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ORIGINAL ARTICLE

Outcome of Management of Large Common Bile Duct Stones

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ABSTRACT

Background: Large common bile duct (CBD) stones (≥15 mm) are difficult to remove and require fragmentation if larger than 20 mm. ERCP, laparoscopic, percutaneous, or open surgery are available options depending on experience. Large or impacted stones often require open surgery, whereas ERCP with sphincterotomy, balloon dilatation, lithotripsy, or SpyGlass is less invasive. This study compared endoscopic and surgical treatment of large CBD stones.

Methods: A prospective cohort of 30 patients with CBD stones >1.5 cm (mean age 56.4 ± 10.1 years, 56.7% females) was studied between January 2024 and June 2025. ERCP was performed in 18 cases (60%), SpyGlass in 6 (20%), and surgery in 6 (20%; 13.3% open, 6.7% laparoscopic). Stone size was 15.7 ± 2.95 mm (ERCP), 14 ± 1.09 mm (SpyGlass), and 17.3 ± 3.62 mm (surgery). All patients underwent clinical, laboratory, and imaging assessments, with exclusion of malignancy or major contraindications.

Results: Stone size and CBD diameter changed significantly ($p<0.001$), with the greatest difference observed during operation. Surgery and SpyGlass groups had higher total and direct bilirubin levels than the ERCP group ($p=0.02$ and $p=0.03$, respectively). Surgical time was longest, SpyGlass intermediate, and ERCP shortest ($p<0.001$). Multiple stents were inserted more frequently with SpyGlass ($p=0.0001$). Hospital stay was longest after surgery and shortest after ERCP/SpyGlass ($p=0.002$). Pain and intraoperative blood loss were significantly greater during surgery ($p<0.001$). No deaths occurred.

Conclusions: ERCP proved effective and minimally invasive, with shorter operative time and hospitalization. SpyGlass was a safe alternative of moderate duration, whereas surgery, reserved for larger stones, involved longer operations, higher complication rates, and prolonged hospital stay.

Keywords: Common bile duct stones; ERCP; SpyGlass cholangioscopy; Surgical exploration; Stone clearance outcomes

INTRODUCTION

Stones larger than 15 mm are harder to remove, and those over 20 mm require fragmentation. A “difficult stone” may be defined by size, intrahepatic placement, barrel-shaped or impacted morphology, or comorbidities [1]. Stone extraction can be complicated by distal strictures. Large CBD stones are defined as ≥15 mm with a stone-to-CBD ratio of 1.0, allowing for comparison to duct diameter [2, 3]. Primary CBD stones or secondary gallbladder stones can occur [4].

Transabdominal ultrasonography and MRCP are the most prevalent non-invasive preoperative diagnostics [5]. Approximately 15% of cholecystectomies explore the duct, and 65% of them remove CBD stones. Laparoscopic, endoscopic, percutaneous, and open methods are used sequentially or together. Preoperative ERCP followed by LC, LCBDE, and LC plus intraoperative ERCP (rendezvous technique) are the most popular methods. Available expertise, not proven superiority, drives choice [6].

CBD stones are difficult to treat despite laparoscopic cholecystectomy replacing open surgery. LCBDE reduces discomfort, shortens stay, and speeds recovery, but it requires advanced equipment, technical expertise, and carries risks such as bile duct injury [7]. Open CBDE remains useful for large stones, complex anatomy, and unsuccessful endoscopic procedures. ERCP with sphincterotomy, established in the 1970s and widely adopted in the 1980s, became the norm for treating bile duct stones before and after cholecystectomy [8].

ESGE recommends endoscopic sphincterotomy with papillary balloon dilation first, followed by mechanical lithotripsy in cases of failure [9]. Cholangioscopy-assisted lithotripsy is becoming safer and more successful, but only in specialized centres. Modern technologies like the SpyGlass system provide single-operator cholangioscopy with high-resolution real-time viewing to fragment and retrieve large or impacted stones [10].

Laser and electrohydraulic lithotripsy improve stone fragmentation. Holmium:YAG laser lithotripsy uses precise, high-energy pulses to break stones into smaller pieces, decreasing tissue stress and boosting clearance rates [11]. Thus, modern CBD stone care uses a personalized combination of minimally invasive and advanced endoscopic procedures based on stone features, patient condition, and institutional expertise.

The aim of the study is to assess the outcome of endoscopic and surgical management of large CBD stones.

METHODS

This prospective cohort study was conducted at the Department of General Surgery, Faculty of Medicine, Zagazig University, between January 2024 and June 2025 under the ethical approval code IRB#: 67/27-Feb-2024.

It included 30 patients with large CBD stones (>1.5 cm), aged above 18 years, ASA I–III, of both genders.

Eighteen patients underwent ERCP; among them, 6 had balloon clearance only and 12 had balloon clearance with Dormia basket, with the largest stone size of 15.7 ± 2.95 mm. SpyGlass endoscopy was performed in 6 patients, where the largest stone size was 14 ± 1.09 mm. Surgery was done in 6 patients, including 4 open CBDE and 2 laparoscopic CBDE, with the largest stone size of 17.3 ± 3.62 mm.

Exclusion criteria included active pancreatitis, ASA IV–V, suspected CBD malignancy, pregnancy or lactation, contraindications to ERCP such as gastrectomy, and relative contraindications to laparoscopy such as prior upper abdominal surgery or advanced cirrhosis.

Sample size was calculated assuming a mean operative time of 231.4 ± 69 minutes for open surgery versus 160.7 ± 67 minutes for endoscopic intervention, with 80% power and 95% CI, resulting in 30 cases.

All patients underwent detailed history taking, general examination including vital signs (heart rate, blood pressure, respiratory rate, and temperature), and calculation of body mass index. Local abdominal examination was also performed.

Laboratory investigations included complete blood count (RBCs, hemoglobin, WBCs, and platelets), blood group, blood glucose,

coagulation profile (PT, PTT, INR), liver function tests (AST, ALT, total and direct bilirubin), and renal function tests (creatinine and BUN).

Imaging assessment consisted of abdominal ultrasound using a Vivid S5 (GE Healthcare, USA) with a 5 MHz curved array probe, performed from the anterior superior iliac spine to the umbilicus with axial and longitudinal scans of the liver. MRCP was done with a 1.5 T MRI system using a phased-array body coil, while abdominal CT scan was performed with a 16-detector row scanner at 90, 120, and 140 kV.

Preoperatively, all patients fasted for 6 hours and received a single prophylactic antibiotic dose. All procedures were carried out under general anesthesia.

EndoscopicRetrograde Cholangiopancreatography (ERCP):

ERCP was performed using a side-viewing endoscope (TJF-145; Olympus, Tokyo, Japan) by a single endoscopist. Standard cannulation was achieved with a sphincterotome, and contrast was injected under fluoroscopy to access the CBD. Cholangiogram was obtained, and CBD and stone diameters were documented. A full sphincterotomy was performed, followed by balloon sphincteroplasty using a 5F balloon-tipped catheter (4 cm length, 180 cm total length). Stones were removed with a retrieval balloon or Dormia basket if balloon clearance failed. After extraction, a 7-Fr pigtail stent was placed for 2–3 weeks, followed by cholecystectomy. If ERCP failed, SpyGlass cholangioscopy was used (Fig. 1, 2).

SpyGlass Cholangioscopy:

SpyGlass was introduced via the duodenoscope to reach the distal CBD stone, with higher stones targeted sequentially. Laser lithotripsy or electrohydraulic mechanical lithotripsy was used to fragment stones for balloon or basket extraction. In poor surgical candidates, fully covered metal stents were inserted for gallstone removal and prolonged drainage. Plastic stents were used for drainage and kept for 2–3 weeks before cholecystectomy. If SpyGlass failed, laparoscopic CBD exploration was performed.

Laparoscopic CBD Exploration (LCBDE):

Patients were placed in the French position with reverse Trendelenburg and slight left tilt. Standard port placement included two 10 mm ports (umbilical and epigastric), two 5 mm ports (right mid-clavicular and right mid-axillary), and an additional 5 mm port in the left mid-clavicular line. After Calot's triangle dissection, the cystic duct and artery were clipped and cut, leaving the gallbladder attached for retraction. CBD was identified, and a 1.5 cm incision was made with stay sutures. A 9.5 F flexible laparoscope (68 cm) visualized the duct. Stones were retrieved using stents, balloon dilation, Dormia basket, flushing, or milking techniques. Intraoperative cholangiogram confirmed clearance before choledochotomy closure with 3-0 PDS sutures (Fig. 3).

Open CBD Exploration:

Open CBDE was done when laparoscopy failed or in cases of impacted stones. Porta hepatis exposure was achieved by lifting the round ligament and retracting the cystic duct. A 10–20 mm vertical choledochotomy was performed on the supraduodenal CBD. Stones were extracted with forceps or flushed with saline; impacted stones were fragmented and removed with a Dormia basket. The incision was closed with absorbable running sutures, and intraoperative cholangiogram confirmed clearance and suture integrity.

After the operation, all patients were monitored for ERCP- or surgery-related complications. They were kept nil per oral for 4 hours post-endoscopy and received antibiotics (extended in case of complications) and analgesics. Discharge

was given once patients were fit, with dietary advice and scheduled follow-up.

Statistical analysis

Statistical analysis was performed using SPSS version 25.0 (IBM, Armonk, NY, USA). Continuous variables were expressed as mean ± SD and range, while categorical variables were shown as frequencies and percentages. Group comparisons for continuous data (ERCP, SpyGlass, and Surgery) were done with one-way ANOVA, or Kruskal–Wallis test when assumptions were unmet. Categorical variables were compared using Chi-square or Fisher's exact test when expected counts were <5. A p-value <0.05 was considered statistically significant.

RESULTS

The study included 30 participants with a mean age of 56.4 ± 10.1 years (range: 40–74). Females constituted 56.7% (n=17) and males 43.3% (n=13). Most participants resided in rural areas (83.3%, n=25) compared to urban areas (16.7%, n=5). Among the patients, endoscopic retrograde cholangiopancreatography with sphincterotomy, sphincteroplasty, and balloon clearance was performed in 9 cases (30%), with Dormia basket in 6 cases (20%), and with mechanical lithotripsy plus Dormia basket in 3 cases (10%). SpyGlass cholangioscopy was used in 6 cases (20%). Laparoscopic common bile duct exploration was performed in 2 cases (6.7%), while open exploration was done in 4 cases (13.3%) (Table 1).

Clinical data showed no significant difference in ASA classification across ERCP, SpyGlass, and Surgery groups (p=0.75). Common bile duct diameter differed significantly (p<0.001), being largest in Surgery (25.3 ± 3.78 mm), followed by SpyGlass (20.7 ± 1.03 mm) and ERCP (13.5 ± 1.65 mm). Stone size also differed significantly (p<0.001), with the largest in Surgery (30.5 ± 3.62 mm), then SpyGlass (25.7 ± 1.86 mm) and ERCP (17.7 ± 1.41 mm). Stone clearance was achieved in all patients; in ERCP cases, half were cleared at the first attempt and half at the second. Total bilirubin showed a significant difference (p=0.02), highest in Surgery (6.9 ± 0.8), followed by SpyGlass (6.0 ± 0.3) and ERCP (5.28 ± 1.1). Direct bilirubin was also significantly different (p=0.03), higher in SpyGlass (2.7 ± 0.4) and Surgery (2.7 ± 0.6) compared to ERCP (2.2 ± 0.4). Table 2

Operative duration differed significantly (p<0.001), being longest in Surgery (151.7 ± 11.7 min), followed by SpyGlass (102.5 ± 8.2 min) and ERCP (60 ± 11.1 min). Conversion rates were not significant (p=0.1583); in ERCP, 8 cases converted to SpyGlass (6 successful, 2 requiring laparoscopic surgery), and 4 cases with impacted distal stones were converted directly to laparoscopic surgery. In SpyGlass, 2 cases required laparoscopic conversion, while in laparoscopic surgery, 4 cases were converted to open surgery. First stent insertion showed a significant difference (p=0.0001), occurring in 50% (n=9) of ERCP, 33.3% (n=1) of laparoscopic, and 50% (n=1) of open surgery patients. Second stent insertion was seen only in ERCP (50%, n=9). Third stent insertion was highest in SpyGlass (100%, n=8), followed by laparoscopic surgery (66.7%, n=2), and open surgery (50%, n=1), with none in ERCP. Length of stay differed significantly (p=0.002), being longest in Surgery (6 ± 2.7 days), followed by ERCP (2.17 ± 1.2 days) and SpyGlass (2 ± 0.1 days). Return to work was also longest after Surgery, then SpyGlass, and shortest after ERCP. Mortality was absent in all groups. Table 3

Complication rates did not differ significantly among ERCP, SpyGlass, and Surgery (p=0.78), though Surgery had the highest rate (33.3%). Bile leak and wound infection occurred only in Surgery, while

bleeding was seen across groups and managed conservatively. Pain scores differed highly significantly (p<0.001); all ERCP and SpyGlass patients reported minimal pain (1–3), whereas Surgery patients reported higher scores (3–4 and 6–7). Intraoperative blood loss also showed a highly significant difference (p<0.001), occurring exclusively in Surgery, affecting all 6 patients (100%). Table 4

Table 1: Demographic data among studied participants

		All patients (n=30)
Age (years)	**Mean ± SD** **Range**	**56.4 ± 10.1** **(40 – 74)**
Sex (n. %)	**Male** **Female**	**13 (43.35)** **17 (56.7%)**
Residence (n. %)	**Rural** **Urban**	**25 (83.3%)** **5 (16.7%)**

Table 2: Clinical data among studied patients

		ERCP (n=18)				Surgery (n=6)	P-value
		ST+SP + Balloon clearance	ST + SP + Dormia basket + Balloon clearance	ST + SP + ML + Dormia basket + Balloon clearance	SpyGlass: Laser + hydro		
Clinical data							
ASA (n. %)	**I** **II** **III**	**6 (33.3%)** **12 (66.7%)**			**3 (50%)** **3 (50%)**	**2 (33.3%)** **4 (66.7%)**	**0.75**
CBD diameter	**Mean ±SD**	**13.5±1.65**			**20.7±1.03**	**25.3±3.78**	**<0.001**
Stone size	**Mean ±SD**	**17.7±1.41**			**25.7±1.86**	**30.5±3.62**	**<0.001**
No. of stones	**One** **Two**	**18 (100%)** **0 (0%)**			**4 (66.7%)** **2 (33.3%)**	**4 (66.7%)** **2 (33.3%)**	**0.03**
Stone clearance	**Yes** **1st attempt** **2nd attempt**	**18 (100%)** **9 (50%)** **9 (50%)**			**6 (100%)**	**6 (100%)**	**-**
Session's no.	**One session** **Two sessions**	**9 (50%)** **9 (50%)**			**6 (100%)**	**-**	**-**
Lab Data							
Total bilirubin Mean ± SD		**5.28±1.1**			**6±0.3**	**6.9±0.8**	**0.02**
Direct bilirubin Mean ± SD		**2.2±0.4**			**2.7±0.4±**	**2.7±0.6**	**0.03**

Table 3: Peri-Operative data among studied patients

	ERCP (n=18)				Surgery (n=6)		P-value
	ST+SP + Balloon clearance	ST + SP + Dormia basket + Balloon clearance	ST + SP + ML + Dormia basket + Balloon clearance	SpyGlass: Laser + hydro			
Operative data							
Duration (min) mean ± SD	60±11.1			102.5±8.2	151.7±11.7		<0.001
					Lap	Open	
Conversion: No Yes	18 (60%) 12 (40%)			6 (75%) 2 (25%)	2 (33.33%) 4 (66.67%)	4 (100%) 0 (0%)	0.1583
Stent insertion (n. %)							
1st time stent insertion	9 (50%)			0 (0%)	1 (33.33%)	1 (50%)	0.0001*
2nd time stent insertion	9 (50%)			0 (0%)	0 (0%)	0 (0%)	
3rd time stent insertion	0 (0%)			8 (100%)	2 (66.67%)	1 (50%)	
Post-Operative data							
LOS (days) mean ± SD	2.17±1.2			2±0.1	6±2.7		0.003
Return to work (days) mean ± SD	7.6±6.1			18.5±12.6	21.5±11.8		0.04
Mortality (n. %)	0 (0%)			0 (0%)	0 (0%)		-

Table 4: Complications among studied patients

	ERCP (n=18)				Surgery (n=6)	P-value
	ST+SP + Balloon clearance	ST + SP + Dormia basket + Balloon clearance	ST + SP + ML + Dormia basket + Balloon clearance	SpyGlass: Laser + hydro		
Complication (n. %)	**4 (22.2%)**			**1 (16.7%)**	**2 (33.33%)**	**0.78**
Bleeding	**2 (11.1%)**			**0 (0%)**	**0 (0%)**	**0 (0%)**
Bile leak	**0 (0%)**			**0 (0%)**	**1 (16.7%)**	**0.13**
Pancreatitis	**2 (11.1%)**			**1 (16.7%)**	**0 (0%)**	**0.6**
Wound infection	**0 (0%)**			**0 (0%)**	**1 (16.7%)**	**0.13**
Pain score: **1-3** **3-4** **6-7**	**18 (100%)** **0 (0%)** **0 (0%)**			**6 (100%)** **0 (0%)** **0 (0%)**	**0 (0%)** **2 (33.3%)** **4 (66.7%)**	**<0.001**
Intraoperative Blood loss (50 – 150 ml)	**0 (0%)**			**0 (0%)**	**6 (100%)**	**<0.001**

Figure 1: Balloon Sphincterotomy.

Figure 2: Laser lithotripsy by Spygalss Choledocoscope

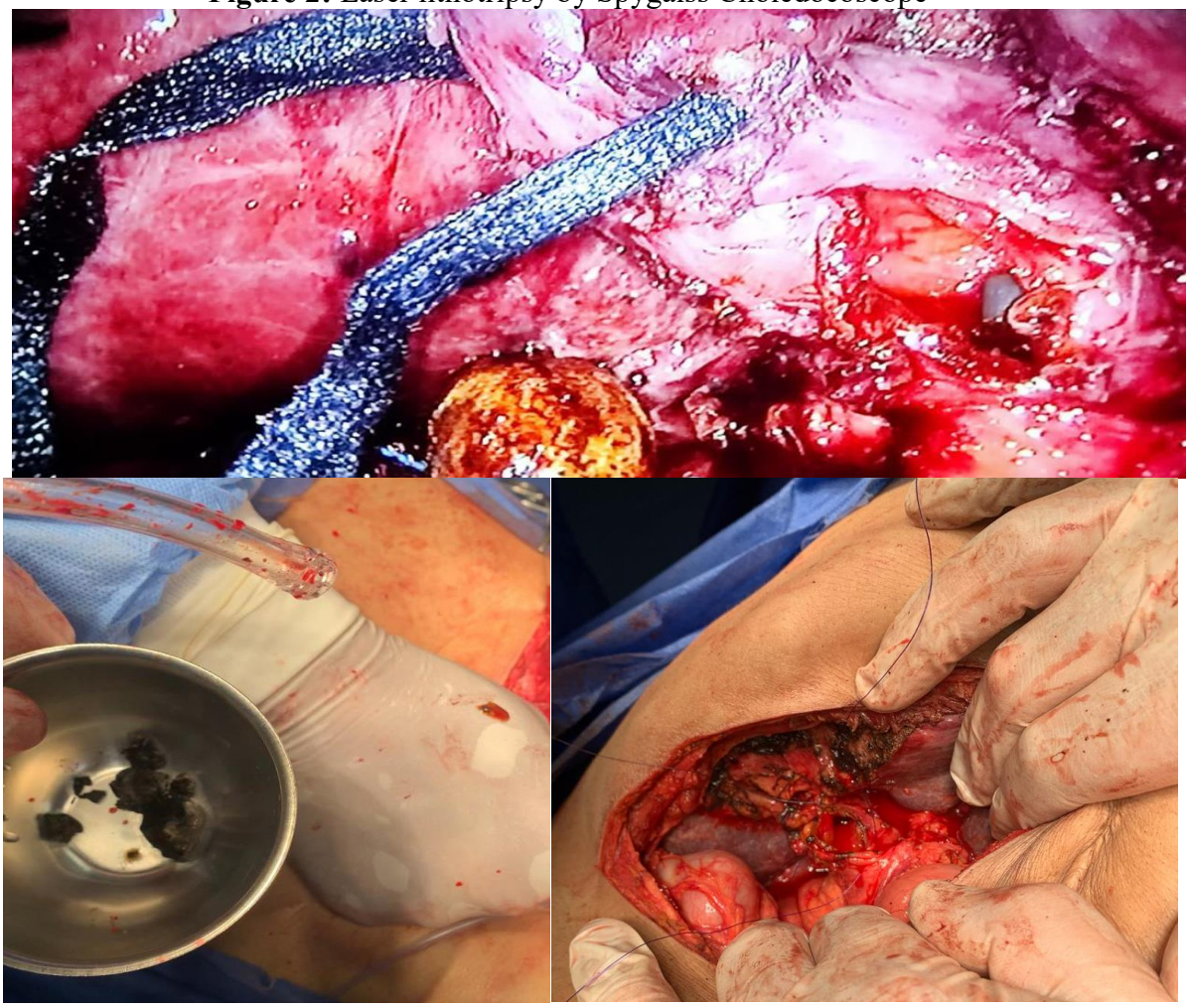

Figure (3): Open CBDE (The CBD was taken over a sling).

DISCUSSION

Common bile duct (CBD) stones are a major cause of biliary obstruction, typically presenting with abdominal pain, jaundice, or cholangitis, and require prompt intervention to prevent serious complications [12]. Large or difficult stones remain challenging due to both anatomical and patient-related factors, although advances in endoscopic techniques have improved clearance rates and reduced adverse events (Tringali et al., 2021a). Endoscopic retrograde cholangiopancreatography (ERCP) with sphincterotomy or balloon dilation is now considered the first-line approach, preferred over surgery due to its lower morbidity and mortality rates [13].

This prospective cohort study aimed to evaluate the outcomes of endoscopic and surgical management of large CBD stones. It was conducted at the Department of General Surgery, Faculty of Medicine, Zagazig University, from May 2024 to May 2025.

The study included 30 patients with a mean age of 56.4 ± 10.1 years (range 40–74), of whom 56.7% were female (n=17) and 43.3% were male (n=13). Most participants were from rural areas (83.3%, n=25), while 16.7% (n=5) were urban residents. These findings are consistent with those of Li et al. (2023) [14], who reported a mean age of 57.5 ± 20.8 years for choledocholithiasis and 63.0 ± 17.9 years for cholangitis, with females comprising 63.4% of choledocholithiasis cases and 48.8% of cholangitis cases. However, unlike our study, 92% of their cases were discharged from urban hospitals, which included younger, non-white, and insured patients, with no significant urban–rural differences in comorbidities or weekend admissions. Shelton et al. (2012) [15] also found that 81% of 111,021 patients with choledocholithiasis resided in urban areas compared with 19% in rural areas, with urban patients more likely to undergo endoscopic therapy (87.7% vs. 82.0%, $p<0.05$), while rural patients were more frequently managed surgically (10.5% vs. 4.9%, $p<0.05$). In contrast, our cohort was predominantly rural. Furthermore, Lisotti et al. (2025) [16] identified age >63 years (OR 3.06, $p<0.001$), male gender (OR 2.54, $p=0.009$), liver function test abnormalities (OR 2.62, $p=0.003$), and bile duct dilation (OR 2.46, $p=0.005$) as independent predictors of CBD stones, whereas our population demonstrated a younger mean age and a female predominance.

In our cohort, ERCP was the most frequently used intervention (60%, n=18). The combination of sphincterotomy, sphincteroplasty, and balloon clearance was the most successful technique (30%, n=9). ERCP with Dormia basket was used in 20% (n=6) and mechanical lithotripsy in 10% (n=3). SpyGlass cholangioscopy was performed in 20% (n=6), while surgery was required in 20% (laparoscopic CBDE 6.7%, n=2; open CBDE 13.3%, n=4). The predominance of ERCP in our series aligns with prior evidence supporting its minimally invasive nature, allowing effective sphincterotomy and stone extraction using balloons or baskets, with high success and safety [17]. SpyGlass was reserved for complex or difficult stones, consistent with previous studies highlighting its value in direct visualization and fragmentation of large or impacted stones. Surgical approaches were required for very large stones, altered anatomy, or marked ductal dilation, as also described by Almadi et al. (2012), Christoforidis et al. (2014), and Dasari et al. (2013) [18–20].

There was no significant difference in ASA classification among the ERCP, SpyGlass, and surgery groups ($p=0.75$). However, CBD diameter and stone size were significantly greater in the surgery group (25.3 ± 3.78 mm; 30.5 ± 3.62 mm), followed

by SpyGlass (20.7 ± 1.03 mm; 25.7 ± 1.86 mm), and smallest in ERCP (13.5 ± 1.65 mm; 17.7 ± 1.41 mm). Complete stone clearance was achieved in all cases, with half of ERCP patients cleared on the first attempt and the remainder on the second. These results are consistent with Sayed et al. (2025) [21], who reported no significant difference in ASA scores or stone counts between ERCP-first and surgery-first groups, and Wu et al. (2024) [22], who found no significant ASA differences between laparoscopic and endoscopic management. Our findings also support those of Obata et al. (2021) [23], who demonstrated that bile ducts ≥14 mm in diameter were associated with reduced success of balloon-assisted ERCP (OR 0.04, p=0.018).

The larger CBD diameters observed in the surgery group likely reflect prolonged obstruction and larger impacted stones, which lead to progressive ductal dilation. Such dilation reduces the effectiveness of endoscopic tools, thereby favoring surgical exploration. This mechanism has been similarly proposed by Haixing Fang et al. (2025), Ji et al. (2022), and Kamuni et al. (2024) [24–26]. Conversely, the smaller ducts in the ERCP and SpyGlass groups likely indicate less severe obstruction, facilitating successful endoscopic clearance without conversion.

Mean total bilirubin levels differed significantly among the groups (p=0.02), being highest in the surgery group, intermediate in SpyGlass, and lowest in ERCP. Direct bilirubin also varied significantly (p=0.03), with higher means in SpyGlass and surgery compared to ERCP. Fang et al. (2025) [24] reported no significant bilirubin variation across different minimally invasive techniques, contrasting with our findings. The elevated direct bilirubin levels in our cohort likely reflect the degree and duration of obstruction, as higher values correlate with acute obstruction, supporting the need for urgent endoscopic intervention [27–29].

Operative duration also differed significantly (p<0.001), being longest in surgery, intermediate in SpyGlass, and shortest in ERCP. Although conversion rates were not statistically significant, 8 ERCP cases required conversion to SpyGlass (6 successful, 2 laparoscopic), 4 ERCP cases proceeded directly to laparoscopic surgery, 2 SpyGlass cases converted to laparoscopy, and 4 laparoscopic procedures required conversion to open surgery. Aloysius et al. (2023) [30] analyzed >14,000 ERCPs and found perforation-associated procedures lasted significantly longer (60.1 ± 29.9 min) than uncomplicated ones (40.3 ± 23.5 min, p<0.001), supporting the association between prolonged duration and complications. SpyGlass procedures were inherently longer due to direct visualization and fragmentation steps [31]. The higher conversion rate in surgical cases likely reflects intraoperative challenges such as adhesions or obscured anatomy [32].

Stent insertion differed markedly among groups (p=0.0001): first stents were most common in ERCP, less frequent in surgery, and absent in SpyGlass; second stents occurred only in ERCP, while third stents were most frequent in SpyGlass, followed by laparoscopic and open surgery. Lara-Orozco et al. (2024) [33] similarly reported greater stent use in ERCP compared to SpyGlass, with multiple reinterventions often required in ERCP but only a single stenting case in SpyGlass.

Hospital stay differed significantly (p=0.002), being longest after surgery, intermediate in SpyGlass, and shortest in ERCP. Return to work followed a similar trend. No mortality occurred. Rogers et al. (2010) [34] reported median hospital stays of 6 days after ERCP versus 9 days after surgery (p<0.05), consistent with our results.

Similarly, Lyu et al. (2019) [35] found no significant morbidity differences between ERCP and laparoscopic CBD exploration (LCBDE) [36]. The shorter hospital stays observed in ERCP and SpyGlass reflect their minimally invasive nature [37,38]. However, De Silva et al. (2022) [39] reported the opposite in 671 patients, with LCBDE (n=578) showing fewer complications than ERCP (n=93), where endoscopy had the highest rates of minor (39.6%), major (27.1%), non-biliary (29.2%), and biliary (8.3%) complications ($p<0.001$).

In our study, there was no significant difference in overall complication rates ($p=0.78$), although surgery had the highest rate (33.3%) due to bile leakage and wound infection. Two ERCP-related bleeding cases were managed conservatively. Pain scores differed significantly ($p<0.001$), being lowest in ERCP and SpyGlass (1–3) and highest in surgery (3–7). Intraoperative blood loss was significant ($p<0.001$), occurring exclusively in surgical cases (100%, n=6). A meta-analysis of 14 RCTs (n≈2,181) by Lan et al. (2023) [40] reported higher bile leakage rates with LC-LCBDE (RR 4.52, 95% CI 2.19–9.31), but lower risks of hemorrhage (RR 0.18, 95% CI 0.07–0.42), postoperative pancreatitis (RR 0.25, 95% CI 0.13–0.46), and cholangitis (RR 0.17, 95% CI 0.05–0.67), partly aligning with our results. Mechanistically, the invasiveness of each procedure explains the observed complication patterns: bile leak and intraoperative bleeding in surgery arise from ductal incision and dissection [41], SpyGlass carries a higher cholangitis risk due to prolonged ductal manipulation and irrigation [42], and ERCP predisposes to pancreatitis from ductal trauma and contrast injection [38,43].

CONCLUSION

Our study showed that endoscopic approaches, especially ERCP, were effective and less invasive for large CBD stones, with shorter operative time and hospital stay. ERCP carried a higher but not statistically significant risk of pancreatitis. SpyGlass offered a safe alternative with moderate duration. Surgery, used mainly for larger CBD stones, required longer operative times, had higher complication rates, and prolonged hospital stay. These results emphasize tailoring treatment to patient condition, stone features, and available expertise.

Conflicts of Interests: The authors declare that they have no competing interests.

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Availability of Data and Material: All data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Authors' Contributions: Not applicable.

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