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Review Article

Techniques for the treatment of common bile duct stones: A review

Mahajan Mayank M* and Manolkar RM

General Surgery Department, SBKS MIRC Sumandeep Vidhyapeeth, Pipariya, Vadodara, India

***Correspondence Info:**
Dr. Mahajan Mayank M,
Post Graduate student,
General Surgery Department,
SBKS MIRC Sumandeep Vidhyapeeth Pipariya, Vadodara, India
E-mail: drmayankmahajan@gmail.com

Abstract

Common bile duct stones (CBDSs) may occur in up to 6%–10% of all adult patients for whom cholecystectomy is performed. Patients presenting with CBDS have symptoms including: biliary colic, jaundice, cholangitis, pancreatitis or may be asymptomatic.

It is important to distinguish between primary and secondary stones, because the treatment approach varies. Stones found before, during, and after cholecystectomy had also different treatments. There is no consensus regarding the ideal management of concurrent gallbladder and CBD stones. Currently the treatment protocol involves most commonly a sequential approach consisting of endoscopic sphincterotomy followed by laparoscopic cholecystectomy or a single stage laparoscopic procedure, including cholecystectomy and exploration of the CBD (transcystic or transcholedochal approach). Endoscopic sphincterotomy has inherent morbidity and complications like CBD stone recurrence whereas laparoscopic CBD exploration demands considerable expertise which is available only at specialized centres. The clinical presentation of the patient, number of stones, size of CBD, available resources and technical expertise at hand are an important consideration for the ideal management in different conditions.

Keywords: Common bile duct stones, Endoscopic sphinterotomy, Laparoscopic cholecystectomy

1. Introduction

Common bile ducts (CBDs) are one of the medical conditions leading to surgical intervention. They may occur in 6%–10% of all patients for whom cholecystectomies are performed. When patients present with CBD, the one important question that should be answered: What is the best modality of treatment under the giving conditions? There are competing technologies and approaches for diagnosing CBDs with regard to diagnostic performance characteristics, technical success, safety, and cost effectiveness. Management of CBDs usually requires two separate teams: the gastroenterologist and the surgical team. One of the main factors in the management is initially the detection of CBDs, before, during, or after cholecystectomy. The main options for treatment are pre- or postoperative ERCP with endoscopic biliary sphincterotomy (EST), laparoscopic or open surgical bile duct clearance. There are other options for the treatment of CBD Stone such as electro hydraulic lithotripsy (EHL), extracorporeal shockwave lithotripsy (ESWL), dissolving solutions, and laser lithotripsy. It is unlikely that one option will be appropriate for all clinical circumstances in all centers. Variables such as disease status, patient demographics, availability of endoscopic, radiological and surgical expertise, and healthcare economics will all have significant influence on practice.

1.1 Pathogenesis and Clinical Manifestation:

CBD Stones can be caused either by primary bile duct stones that originate in the bile duct or by secondary bile duct stones that have descended from the gallbladder. In the primary stones, bilirubin is dominant component and is associated with biliary stasis and infection. In secondary stones, cholesterol is dominant component. It is therefore important to distinguish between primary and secondary stones. Cholecystectomy and choledocholithotomy are sufficient in the management of secondary stones, while the presence of primary stones often necessitates a more complex drainage procedure to prevent recurrence. Table 1 shows the types of bile duct stones [1]. In addition, cholecystectomy at a young age leads to CBD dilatation and is another acquired risk factor for CBD stones. The symptoms and signs of CBD Stones are highly variable and can range from patients being completely asymptomatic, to complications such as cholangitis or pancreatitis. Literature describes the Prevalence of asymptomatic CBD Stones between 5.2% and 12%. A common presentation of CBD Stones is the biliary colic. Pain is often situated in the right hypochondrium or epigastrium

and can last from 30 minutes to several hours, with associated symptoms such as nausea and vomiting. Other common symptoms include pale stools and dark-colored urine, which can be elicited in the patient history by a thorough review of systems. Two serious complications of CBD Stones are cholangitis and gallstone pancreatitis. Acute obstructive cholangitis (AOC) is a life-threatening complication caused by an infection of the biliary ductal system secondary to biliary obstruction. Cultures are most often positive for *E. coli*, and the infection clears in more than 75% of cases with antibiotic treatment. In cholangitis, the classic symptoms of Charcot's triad may be encountered, and the less common Reynold's pentad adds to the diagnosis. Despite the advancement in treatment, AOC still carries a mortality rate of 10–20%. It remained unclear for a long time why some gallstone patients suffer from pancreatitis, while others are spared from this potentially lethal complication. Recent data indicate that small gallstones, excess cholesterol crystals, and good gallbladder emptying are associated with increased risk of pancreatitis. Small gall stones could lead to a more distal obstruction with potential reflux of bile into the pancreatic ducts. This could induce a common pathway of pancreatic duct injury with release of activated pancreatic enzymes into the glandular interstitium. The majority of these patients will have self-limiting disease, but mortality still remains about 10%. The mortality rate is less than1% for mild acute pancreatitis, but it can approach 10% to 30% for severe acute pancreatitis.

Table 1: Classification Of Gall Stones

	Cholesterol	**Brown pigment stone**	**Black pigment stone**
Origin	Gall bladder (secondary stones)	Ducts± gallbladder (primary stone)	Gallbladder± ducts (primary or secondary stones)
Component	40-70% cholesterol	15% cholesterol 60% calcium bilirubinate 15% calcium phosphate	2% cholesterol 6% calcium carbonate 40% calcium bilirubinate 9% calcium phosphate
Predisposing factors	Obesity Decreased bile duct pool Increased cholesterol synthesis Increased progesterone	Diet: low protein, high carbohydrate cholangitis biliary stricture Biliary infections; bacterial, parasitic Biliary stasis; total parenteral nutrition, vagotomy	Cirrhosis Chronic hemolysis Sickle cell anemia Heart valve replacement
Shape, size, number	Multiple: smooth faceted Single: ≥ 2.5cm, smooth, round	Smooth, round 1-3cm	Multiple, irregular or smooth usually <0.5cm
Physical characteristics	Hard, laminated	Hard	Soft, Friable

1.2 Assessment and Diagnosis

1.2.1 Laboratory Tests

Patients exhibiting the described symptoms require diagnostic investigations to assess for the presence of CBD Stones. Liver function tests (LFTs) can be used to screen for CBD Stones. Elevated serum bilirubin and alkaline phosphatase typically reflect biliary obstruction, but these are neither highly sensitive nor specific for CBD Stones. In a study by Anciaux *et al*., elevated serum gamma glutamyl transpeptidase (GGT) and alkaline phosphatase (ALP) were the most frequent abnormalities in laboratory valves of patients with symptomatic CBD Stones. Serum bilirubin levels may be markedly elevated depending on whether the obstruction of the bile duct is complete or incomplete. Murohisa *et al* and Sheen-Chen *et al* in a case study reported high level CA 19-9 in CBD Stone with cholangitis. Most of the studies have shown that laboratory studies must be used in addition to imaging modalities to predict the likelihood of CBD Stone, and the multivariate analysis models have found a dilated bile duct to be an independent variable in predicting CDB Stones.

2. Imaging Modalities

2.1. Transabdominal Ultrasonography (TUS)

It is the first line investigation in patients with suspected CBD Stone. Its sensitivity for detecting CBD Stone is between 25% and 63%, with a specificity of approximately 95% depending on the degree of dilation of the CBD and investigators experience. Barkun *et al* reported that in patients older than 55 years with abnormal liver enzymes and CBD dilation in ultrasound examination, CBD Stone is predicted in up to 95%. Endoscopic retrograde cholangiopancreatography (ERCP) is often described as the gold standard test to for the detection of CBD Stones. This procedure was initially used primarily in diagnosis, but today is more commonly used as a therapeutic modality. ERCP has sensitivity between 90%-95% in detecting CBD stones and a specificity of 92%- 98%. Christensen *et al*, demonstrated that the ERCP exam has a morbidity rate of 15.9% and a mortality rate of 1%. [2]

2.2. Endoscopic Ultrasound (EUS)

It involves the endoscopic insertion of an ultrasound probe through the stomach and up to the second half of the duodenum, allowing for ultrasound images of the CBD without the interference of subcutaneous fat and bowel gas.

Sensitivity of EUS varies from 95%, while specificity is between 95–98%. EUS is significantly more sensitive than TUS in detecting CBD stones. Its sensitivity is comparable to the diagnostic ERCP, while its major advantage is a significantly decreased morbidity compared to ERCP. The EUS examination is a noninvasive test, with excellent overall sensitivity and specificity for diagnosing choledocholithiasis, but it is highly dependent on the examiner.

2.3. Magnetic Resonance Cholangiopancreatography (MRCP)

It has emerged as an accurate, noninvasive diagnostic modality for investigating the biliary ducts. It may be especially beneficial in identifying patients who would benefit from early intervention. A recent authoritative meta-analysis of 67 published controlled trials shows that MRCP has an excellent overall sensitivity of 95% and a specificity of 97% for demonstrating CBD Stones.

Verma *et al* reported no statistically significant differences between EUS and MRCP in the detection rate of CBD Stone. Some major disadvantages of MRCP, as compared to ERCP, are the lower spatial resolution, unit availability, potential for claustrophobia, and the inability to evaluate patients with pacemakers or ferromagnetic implants.

2.4. Intraoperative Cholangiography (IOC)

The routine use of IOC is still controversial. Some authors supporting routine IOC, while others favor selective IOC and others report no advantages in IOC with respect to missed CBD stones. However, it can be a useful tool to identify choledochalstones. This procedure can be performed during open or laparoscopic cholecystectomy. IOC has a sensitivity of 98% and specificity of 94% to detection of CBD Stone. IOC can fail primarily due to inability to cannulate the cystic duct. Other reasons for failure are leakage of contrast fluid during the injection, air bubbles mimicking stones, failure to fill the biliary tree because of too rapid contrast injection into the duodenum, and spasm of the sphincter of Oddi. Supporters of routine IOC claim that this practice ensures fewer retained stones, fewer postoperative ERCPs, and a reduction in the number of CBD injuries. One drawback is the consequent lengthening of the operative time by approximately 15 minutes. Li *et al* in 2009 have shown that intracorporeal laparoscopic ultrasonography (LUS) is more sensitive than IOC for detecting stones but IOC is better for delineating the anatomy. Both these techniques should be viewed as complementary method to maximize the intraoperative detection of occult CBD stones.

2.5. Conventional Computed Tomography (CT)

It has a sensitivity of 87% and a specificity of 97% for the diagnosis of CBD stones. Kondo et al, showed that CT scanning was equivalent to MRCP, with the added risk of allergic reaction to contrast injection.

2.6. Intraductal Ultrasonography (IDUS)

Although the utility of intraductal ultrasonography (IDUS) for common bile duct stones has been reported, the clinical significance of this procedure in making therapeutic decisions has not been well clarified. IDUS is a valuable method for residual small stones in the common bile duct after endoscopic lithotripsy. IDUS increases sensitivity and specificity in the diagnosis of choledocholithiasis, and these gains are not coupled with a notable increase in procedure time (7–15 minutes). IDUS is especially recommended in patients who have a dilated bile duct with suspected small bile duct stones when ERCP is not diagnostic.

2.7. Percutaneous Transhepatic Cholangiography (PTC)

It is not a routine initial diagnostic test in patients with CBD stones but is the modality of choice in patients with previous gastric surgery, distal obstructing CBD Stone that failed ERCP or in patients with cholangiohepatitis and extensive intrahepatic stone disease. It is important to consider that uncorrected coagulopathy is a contraindication for PTC.

2.8. Endoscopic Retrograde Cholangiopancreatography (ERCP)

It is should be performed only in patients who are expected to require an intervention; it is not recommended for use solely as a diagnostic test.

3. Review of Literature

Several studies have compared a "laparoscopic-first" approach to the management of CBD stones with the more commonly used "sequential treatment" i.e. endoscopic extraction followed by laparoscopic cholecystectomy. Laparoscopic CBD exploration involves either transcystic approach (fluoroscopy guided or choledochoscopy) or laparoscopic choledochotomy and stone extraction. The treatment of known CBD stones—preoperative Endoscopic Sphictorotomy(EST) followed by laparoscopic cholecystectomy (LC) vs. Combined laparoscopic cholecystectomy and CBD exploration (LCBDE) was compared in two randomized control trials. The results of the two approaches are similar, although the length of hospital stay is shorter with LCBDE in the Cuscheiri *et al* study. The weakness inherent in these studies is that they fail to include the morbidity of negative preoperative ERCP. Costi *et al* performed a case–control study comparing a single stage laparoscopic approach with sequential treatment. No difference emerged concerning early and late complications, mortality, or laparotomies needed to accomplish cholecystectomy and CBD clearance. The postoperative hospital stay was shorter in the single stage group. In this group, only 22 patients underwent choledochotomy (45 %) and 15 patients underwent perioperative ERCP (30 %). Conversions decreased with practice. After choledochotomy, an increasing number of patients underwent primary closure of the CBD (with no biliary drain), without complications. They came to the conclusion that a single stage laparoscopic approach to gallbladder/CBD stones is safe and feasible. It may allow the majority of surgeons to avoid excessively

difficult/dangerous surgical procedures as well as unnecessary ERCPs in most cases. A tendency toward a lower incidence of conversions and a rarer use of biliary drains may lead to an improved immediate outcome for patients undergoing a single stage approach. Bansal *et al* [3] conducted a prospective randomized trial which compared single stage laparoscopic treatment with sequential treatment of CBD stones. 15 patients were randomized to each group and the two groups had comparable demographic and clinical profile. In group I there was a success rate of 93.5 % in comparison with 86.7 % in group II (p00.32, Fisher's exact test). The complications were similar in the two groups. The results showed equivalent success rate in terms of morbidity and hospital stay. They concluded that laparoscopic approach seems to be favorable because of the smaller number of procedures and hospital visits.

Chander *et al* operated on 150 patients with documented CBD stones. Of these, 4 patients underwent transcystic exploration of CBD and 146 patients had their CBD stones removed through the transcholedochal route. There were 34 men and 116 women patients with age ranging from 15 to 72 years. The mean size of the CBD on ultrasound was 11.7±3.7 mm and on MRCP 13.8±4.7 mm. The number of stones extracted varied from 1 to 70 and the size of the extracted stones from 5 to 30 mm. The average duration of surgery was 139.9±26.3 min and the mean intraoperative blood loss was 103.4±85.9 ml. There were 6 conversions to open procedures, 1 postoperative death (0.7 %), and 23 patients (15 %) had nonfatal postoperative complications. Three patients had retained stones (2 %) and one developed recurrent stone (0.7 %). In their opinion LCBDE when performed by an experienced surgeon results in no additional morbidity or mortality as compared to open surgery, with excellent success rates (98 % in this series), and thus specially benefits the subgroup of patients with multiple, large, impacted stones in a dilated CBD who were traditionally subjected to open exploration.

Karaliotas *et al* performed transcholedochal laparoscopic CBD exploration on 32 patients who had unsuccessful attempts at endoscopic CBD stone extraction. Previous operations, cholangitis, anatomic abnormalities, and stone impaction were the principal reasons for failure of ERCP. Stone extraction under direct laparoscopic choledochotomy was achieved in 20 of 31 patients (64.51 %). Biliary stents were inserted in 7 patients (21.8 %) and T tubes were placed in 21 patients (65.6 %). Five laparoscopic choledochoduodenostomies were performed. There were 11 conversions to open surgery. Morbidity was 12.5 %. These authors believed that patients with previous operations in the upper abdomen, because of adhesions, excessive fibrosis in the hepatoduodenal ligament, and altered anatomy (from Billroth II or Roux-en-Y reconstruction) and pathologic entities (Mirizzi syndrome and intrahepatic lithiasis of the left biliary tree) had the greatest relative risk of conversion to an open procedure. Stone impaction was not a predictor of method failure (odds ratio 00.44), while it has been regarded as the number one factor of failed CBD clearance in ERCP. Laparoscopic CBD exploration after failed endoscopic stone removal was shown to be very effective (successful duct clearance was 64.51 %) despite the predicted high degree of difficulty for this patient population. Ahmed *et al*, compared preoperative versus intraoperative endoscopic sphincterotomy for management of CBD stones. 198 patients diagnosed preoperatively with gallbladder and CBD stones were eligible. They were randomly divided into two groups: Preoperative endoscopic Sphincterotomy (PEST)/LC group (n0100) and LC/Intraoperative endoscopic Sphincterotomy (IOEST) group (n0 98). The operative duration, surgical success rate, number of stone extracted, postoperative complications, retained common bile duct stones, and postoperative lengths of stay were compared prospectively. There were no statistically significant differences in surgical time, surgical success rate, CBD diameter, stone size, or stone number between the two groups. The success rate was 95.3 % and 97.8 % for PEST/LC and LC/IOEST, respectively. There were no significant difference in postoperative retained stones, surgical time, and complications, but the total hospital stay was significantly shorter in the LC/IOEST group. They concluded that PEST/LC and LC/IOEST are both good options for dealing with preoperatively diagnosed CBD Stone, but when there is enough experience and facilities, LC/IOEST, as a single-stage treatment, should be preferable. When CBD stones are discovered intraoperatively, a surgeon has to decide whether to go ahead with single stage laparoscopic management or complete the cholecystectomy followed by sequential endoscopic clearance of CBD. Two prospective randomized studies have evaluated the merits of immediate versus delayed treatment for bile duct stones.

Rhodes *et al* [4] randomized 80 patients at the time of diagnosis by cholangiography to either laparoscopic exploration or delayed postoperative EST. Patients were excluded if they had preoperative EST, cholangitis, or acute pancreatitis. The laparoscopic approach entailed transcystic exploration (n028) of the duct followed, if necessary, by laparoscopic choledochotomy (n012) in those patients with CBD exceeding 6 mm in diameter. This study showed that both techniques were associated with a 75 % successful bile duct clearance rate at the time of first intervention. Final duct clearance was not significantly different, although there was a trend towards better clearance with the laparoscopic approach. The length of hospital stay was significantly shorter with the single stage approach (1 day, 3.5 day; $p< 0.001$). There was no significant difference in morbidity (18 %, 15 %; p0NS) or mortality (0 %, 0 %).

Nathanson *et al* conducted a study wherein they compared single stage laparoscopic management with delayed endoscopic management of intraoperatively discovered CBD stones. Patients were included only if the transcystic approach

failed to clear the intraoperatively discovered CBD stones. Eighty six patients were randomized to laparoscopic choledochotomy or delayed postoperative EST. There were no differences between the two approaches in terms of bile duct clearance rates, morbidity, or length of hospital stay. However, the patients undergoing choledochotomy experienced a significantly higher rate of bile leak (14.6 %) from the choledochotomy.

Hong *et al* compared laparoscopic cholecystectomy combined with intraoperative endoscopic sphincterotomy with laparoscopic CBD exploration. For this study, 234 patients with cholelithiasis and choledocholithiasis diagnosed by preoperative B mode-ultrasonography and intraoperative cholangiogram were divided at random into an LC-LCBDE group (141cases) and an LC-IOEST group (93 cases). There was no difference between the two groups in terms of surgical time, surgical success rate, number of stone extractions, postoperative complications, retained common bile duct stones, postoperative length of stay, and hospital charge. It was concluded that both LC-IOEST and LCLCBDE were shown to be safe, effective, minimally invasive treatments for concomitant gallbladder and CBD stones.

Greca *et al* [5] reviewed the simultaneous laparoendoscopicrendezvous (RV) for the treatment of CBD stones with single stage totally laparoscopic (TL) treatment and sequential treatments (ST). Data was collected from 27 papers concerning 795 patients. The overall effectiveness of RV was 92.3 %. The morbidity rate was 5.1 %, and the mortality rate was 0.37 %. Almost all the authors were satisfied with the procedure. The authors' comparison to ST and TL showed that the advantages outweigh the disadvantages mostly related to logistical problems. They were of the view that the results are at least comparable with those of the other available approaches. The effectiveness of RV is greater with reciprocal implementation of surgical and endoscopic procedures. The morbidity and the risk of iatrogenic damage seem lower than with ERCP-ES and the risk of residual stones lower than with TL treatment. The RV procedure is safe and can sometimes be the preferable option, but collaboration between surgeon and endoscopist is mandatory.

4.Treatment

4.1 Medical

Patients with cholangitis or gallstone pancreatitis are generally acutely ill, and they often require aggressive rehydration as well as complete bowel rest. Enteric gram-negative bacteria are usually cultured from the bile of patients with acute cholangitis, especially *E. coli* and *Klebsiella* species. In the last decades the microbiological profile has changed due to increased instrumentation of the bile ducts and wide spread use of antibiotics in the population. Polymicrobial bile cultures are also often found. Anaerobic bacteria are usually isolated in conjunction with aerobic bacteria. Choice of antibiotics should be influenced by patient characteristics (e.g., antibiotic hypersensitivity, renal function, hearing loss, severity of disease, and previous instrumentation of the bile ducts) and regional antibiotic sensitivity patterns. The combination of an amino glycoside with amoxicillin-clavulanic acid is primarily used as the first-line of treatment. In the event of contraindications to amino glycosides, broad-spectrum antibiotics (e.g., piperacillin or piperacillin-tazobactam or meropenem or tigicycline) are reasonable alternatives.

4.2 Intervention or Surgery

Today, therapeutic decision making is based on the local availability of expertise. Two groups of interventions have significant roles in management of CBD stones (1) pre- or postoperative ERCP with endoscopic biliary sphincterotomy (EST) in a *two-stage procedure*, (2) surgical bile duct clearance and cholecystectomy as *one stage procedure*. Several randomized controlled trials showed almost similar effectiveness for both methods of treatment. Kharbutli *et al* reported that one-stage management of symptomatic CBD Stone is associated with less morbidity and mortality (7% and 0.19%) than two-stage management (13.5% and 0.5%). Other methods include electro hydraulic lithotripsy (EHL), extracorporeal shockwave lithotripsy (ESWL), laser lithotripsy, and dissolving solutions that are indicated only in special situations. Although these techniques are useful in the management of the complicated biliary tract, they are not without cost, morbidity, mortality, and significant reduction in quality of life [6].

4.2.1. Preoperative Endoscopic Management

More than a decade ago, randomized controlled trials showed superior outcomes for standard open bile duct surgery as compared to the endoscopic (ERCP/EST) treatment of CBD Stone. ERCP/EST was performed with leaving the gallbladder in situ in patients with preoperative cholangitis or pancreatitis, older than 80 years of age, substantial comorbidity and where CBD stones were discovered. Although the success rate for stone clearance in isolated ERCP treatment is up to 87% to 97%, up to 25% of patients require two or more ERCP treatment. This method is associated with morbidity and mortality rates of 5% to 11% and 0.7% to 1.2%, respectively.

Schreurs *et al* showed 75%–84%patients undergoing ERCP/EST had no symptoms with up to 70-month follow up. Complications of ERCP include bleeding, duodenal perforation, cholangitis, pancreatitis, and bile duct injury. Moreover, ERCP is not possible in 3% to 10% of all patients. Endoscopic balloon dilation of the papilla has been advocated as an alternative method to EST, in comparison to this procedure is easier, has lower bleeding rate, less disruption of function to the sphincter of Oddi. In comparison to EST, the rate of pancreatitis is higher than EST and is not the procedure of choice for patients undergoing stone extraction [7].

Weinberg *et al* reviewed several randomised clinical trials comparing endoscopic balloon dilation versus EST for the removal of CBD Stones and reported that endoscopic balloon dilation is less successful than EST. In these cases, endoscopic balloon dilation was done, respectively, in patients with coagulopathy, and at risk for infection. It is important to ensure adequate biliary drainage in patients with CBD Stones that have stoned not yet extracted. Therefore, short-term use of a biliary stent followed by further endoscopy or surgical treatment is advocated. For patients over 70 years of age or with debilitating disease, biliary stenting has also been examined as an alternative to the endoscopic method. Biliary stenting as a "bridge" to further therapy is recommended, as is its use as a definitive treatment for CBD Stone should be restricted to patients who have limited life expectancy or are judged by a surgeon to be at prohibitive surgical risk.

4.2.1.2 Laparoscopic Common Bile Duct Exploration

The successful laparoscopic management of CBD stones depends on several factors including surgical expertise, adequate equipments, the biliary anatomy, and the number and size of CBD stones. With advancing technology and minimally invasive surgery, laparoscopic biliary surgery has become safe, efficient, and cost effective. Laparoscopic common bile duct exploration (LCBDE) was associated with successful stone clearance rates approximately 95%. Laparoscopic exploration is very effective for clearing difficult CBD stones. Tai *et al* reported that the clearance rate was 100%, and no recurrence was discovered during a mean follow-up period of 16 months.

Golipour *et al* showed LCBDE to be an effective procedure as the initial modality of management for acute gallstone cholangitis. Complications from this method include CBD laceration, stricture formation and bile leak. Patients treated with LCBDE had a significantly shorter hospital stay and lower hospital costs as compared with ERCP/EST. During laparoscopic cholecystectomy, if CBD Stones are found with IDUS, IOC, or other modalities, LCBDE can be performed. There are two primary methods for LCBDE: trans-cystic (via the cystic duct) and trans-ductal (via choledochotomy). If CBD Stones are detected at the time of laparoscopic cholecystectomy, the best treatment is a transcystic laparoscopic approach during the same operation. If this fails, alternate approaches such as intraoperative or postoperative ERCP/EST, laparoscopic choledochotomy, or open CBD Exploration may be used. A trans-cystic approach is generally used for small stones in a small bile duct whereas trans-ductal approach is preferred for large occluding stones in a large duct, intrahepatic stones, or aminiscule or tortuous cystic duct. Selection of the differing approaches is influenced by several factors (Table 2).[6]

Table 2: Effective and important factors in CBD stone approach

Factor	Trans-cystic approach	Trans-ductal approach
Single stone	Yes	Yes
Multiple stones	Yes	Yes
Stone < 6mm diameter each	Yes	Yes
Stone > 6mm diameter each	No	Yes
Intrahepatic stones	No	Yes
diameter of cystic duct < 4mm	No	Yes
Diameter of cystic duct > 4mm	Yes	Yes
Diameter of CBD < 6mm	Yes	No
Diameter of CBD > 6mm	Yes	Yes
Cystic duct entrance-lateral	Yes	Yes
Cystic duct entrance-posterior	No	Yes
Cystic duct entrance- distal	No	Yes
Inflammation- mild	Yes	Yes
Inflammation- marked	Yes	No
suturing ability- poor	Yes	No
suturing ability- good	Yes	Yes

4.2.1.3 LCBDE-Trans-Cystic Approaches

In the trans-cystic approach, 100–200mL isotonic sodium chloride solution with 1–2mgglucagon (for relaxation of Oddi's sphincter) is used to irrigate the CBD in an attempt to flush small stones through the sphincter of Oddi or out through the opening in the cystic duct. If this is not successful, a helical basket can be passed over a guide wire through the cystic duct to extract stones under fluoroscopic guidance. Today, LCBDE under fluoroscopic guidance seems to be the procedure of choice. If this procedure fails, a choledochoscope (≤10 Fr) should be subsequently attempted in order to remove the stones under direct sight. If the CBD stone is larger than the lumen of the cystic duct, the cystic duct can be balloon-dilated. This dilation should never be larger than the internal diameter of the CBD. A flexible choledochoscope can be passed into the peritoneal cavity through a mid axillary port and the CBD examined under direct sight. The CBD should be kept inflated with isotonic sodium chloride solution for better visualization. Intraluminal stones can be extracted with a basket under direct vision using

the working port of the scope. A Segura type stone basket is advanced via the working channel of the scope beyond the stone and then opened. As the basket is pulled backwards and simultaneously rotated, the stone is ensnared. A cholangiogram or ultrasound should always be performed to conclusively demonstrate clearance of the duct. The outcome of the transcystic method proved to be consistent with the goals of a laparoscopic approach: minimal morbidity, no T-tube, no drain, and a rapid return to normal activity in most cases. [6] Other novel transcystic approaches include balloon dilatation of the sphincter of Oddi and antegrade sphincterotomy. Balloon dilatation of the sphincter of Oddi can be performed when all other techniques have failed to clear the stones. A risk exists for developing mild pancreatitis with this method (15% in one series). Therefore, this technique should be avoided in patients with pre-existing pancreatitis, CBD dyskinesia, or sphincter anomalies. Successful transcystic duct clearance has been described in 95% of patients. Complications such as infection and pancreatitis have been reported in few patients, with a mortality rate of 0.5%. The duration of hospitalization following an uncomplicated transcystic duct stone extraction is the same as that for laparoscopic cholecystectomy alone, averaging approximately 1–2 days. The main advantage of the transcystic approach is that it avoids the need for choledochotomy. [5]

4.2.1.4 LCBDE-Trans-Ductal Approaches

If the transcystic approach fails, then recommend laparoscopic choledocholithotomy. Laparoscopic choledocholithotomy can be accomplished with a variety of techniques. Choledocholithotomy may involve performing a number of technical maneuvers such as dilation of the distal CBD, balloon catheter manipulation, basket manipulation with or without fluoroscopic guidance, choledochoscopic manipulations as well as IOC. After the stones are removed under endoscopic visualization, the ductotomy is usually closed either primarily or over an appropriately sized T-tube. The indication for T-tube insertion is decompression of the duct in patients with residual distal obstruction, ductal imaging in the postoperative period and providing an access route for the removal of residual CBD stones [6].Most authors prefer a longitudinal choledochotomy over a distance of approximately 1–1.5 cm, a 14-French latex T-tube (or larger), and closed over a 16-French T-tube using 4-0 monofilament absorbable sutures. Some centers use transcystic tubes (C-tube) or antegrade stenting with choledochorrhaphy for CBD drainage. C-tube drainage via the cystic duct following CBD exploration would seem to be the preferred choice of treatment for patients who require choledochotomy because of large multiple stones in the CBD using this technique. Management of T-tubes in the postoperative period may involve bacteremia, dislodgment of the tube, obstruction by the tube, or fracture of the tube. Broad-spectrum antibiotic coverage while the T-tube is in situ may be necessary. The patient can generally be discharged 2–4days postoperatively. T-tube cholangiography should be performed before removal of the tube (6–18 days postoperatively).Removal of T-tubes has been suggested as early as 5–6days postoperatively and as late as 2-3 weeks after surgery. Retained stones demonstrated by T-tube cholangiography may be effectively removed percutaneously after allowing maturation of the T-tube tract. Percutaneous extraction is successful in more than 95% of patients with retained stones, otherwise postoperative ERCP can be required. Despite the advantages of T-tube drainage and because of the potential complications of T-tube placement, primary closure of the CBD without drainage has been advocated by some authors in open biliary tract surgery. Shorter operative times and lengths of hospital stay have been observed with primary closure. No increase in bile leakage or peritonitis has been noted with primary closure in the open literature. Higher patient satisfaction has also been associated with primary closure [6]. Some studies proposed that choledochotomy with primary laparoscopic closure of the CBD are safe, eliminates the need for T-tube placement, and reduces operating time and postoperative morbidity.

Yamazaki *et al* reported significant differences in hospital stay between primary closure and T-tube insertion (18.3 days versus 31.5 days). In other study, Leida *et al*, showed in patient with primary closure of the CBD that the time until return to work (12.6 □} 5.1 versus 20.4 □} 13.2 days) was significantly shorter. Hospital expenses were significantly lower and the incidence of postoperative complications (15% versus 27.5%) and especially biliary complications (10% versus 20%) were significantly lower than in the T-tube drainage patients.

4.2.2 Postoperative Evaluation and Management

Postoperative ERCP is used as a treatment modality for CBD Stone clearance when LCBDE failed or retained stones are discovered after an operation (2.5%). If secondary ERCP fails, clinicians must be ready for laparoscopic or open exploration. Percutaneous transhepatic therapies can be considered for CBD Stones under TUS guidance in selected patients. Extraction of stones, sphincterotomy, or percutaneous drainage can be performed using this method. New approaches have been performed which exclude ERCP, such as past gastric surgery. The most common gastric surgery presently performed is the Roux-Y gastric bypass. In which, a small gastric pouch is created and anastomosed to a limb of the jejunum. The majority of the stomach, duodenum, and proximal jejunum are bypassed by this method. Combined laparoscopic surgical and endoscopic procedures have also been described. Endoscopic access can be achieved via a gastrostomy or jejunostomy. The endoscope can also be passed into the abdomen during surgical management, and an ERCP can be performed in the standard technique. These procedures have been described in few case reports.

4.2.2.1 Open Common Bile Duct Exploration

When LCBDS and postoperative ERCP have failed, the surgeon must use the open approach to surgery. Martin *et al*. reported open surgery as being more successful and being lower mortality than ERCP in CBDS. There are two options for open common bile duct exploration: choledochoenterostomy or sphincterotomy. Surgeon experience should therefore dictate which one is performed. Some authors prefer choledochoenterostomy for CBD greater than 2 cm in diameter in order to create a large opening between the bile duct and intestine.

Sphincterotomy

It consists of incising the distal part of the sphincter musculature over a length of approximately1 cm. This incision should not extend beyond the outer wall of the duodenum. After the choledochotomy, a catheter or dilator is passed distally and a Kocher maneuveris performed, then duodenotomy is performed at the level of the ampulla. The dilator is advocated to bring the ampulla into the operative field, where it is then incised sufficiently along the anterosuperior border (opposite the pancreatic duct orifice) to permit removal of the impacted calculus.

Choledocoenterostomy

It is the most commonly performed as a side-to-side choledochoduodenostomy, usually in the setting of a dilated CBD with multiple stones, a recurrence of CBD Stone in the Vater's ampulla occurred after ES and dilated CBD (≥2.0 cm). These patients require drainage for good long-term results without recurrence of jaundice or cholangitis. The technique most commonly used is that of a side-to-side hand-sutured anastomosis between the supraduodenal common bile duct and the duodenum [8]. A Kocher maneuver is performed and the distal CBD is exposed. Choledochotomy is made within 2-3 cm of the lateral border of the duodenum. A diamond-shaped anastomosis is performed with interrupted absorbable sutures. One potential complication is the "sumpsyndrome" caused by food or other debris caught in the distal CBD. This complication is rare (1%) and can be managed with ERC/ES. The alternative operation, transection choledochoduodenostomy, excludes the distal (transpancreatic) segment of the bile duct from the end to-side anastomosis of the transected common bile duct with the second part of the duodenum. The long-term results of this procedure are excellent [8]. Another optimal option is the choledochojejunostomy with a roux-en-Yloop.

4.2.2.2Electrohydraulic Lithotripsy (EHL):-EHL uses direct high voltage to generate a shockwave through a liquid medium to fragment the bile duct stone. The procedure has been performed successfully under cholangioscopic guidance or under fluoroscopic control using a balloon catheter [9]. Typically, its use is reserved for cases of CBD packed with multiple faceted stones or a single large impacted stone. For EHL to be successful the stone must be targeted under direct sight, otherwise there is increased risk of damaging the bile duct wall. This method is rarely used because of its high potential for tissue damage and bleeding.

4.2.2.3 Extracorporeal Shockwave Lithotripsy (ESWL):- *ESWL* was first used treating gallstones in 1980s following its successful use in fragmenting renal calculi. ESWL involves the percutaneous administration of sound waves directed at the liver and bile duct. It is not performed during endoscopy, but rather before an ERCP in hopes of shattering large stones into smaller, more manageable fragments. European studies evaluating ESWL report duct clearance rates of 83% to 90%, but its acceptance in the United States has been low.

4.2.2.4 Laser Lithotripsy:-Laser lithotripsy uses amplified light energy at a particular wavelength, which is focused into a single beam and directed onto a stone within the bile duct. Laser lithotripsy can be performed under direct vision with cholangioscopy using mini scopes or can be performed under fluoroscopic control using standard equipment. The success rate of duct clearance for retained CBDS using laser lithotripsy is between 64% and 97% in several studies.

4.2.2.5 Dissolving Solutions:-Table 3 shows several types of solutions that are used for dissolving gallstones and CBD stones. These solutions have few toxic side effects and do not cause irritation of the biliary tree. Every dissolution therapy will last for several weeks; therefore the ideal solvent has not yet been produced [1].

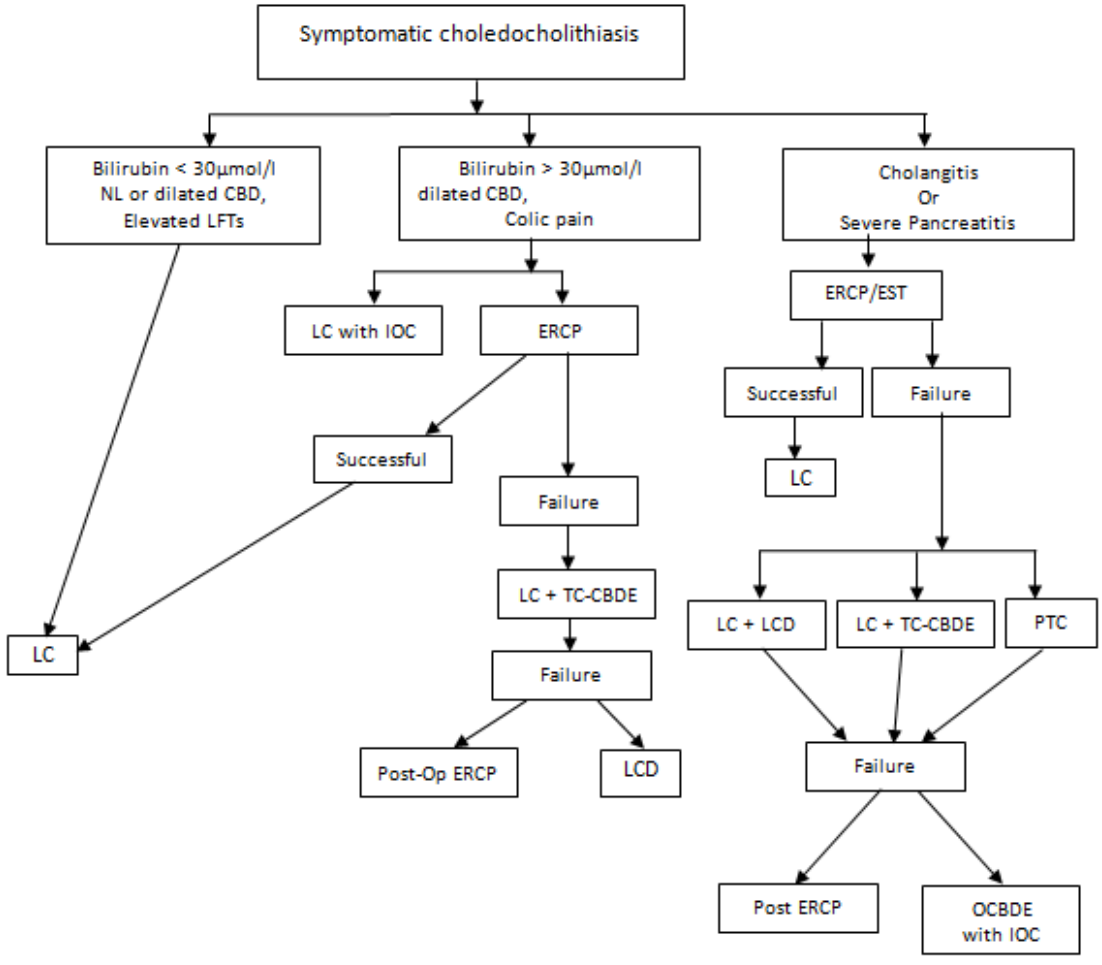
The use of ursodeoxycholic acid (UDCA) and chenodeoxycholic acid has only been shown to dissolve cholesterol-containing stones. Approximately 85–95% of patients in the Western World will have cholesterol stones. Continuing therapy with UDCA appeared to prevent recurrence of gallbladder microlithiasis. Methyl-Tertbutyl-Ether (MTBE) is an excellent cholesterol solvent that has been shown to work faster, but it is toxic to liver and duodenal mucosa. It has been proposed by several studies that using dissolution in combination with endoscopic retrieval or lithotripsy has better outcomes. [1]

Katsinelos *et al* suggested that UDCA does not seem to contribute to the reduction in stones' size or stones' fragmentation during the endoprosthetic procedure.

Table 3: Types of dissolving solution

Substance	Year	Author (s)	Country
Ether	1891	Walker	England
Turpentine	1908	Wright	England
Chloroform	1945	Narat and Cipolla	USA
Heparin saline	1971	Gardner *et al*	USA
Na cholate	1972	Way *et al*	USA
Chenodeoxycholic acid	1972	Danziger *et al*.	USA
Urodeoxycholate	1975	Makino *et al*.	USA
Mono-octanoin	1981	Gadacz	Japan
Methyle-tert-butyl ether	1985	Allen *et al*.	USA

So, now we can also present a possible algorithm for the treatment of CBD stone below:



5. Conclusion

Today, management of CBD Stone is a complicated procedure for the treating medical stone. Ultrasonography and ERCP are routine diagnostic modalities in most centers, but clinicians can often choose from other low-invasive modalities such as MRCP or CT. LCBDE (trans-cystic or trans-ductal) is a standard method with a high efficacy and low morbidity and mortality for the treatment of CBD Stone in most of the centers. Pre- or postoperative ERCP/EST can be use as an alternative method. We recommend that for patients with CBD Stone, ERCP should be performed as a first step and in the event of failure LCBDE can be performed. It should not be forgot that the open approach always remains as a final option when others modalities have failed. Electrohydraulic lithotripsy, extracorporeal shockwave lithotripsy, laser lithotripsy, and dissolving solutions have especial indications and more clinical trial in this area must be performed.

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