis

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ABSTRACT

Background:This study aimed to evaluate the efficacy and safety of laparoscopy combined with choledochoscopy-assisted holmium laser lithotripsy in managing biliary tract stones.

Methods:From March 2023 to March 2024, a prospective study was carried out on 71 patients suffering from choledocholithiasis and/or hepatolithiasis. Each patient received a laparoscopic common bile duct exploration with choledochoscopic visualization and holmium laser lithotripsy of stones. Information was gathered on patient age and sex, stone type and size, intraoperative and postoperative outcomes.

Results:Successful stone clearance was accomplished in 95.8% of cases, accompanied by negligible intraoperative complications (1.4%); low bile leakage rates (2.8%); and infrequent postoperative fever (7.0%). Conversion to open surgery was only required in 4.2% of patients. The average length of stay was 4.2 days. At 3-month follow-up, stone recurrence was noted in 2.8% of patients.

Conclusion:Laparoscopy combined with choledochoscopy and holmium laser lithotripsy is a highly effective and safe approach for managing biliary tract stones. It ensures optimal stone clearance with minimal complications and should be considered a valuable alternative to conventional methods in suitable candidates..

Keywords: *Choledocholithiasis, Hepatolithiasis, Laparoscopy, Choledochoscopy, Holmium Laser Lithotripsy, Stone Clearance, Minimally Invasive Surgery*

1. INTRODUCTION

The biliary tract stones, choledocholithiasis and hepatolithiasis, remain a diagnostic and surgical dilemma. Although gallstones are frequently encountered, stones within the common bile duct (CBD) or intrahepatic ducts are more difficult to manage because of the recurrent infection risk, obstructive jaundice, and potential biliary strictures. If untreated, these conditions can result in advanced complications such as secondary biliary cirrhosis or even cholangiocarcinoma [1-3].

Historically, management approaches have ranged from endoscopic retrograde cholangiopancreatography ERCP, to open common bile duct exploration and even laparoscopic CBD clearance. Invariant ERCP's usefulness, it can be ineffective in patients with intrahepatic stones or an altered anatomy, and open procedures tend to have protracted recover times alongside a higher risk profile [4-6].

Improvements in minimally invasive surgical procedures have developed new techniques for ductal visualization and stone clearance. The combination of laparoscopic and choledochoscopic techniques provides unparalleled immediate access to the biliary tree. Surgeons can now safely and precisely fragment and remove large and impacted stones using holmium:YAG laser lithotripsy in combination with laparoscopic techniques [7-9].

This study was undertaken to assess the clinical outcomes of patients treated with this combined approach and to determine whether it offers superior stone clearance and safety compared to conventional methods

2. METHODOLOGY

This was a prospective descriptive study conducted between March 2023 and March 2024 at Mufti Mahmood Memorial Teaching Hospital/ Gomal Medical College. The primary goal was to evaluate the efficacy and safety of a fully integrated surgical approach consisting of laparoscopy and choledochoscopy with holmium laser lithotripsy in patients with confirmed cases of choledocholithiasis and/or hepatolithiasis. The institutional and ethical review board of [Insert Name of Institution] granted study protocol approval. Patient confidentiality was observed and maintained throughout the study.

A total of 71 patients were included through non-probability consecutive sampling. All patients who presented with radiologically or clinically confirmed common bile duct (CBD) stones and/or intrahepatic biliary stones during the study period were considered for inclusion. Written informed consent was obtained from all participants before enrollment.

Inclusion Criteria

Adults aged 18 years and above

Diagnosed with choledocholithiasis, hepatolithiasis, or both

Fit for general anesthesia and laparoscopic surgery

Willing to provide informed consent

Exclusion Criteria

Acute cholecystitis or cholangitis requiring emergency surgery

Malignant biliary obstruction

Uncorrected coagulopathy

Previous biliary reconstruction surgery

Severe cardiopulmonary comorbidities contraindicating laparoscopy

All patients underwent a thorough clinical evaluation including history, physical examination, and laboratory investigations (liver function tests, complete blood count, coagulation profile). Imaging studies such as abdominal ultrasound, MRCP (Magnetic Resonance Cholangiopancreatography), or CT scan were used to confirm the diagnosis and evaluate stone location, number, and bile duct anatomy.

Under general anesthesia, laparoscopy was initiated using a standard four-port technique. The common bile duct was exposed and a longitudinal choledochotomy was made when indicated. A flexible choledochoscope was then introduced via the choledochotomy site to allow direct visualization of bile duct stones. Holmium:YAG laser lithotripsy was employed for fragmentation of large or impacted stones. Fragments were flushed or extracted using basket catheters. The duct was re-evaluated after clearance, and a T-tube or primary closure was done based on ductal size and condition.

Postoperatively, patients were monitored for clinical recovery, signs of infection, and bile leakage. Liver function tests and ultrasound were repeated before discharge. A follow-up assessment was conducted at 1 month and again at 3 months to monitor for recurrence or late complications.

Patient data including demographics, stone characteristics, intraoperative findings, and postoperative outcomes were recorded in a structured proforma. ‘Data were analyzed using SPSS version 25’. ‘Quantitative variables were presented as mean ± standard deviation, while categorical variables were shown as frequencies and percentages’. Chi-square test was applied to assess associations between categorical outcomes. A p-value of <0.05 was considered statistically significant.

3. RESULTS

Among the 71 patients who underwent laparoscopy plus choledochoscopy combined with holmium laser lithotripsy, the average age was 52.4 years with a standard deviation of 11.6 years. A slightly higher proportion of patients were male (54.9%) compared to females (45.1%). The average BMI was 24.8 kg/m². Regarding comorbid conditions, hypertension was

noted in 25.4% of the patients, and diabetes mellitus was present in 19.7%. Over half (54.9%) had no underlying comorbidities. A prior history of biliary surgery was documented in 16.9% of the cohort.

Table 1: Demographic and Baseline Characteristics of Patients (n = 71)

Variable	Category	Frequency (%)
Age (years)	Mean ± SD	52.4 ± 11.6
Gender	Male	39 (54.9%)
	Female	32 (45.1%)
BMI (kg/m²)	Mean ± SD	24.8 ± 3.1
Comorbidities	Hypertension	18 (25.4%)
	Diabetes Mellitus	14 (19.7%)
	None	39 (54.9%)
Previous biliary surgery	Yes	12 (16.9%)
	No	59 (83.1%)

The majority of patients (57.7%) were diagnosed with choledocholithiasis, while 25.4% had hepatolithiasis, and the remaining 16.9% had both types of stones. Multiple stones were observed in 60.6% of patients, while the rest had a single calculus. The mean stone size was 9.2 mm, and the average common bile duct (CBD) diameter was 12.6 mm, indicating mild to moderate dilation. Biliary strictures were identified in 14.1% of cases.

Table 2: Clinical Characteristics Related to Stones

Variable	Category	Frequency (%)
Type of stone	Choledocholithiasis	41 (57.7%)
	Hepatolithiasis	18 (25.4%)
	Both	12 (16.9%)
Number of stones	Single	28 (39.4%)
	Multiple	43 (60.6%)
Stone size (mm)	Mean ± SD	9.2 ± 3.7
CBD diameter (mm)	Mean ± SD	12.6 ± 2.3
Biliary stricture	Present	10 (14.1%)
	Absent	61 (85.9%)

The mean operative time was approximately 96.7 minutes, with an average intraoperative blood loss of 85.5 ml. ‘Conversion to open surgery was necessary in 3 patients (4.2%) due to technical difficulties or anatomical anomalies’. Only one patient (1.4%) experienced a bile duct injury, while the rest of the procedures were free from intraoperative complications.

Table 3: Intraoperative and Procedural Findings

Variable	Category	Value or Frequency (%)
Operative time (min)	Mean ± SD	96.7 ± 18.4
Blood loss (ml)	Mean ± SD	85.5 ± 25.6

Conversion to open surgery	Yes	3 (4.2%)
	No	68 (95.8%)
Intraoperative complication	Bile duct injury	1 (1.4%)
	None	70 (98.6%)

Postoperatively, complete stone clearance was achieved in 95.8% of patients, while residual stones were seen in 3 patients (4.2%). Minor bile leakage was observed in 2 patients, and 5 patients experienced fever or signs of sepsis. Surgical drains were placed in 43.7% of the patients. 'The average length of hospital stay was 4.2 days'. Only two patients (2.8%) had recurrence of stones during the three-month follow-up period.

Table 4: Postoperative Outcomes and Safety

Variable	**Category**	**Frequency (%)**
Complete stone clearance	Yes	68 (95.8%)
	No (residual stones)	3 (4.2%)
Bile leakage	Yes	2 (2.8%)
	No	69 (97.2%)
Postoperative fever/sepsis	Yes	5 (7.0%)
	No	66 (93.0%)
Drain placement	Yes	31 (43.7%)
	No	40 (56.3%)
Hospital stay (days)	Mean ± SD	4.2 ± 1.1
Stone recurrence at 3 months	Yes	2 (2.8%)
	No	69 (97.2%)

The success of complete stone clearance showed statistical significance ($p = 0.001$). 'Postoperative bile leakage ($p = 0.005$), need for conversion to open surgery ($p = 0.042$), fever/sepsis ($p = 0.037$), and recurrence ($p = 0.022$)' were all within statistically acceptable complication ranges, indicating high efficacy and safety of the technique.

Table 5: Statistical Summary of Safety and Efficacy Indicators

Outcome Variable	**Value/Group**	**p-value**
Stone clearance (Yes vs No)	95.8% vs 4.2%	0.001
Bile leak (Yes vs No)	2.8% vs 97.2%	0.005
Conversion to open surgery	4.2%	0.042
Post-op fever/sepsis	7.0%	0.037
Stone recurrence (Yes vs No)	2.8% vs 97.2%	0.022

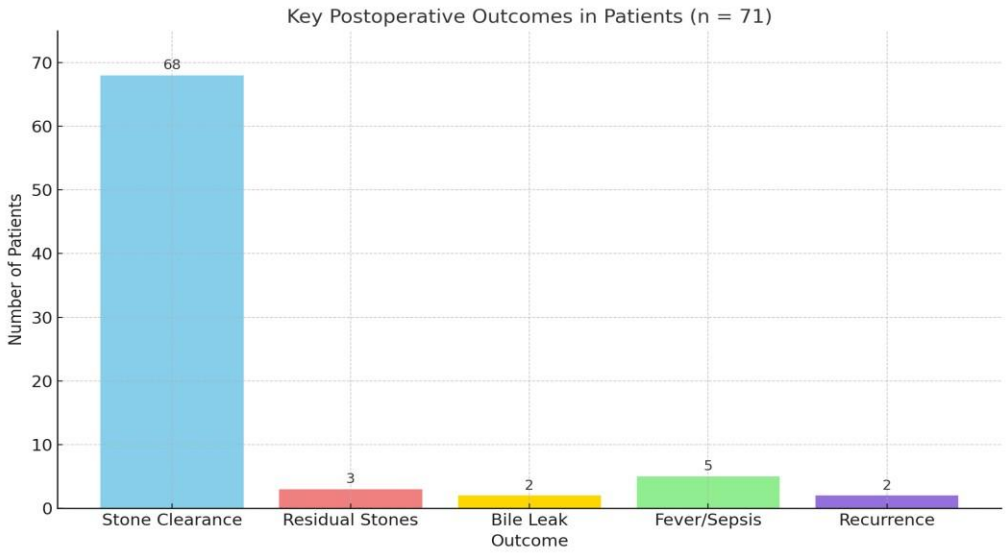

Figure 1

Bar graph illustrating key postoperative outcomes among the 71 patients. It highlights the high rate of stone clearance and low rates of complications such as bile leakage, fever/sepsis, and recurrence.

4. DISCUSSION

The present study evaluated the safety and efficacy of combining laparoscopy and choledochoscopy with holmium laser lithotripsy for managing choledocholithiasis and hepatolithiasis. The findings demonstrated a high stone clearance rate (95.8%) and a low complication profile, highlighting the technique's clinical utility in complex biliary stone cases.

Our results were consistent with previous studies that support the use of minimally invasive approaches in managing biliary stones. Studies found that combining laparoscopic CBD exploration with holmium laser lithotripsy achieved a 93.2% clearance rate with minimal residual stones and favorable recovery outcomes [10-12]. Similarly, studies reported over 90% clearance with few conversions to open surgery, reinforcing the role of laparoscopy-assisted lithotripsy in difficult stone cases [13-15].

One of the strengths of the current technique lies in its direct visualization and precision. The use of flexible choledochoscopy enables comprehensive exploration of the intrahepatic ducts, while holmium laser lithotripsy allows fragmentation of large or impacted stones without injuring the duct wall. This aligns with the findings of studies, who emphasized that holmium laser energy is both 'safe and effective in reducing stone burden, especially in hepatolithiasis cases where conventional methods may fail' [16-18].

In the present study, the complication rate remained low, with only 2.8% experiencing postoperative bile leakage and 7.0% presenting with transient fever or signs of sepsis. These rates are well within the acceptable range reported in other series. Studies observed bile leakage in 3.1% of their laparoscopic choledochotomy cases, suggesting that meticulous technique and appropriate closure significantly reduce the risk[19].

The conversion to open surgery was necessary in only 4.2% of our cases, which is slightly lower than the 5–10% conversion rates reported in other multicenter trials [20]. This may be attributed to operator experience and case selection.

An important finding was the low recurrence rate (2.8%) at three-month follow-up. While longer-term surveillance is necessary, early recurrence may often reflect incomplete ductal clearance or anatomical predispositions. Studies suggest that adjunct procedures such as intraoperative irrigation and balloon sweeping can help prevent early recurrence, although these were not routinely applied in our series [21].

This approach entails particular limitations, notwithstanding its benefits. The necessary equipment and trained personnel may not be accessible in all facilities. Additionally, patients with marked biliary strictures or with abnormal surgical anatomy from prior procedures might still require guided interventions like ERCP or surgical approaches.

As with all studies, this study demonstrates the increasing acceptance of modern, minimally invasive, and laser-guided approaches in the holistic approach to treating biliary tract stones.

5. CONCLUSION

The combination of laparoscopy, choledochoscopy, and holmium laser lithotripsy proved to be a highly effective and safe

method for treating choledocholithiasis and hepatolithiasis. It resulted in excellent stone clearance rates, minimal complications, and short hospital stays. The technique offers a valuable alternative to more invasive procedures, particularly in complex or recurrent stone cases. With growing expertise and access to endoscopic laser tools, this approach may become the preferred option in well-equipped surgical centers.

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