Biliary Stones

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Introduction

Choledocholithiasis is a frequently encountered problem and is potentially associated with complications such as cholangitis, sepsis, and death. About 5–10 % of patients undergoing cholecystectomy for cholelithiasis and 18–33 % of patients with acute biliary pancreatitis have choledocholithiasis.[1]. Management is determined by risk stratification for the likelihood of finding common bile duct (CBD) stones using clinical parameters, liver tests, and imaging. Patients with very high or high probability of stones are managed by endoscopic retrograde cholangiopancreatography (ERCP). Patients with intermediate probability are further evaluated by magnetic resonance cholangiopancreatography (MRCP) or endoscopic ultrasound (EUS) to determine the need for ERCP.

The natural history of choledocholithiasis is not well known. Approximately one out of five stones pass spontaneously within 1 month. Small stone size (<5 mm) was determined to be an independent factor for spontaneous passage of the stone [2]. On the other hand, stones that do not pass spontaneously can cause further complications including acute pancreatitis, acute biliary colic, cholangitis, secondary biliary cirrhosis with subsequent sequelae of sepsis, portal hypertension, and possibly death. Hence, suspected choledocholithiasis should be further investigated and once confirmed, stones should be extracted.

Most stones can be extracted using conventional techniques involving sphincterotomy, balloon dilation, and balloon or basket extraction with high success rates averaging 90–95 %. However, factors increasing the difficulty of stone management include abnormal and postsurgical anatomy, large stones (greater than 15–20 mm), cystic duct stones with Mirizzi's syndrome, and intrahepatic stones. Development of instruments and techniques such as endoscopic sphincterotomy with large balloon dilation of the sphincter (ESLBD), mechanical lithotripsy, electrohydaulic lithotripsy, laser lithotripsy has enabled successful clearance of the biliary tract in difficult cases with rates ranging from 77 to 98 %. Intraductal ultrasound (IDUS) can be a valuable tool to ensure complete clearance of the CBD of stones in equivocal cases where the cholangiogram is not definitive.

Case Study

A 45-year-old female presented with RUQ pain and jaundice. Labs were notable for total bilirubin 7.8 mg/dl, AST 80 IU/L, ALT 60 IU/L, and alkaline phosphatase 235 IU/L. An abdominal ultrasound showed multiple gallstones within the gallbladder. The CBD measured 8 mm but no

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stones were seen in the CBD. What is the next best step?

How Are Patients Risk Stratified for Possible Choledocholithiasis?

The initial workup for suspected choledocholithiasis should be least invasive and cost-effective and consequently includes liver biochemical tests and a transabdominal ultrasound (US). Liver biochemical tests have a low positive predictive value (15 %) but a high negative predictive value (95 %) and hence are useful in ruling out choledocholithiasis [3]. Higher levels of bilirubin and alkaline phosphatase occur with longer duration and severity of biliary obstruction, and thus are more predictive of the presence of CBD stones. The US has a low sensitivity (less than 50 %) but a very high specificity (100 %) in the detection of choledocholithiasis. Thus, the presence of a stone confirms the diagnosis but the absence of a stone does not rule out choledocholithiasis. However, the US finding of a normal sized CBD (<6 mm in patients with intact gallbladder) has a high negative predictive value of 95 % and is consequently helpful in excluding stones [4]. Thus, the combination of normal liver biochemical tests and a normal sized CBD on US with a negative predictive value of 95 % are useful in ruling out choledocholithiasis.

Risk stratification to determine the presence of choledocholithiasis helps avoid unnecessary procedures and streamlines the management in an efficient manner. The ASGE standards of practice committee has guidelines to risk stratify patients with symptomatic cholelithiasis into three groups based on the probability of choledocholithiasis: high risk (>50 %), intermediate (10–50 %), and low risk (<10 %) [1]. The presence of any very strong clinical predictor (clinical ascending cholangitis, ultrasound showing a stone, or total bilirubin >4 mg/dl) or both strong predictors (US showing a dilated CBD and total bilirubin 1.8 mg/dl-4 mg/dl) places the patient at high risk of having choledocholithiasis with recommendations to proceed with ERCP for further management. The absence of any clinical predicators places the patient at low risk of having choledocholithiasis. These patients can proceed with cholecystectomy with no further testing. All other patients have an intermediate risk of having choledocholithiasis and should proceed with either EUS or MRCP preoperatively or an intraoperative cholangiogram (IOC) during cholecystectomy. In a recent study, IOC, when attempted routinely in patients undergoing cholecystectomy, was successful in 95 % with a sensitivity of 97 % and specificity of 99 % [5]. However, IOC is highly operator dependent, adds to procedure time, and may not be feasible in cases of severely inflamed gallbladder. If a stone is confirmed on the IOC, it can be removed via laparoscopic CBD exploration (LCBDE) or via postoperative ERCP. An advantage of performing preoperative confirmatory studies (EUS/MRCP) in this group is that the stone can be removed during preoperative ERCP, and if ERCP is unsuccessful, LCBDE can be performed to remove the stone during cholecystectomy. However, proceeding with a cholecystectomy and IOC would not be unreasonable when surgical expertise is available, thus avoiding the risk of possible complications associated with ERCP which may delay the cholecystectomy.

EUS in selected patients has been shown to decrease the need for ERCP by 70 % and adverse events related to the ERCP by 65 % [6]. EUS has been compared to MRCP for the detection of choledocholithiasis and has a higher sensitivity (93 vs 85 %), specificity (96 vs 93 %), positive predictive value (93 vs 87 %), and negative predictive value (96 vs 92 %) but the differences were not statistically significant [7]. The sensitivity of MRCP decreases with smaller stone size and approaches 70 % when evaluating for stones <5 mm but has the advantage of being noninvasive [8]. Thus, the choice between these modalities should be based on local availability, expertise, patient characteristics, and preference.

Tips for Preparation and Technique of Cholangiogram During ERCP

Obtaining a comprehensive history and review of previous imaging and records is essential for providing optimal care and avoiding unanticipated roadblocks during the procedure. Reviewing previous diagnostic imaging also provides a roadmap for performing the ERCP. Antibiotics are continued in patients with acute cholangitis until the procedure and after if complete drainage is not achieved. Patients with sepsis related to the cholangitis should be resuscitated prior to the procedure. After cannulation of the bile duct and deep advancement of the wire, aspiration of bile prior to injecting contrast helps minimize the hydrostatic pressure of injection and over distension of the bile duct, thereby decreasing the risk of bacteremia in the setting of cholangitis. A good cholangiogram should be obtained to identify the stone burden, location and size of the stones, size of the duct, and any strictures that will have an impact on the stone extraction strategy as will be discussed further below. We inject half strength contrast starting at the distal aspect of the CBD and carefully evaluate for any filling defects as the contrast extends proximally into the bifurcation of the right and left hepatic ducts. Care should be taken not to overdistend the biliary system as it predisposes to cholangitis. The cystic duct is opacified to ensure patency. The gallbladder should not be overfilled as this causes pain and may predispose to cholecystitis. A balloon occlusion cholangiogram is performed after removal of all stones to ensure complete clearance. Nonopacification of the cystic duct during the occlusion cholangiogram is evidence of cyst duct blockage and makes a case for cholecystectomy.

Case Continued

Because the patient was at high risk for CBD stone, an ERCP was performed which revealed a smooth narrowing in the distal biliary tree. A sphincterotomy was performed but a balloon sweep showed no stone and a stent was placed (Fig. 5.1a, b). A laparoscopic cholecystectomy was then performed. She returned for a second ERCP, which revealed a persistent narrowing, and the stent was replaced. She was then referred for further management.

How Are Uncomplicated Stones Retrieved During ERCP?

Among other factors, stone size is an important determinant of successful endoscopic removal after a sphincterotomy (Fig. 5.2). As a general rule, stones smaller than 10 mm can be successfully removed following a sphincterotomy [9].

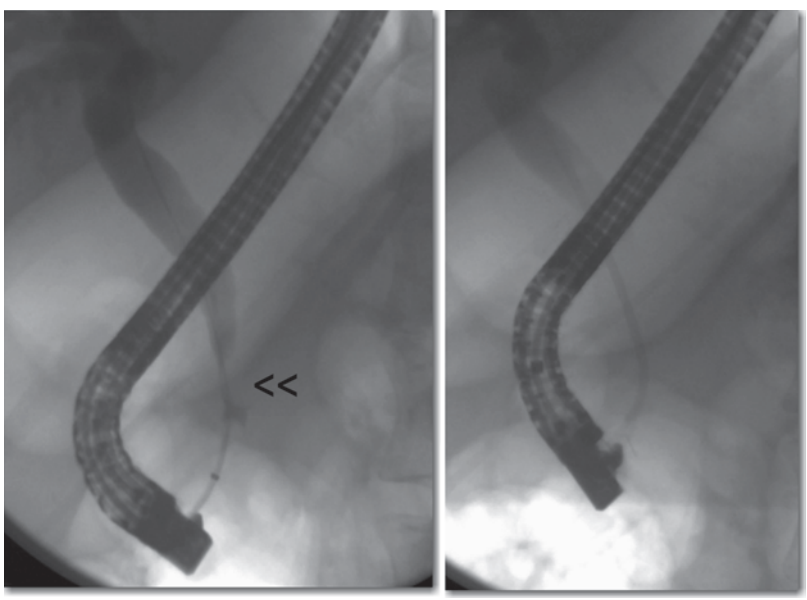

Fig. 5.1 **a**. ERCP with a smooth eccentric narrowing (*arrows*) in the distal biliary tree without evidence of a mobile filling defect or a distinct stone. **b**. Stent is placed

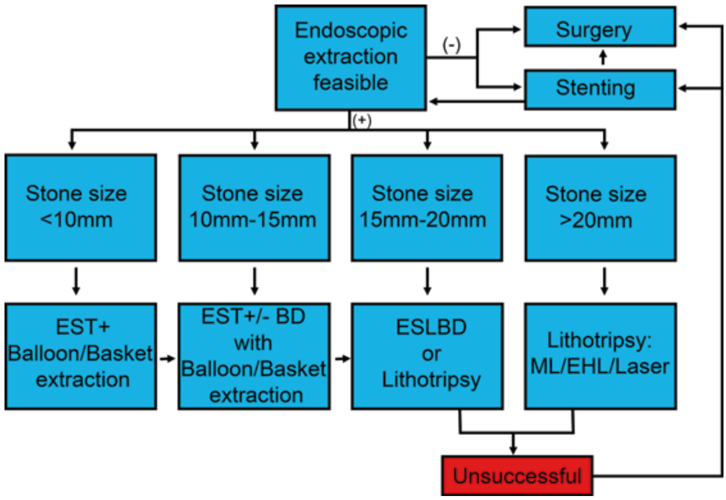

Fig. 5.2 Algorithm for management of established bile duct stones. *EST* = endoscopic sphincterotomy; *BD* = balloon dilation; *ESLBD* = endoscopic sphincterotomy and large balloon dilation; *ML* = mechanical lithotripsy; *EHL* = electrohydraulic lithotripsy

As such if a stone appears smaller than the diameter of the scope, it can be extracted with a balloon catheter or a basket without difficulty after sphincterotomy. In the setting of a dilated bile duct with small stones, a basket is more helpful in extraction as the stones tend to slide by the balloon within the large duct during removal. Any stones impacted in the lower CBD should be pushed up into the proximal duct to avoid inadvertent rupture of the duct. During retrieval of stones using a basket, the stone is first engaged within the basket by to and fro motion around the stone, and the stone is extracted without closing the basket. This is to prevent inadvertent impaction of the stone within the basket and subsequent inability to remove the basket containing the stone through the papilla due to a mismatch between the size of the stone and the papillary orifice. When multiple stones are present, they should be removed one at a time starting with the most distal stone first to avoid impaction. As a general rule, the balloon or basket containing the stone is withdrawn until at the papilla and locked in this position at the biopsy port with the left hand while simultaneously pushing the big dial away and gently advancing the scope using clockwise torque with the right hand. This technique of stone removal aligns the vector of the extraction force with the axis of the bile duct while maintaining visualization of the papilla to confirm stone extraction.

Some factors which make stone extraction difficult include the following:

1. Large stones (> 1.5–2 cm)
2. Impacted stones
3. Cystic duct stones causing Mirizzi's syndrome
4. Stones in the intrahepatic ducts
5. Concomitant presence of a downstream stricture.

When to Perform Sphincterotomy, Balloon Dilation or Both?

Endoscopic sphincterotomy (EST) has a high success rate of stone extraction approaching 85–98 %, but can be associated with a risk of bleeding, perforation and pancreatitis [10]. The risk of postsphincterotomy bleeding is increased in patients with coagulopathy either due to intrinsic liver disease or from the use of anticoagulants and antiplatelet agents [11]. EST also leads to permanent loss of the sphincter function with a theoretical risk of free bacterial access to the bile duct leading to recurrent stone formation [12]. Endoscopic balloon dilation of the native papilla (EBD) was initially developed as an alternative to EST to minimize the risk of adverse events and also preserve the sphincter function [13]. Balloon dilation of the papilla can be performed using balloons ranging from 4 to 8 mm. Although one meta-analysis showed lower efficacy of stone clearance with EBD compared to EST [14], other studies have demonstrated high success rates of 91–97% for stone extraction with EBD, comparable to that of EST [15–17]. Equal efficacy of EST and EBD for extraction of small to medium-sized stones up to 8 mm has been shown in randomized controlled trials (RCT) [15, 16]. A meta-analysis by Baron et al confirmed comparable efficacy for stone removal with both techniques, albeit with a lower risk of pancreatitis in patients undergoing EST [17]. A few studies have reported an increased risk of serious complications including severe pancreatitis with EBD, with one RCT terminated prematurely due to complications and two deaths related to severe pancreatitis in the EBD group [15]. Thus, EBD has fallen out of favor as a primary choice for stone extraction. With its lower risk of bleeding and perforation, EBD has been recommended as an option for stone removal in patients with coagulopathy [15–17]. Therefore, for small to medium-sized stones, EST would be the preferred method to facilitate stone extraction with EBD used sparingly in patients with coagulopathy that cannot be corrected, altered anatomy where sphincterotomy cannot be achieved, or periampullary diverticulum that makes sphincterotomy difficult.

Large stones (> 1.5 cm) may require lithotripsy to deliver the stone following EST or EBD. An alternative combines an initial small to less than maximal sphincterotomy followed by large balloon dilation (10–20 mm), which is termed endoscopic sphincterotomy with large balloon dilation (ESLBD) and was first described by Ersoz et al. [18]. Subsequently, several studies have demonstrated successful extraction of complex stones with this procedure [19, 20]. This technique of initial sphincterotomy separates the biliary and pancreatic sphincters and helps direct the controlled tear of the sphincter by the large balloon dilation away from the pancreatic duct, thus theoretically minimizing the risk of pancreatitis [21]. A meta-analysis by Feng et al comparing ESLBD with EST to facilitate removal of large stones showed fewer complications and decreased need for mechanical lithotripsy in the ESLBD group [22]. A RCT comparing mechanical lithotripsy following EST to ESLBD demonstrated equal efficacy in stone removal but a higher rate of complications in the lithotripsy group [23]. ESLBD also decreases the need for mechanical lithotripsy, fluoroscopy time, total procedure time, [24], and total hospital cost [25]. The rate of pancreatitis following ESLBD is lower than 5%, which is comparable to EST and lower than EBD [26]. Rare but serious perforations and occasional bleeding have occurred following ESLBD. Care should be taken to match the size of the balloon with the diameter of the native distal CBD to avoid perforation.

The currently available balloons for large dilation were intended for use in the luminal GI tract, and due to their length may present some problems if the CBD has numerous stones (Fig. 5.3). The stones need to be either pushed upstream or the balloon placed very distal in the CBD just enough to dilate the papilla without lying beside stones (Fig. 5.4a, b). This is important as inflating the balloon beside a stone may carry a risk of perforation, especially if the stone is angulated rather than smooth. Regarding how long to dilate, a nonblinded RCT comparing 1 versus 5 min dilation of the papilla without EST showed

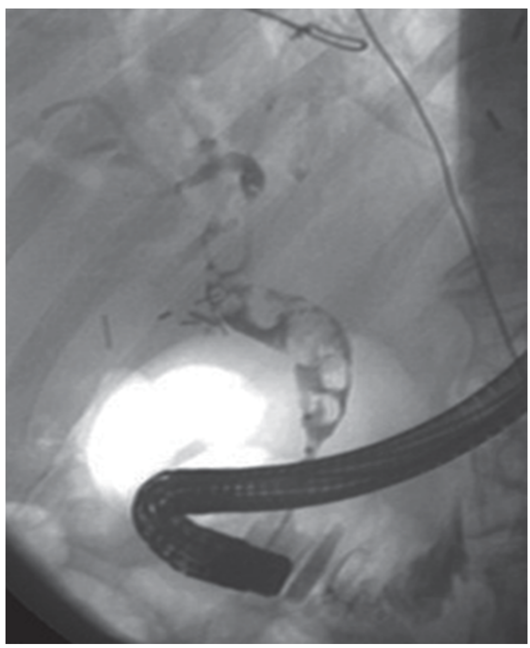

Fig. 5.3 ERCP cholangiogram with multiple CBD stones down to the distal CBD

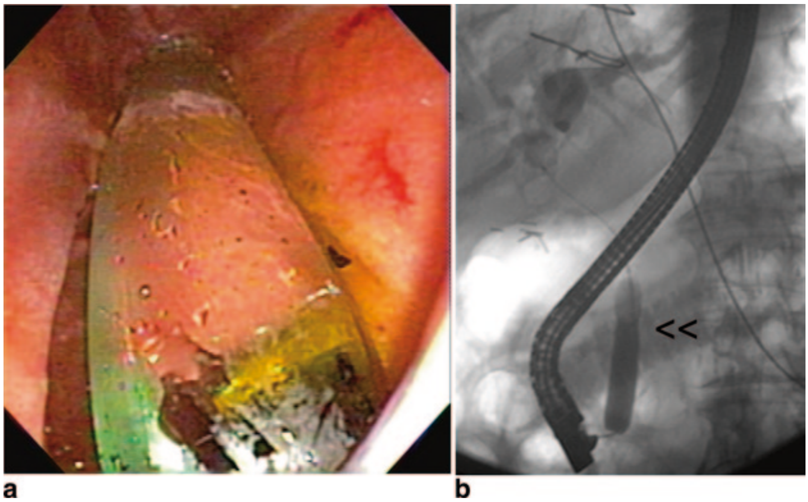

Fig. 5.4 **a**. Balloon inserted with minimal balloon *above* the major papilla. **b**. The radiographic view showing a waist in the balloon (*arrows*) at the papilla with minimal balloon upstream

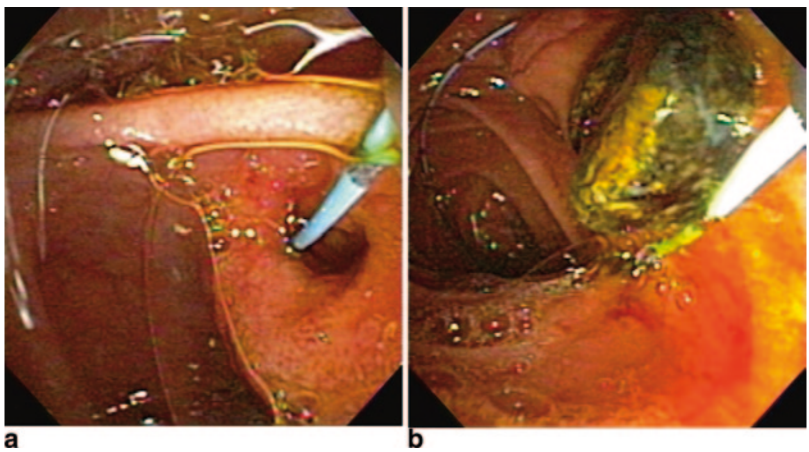

Fig. 5.5 **a**. Ampulla postdilation. **b**. Stone extracted postdilation

significantly higher technical success for stone extraction (80 vs 93 %) and lower rate of pancreatitis (15 vs 5 %) in the group that underwent 5 min dilation[27]. However, the control group (1 min dilation) had a much lower rate of technical success than generally expected (80 %), which may have overinflated the difference in success between the two groups. We tend to sequentially dilate the papilla for 1 min at each level of the balloon thus totaling 3 min. Once the dilation is complete, the stone can be extracted with a balloon or basket (Fig. 5.5a, b). Thus, ESLBD combines the best of both worlds with lower rates of pancreatitis than EBD and decreased need for mechanical lithotripsy compared to EST in the extraction of large stones (up to 2 cm), provided the distal CBD is dilated enough to accommodate the large balloon.

During stone extraction using a basket, it is prudent to have a rescue lithotripter system available such as a Soehendra lithotripter (Cook Medical, Bloomington, IN) or an Olympus reusable emergency lithotripter (Olympus, Center Valley, PA) because stone/basket impaction is a potential complication with possible significant repercussions if not resolved (Fig. 5.6a). A technique for resolution is to cut the handle and remove the sheath from the basket and the endoscope from the patient. Next insert the metal sheath of the lithotripter over the broken wires of the basket, place the wires in the handle, advance the lithotripter under fluoroscopic guidance, and crush the

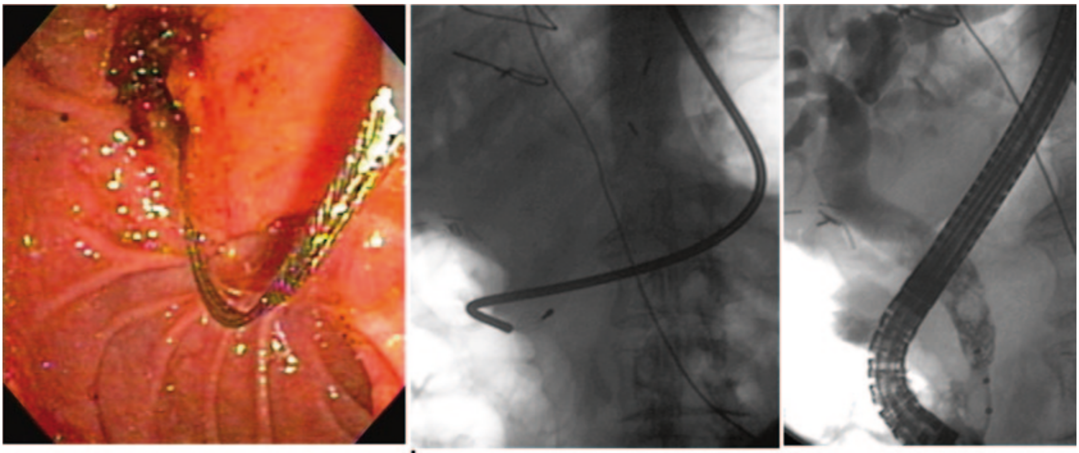

Fig. 5.6 **a**. Endoscopic view of basket wire with plastic sheath covering removed after failed stone extraction. **b**. The endoscope has been removed and the "rescue" lithotripter sheath inserted over the wire. **c**. Following stone fragmentation and basket removal, stone fragments are ready for extraction

impacted stone (Fig. 5.6b, c). Some rescue lithotripters operate through the scope channel while others require removal of the duodenoscope.

Lithotripsy

Mechanical lithotripsy was first described by Demling in 1983 as a safe and effective way of fragmenting large stone thus facilitating removal. Mechanical lithotripsy improves rate of bile duct clearance in difficult stone cases up to 90% with about 4–13% rate of complications including pancreatitis, bleeding, perforation, and basket impaction [28]. This technique involves using a nonemergency lithotripter composed of a basket, plastic sheath, and outer metal sheath to capture the stone within the basket and advance a metal sheath over it to fragment the stone. The device is introduced through the papilla using the "kissing technique" whereby close contact is maintained between the scope and papilla while cannulating the duct. Once confirmed fluoroscopically within the bile duct, we like to pass the closed basket above the stone and draw the open basket down to engage the stone with a shaking movement to try to ensure placement of the wires symmetrically around the stone. The basket is then closed and the metal sheath approximated against the basket to crush the stone. The fragments are disengaged from the basket. Contrast is then injected to see whether any large stone fragments remain that require additional lithotripsy. After the apparatus is withdrawn, the remaining stone fragments can then be extracted with a basket or a balloon. The distal fragments are first extracted to ensure that the fragments do not get impacted at the outlet, and work should progress from the distal to proximal bile duct until all fragments are removed. In about 10% of patients, mechanical lithotripsy will fail, necessitating other techniques such as electrohydraulic lithotripsy (EHL) or laser lithotripsy (LL) (28). These latter approaches are typically best suited for large impacted stones.

EHL involves creating an oscillating cavitation bubble in a liquid media by an electrical spark from an EHL probe which then forms a mechanical shockwave that fragments the stone. This technique was adapted from the mining industry. The EHL probe measuring 3Fr is introduced through the working channel of a Spyglass ® (Boston Scientific Inc, Marlborough, MA) cholangioscope via a therapeutic duodenoscope or a peroral cholangioscope and advanced under direct visualization to the level of the stone with at least 5 mm of the probe protruding from the tip of the endoscope. Shots are fired in 1–2 s bursts at energy ranging from 50 to 100 W. Care is taken to maintain direct contact between the probe and the stone and to avoid the bile duct wall to minimize injury. Saline is intermittently injected into the bile duct to clear the field for better visualization of the stone fragmentation. EHL successfully fragments large stones and enables bile duct clearance in up to 98 % of cases in various studies with overall complication rates of 3–15 %, which include a risk of hemobilia, cholangitis, pancreatitis, bile leak, hemothorax, and perforation [29–33]. Advantages of EHL include its relatively low cost and lack of need for special protective equipment.

Laser lithotripsy involves creating an oscillating cavitation bubble in a liquid media using optical energy from lasers of specific wavelengths which then forms a mechanical shockwave that fragments the stone. Over the years, several different types of lasers have existed ranging from dye lasers to solid state lasers with different physical properties defined by specific wavelengths which determine the depth of penetration. The shorter the wavelength, the greater the depth of penetration. The dye lasers have shorter wavelengths and consequently a higher degree of penetration (> 5 mm), thus making them very effective but also expensive and more prone to cause injury. The solid-state lasers have longer wavelengths and lower penetration (< 5 mm) with lower cost and higher safety. A hybrid of these two technologies—Frequency Doubled Double Pulse neodymium (FREDDY)—uses coumarin dye in succession with neodymium:YAG and in studies effectively fragments stones and enables duct clearance in 88–92 % of cases with a complication rate of 7–23 % [34–36]. Holmium:YAG laser has a longer wavelength very close to the peak absorption of water thus minimizing any scatter which makes it theoretically precise and safe by minimizing duct injury. Holmium:YAG laser has been evaluated in studies showing effective bile duct clearance rates of 90–100 % with complication rates of 4–14 % [37–39]. We do not routinely administer antibiotics during lithotripsy unless there is incomplete stone removal.

ESWL is another modality for management of large stones with ductal clearance rates of ~ 80 % [40]. However, the availability of ESWL equipment is limited to few centers as it is expensive. Two randomized trials comparing LL to ESWL demonstrated higher rate of ductal clearance with LL (83–97 % vs 53–73 %) [41, 42]. A randomized trial comparing EHL to ESWL showed comparable rates of ductal clearance (74 vs 79 %) [43]. Given the widespread availability and comparable to superior efficacy of endoscopic lithotripter tools, most if not all large stones can be successfully removed using intraductal lithotripsy, obviating the need to use ESWL in biliary stones. There is however a role for ESWL in managing pancreatic duct stones which are hard and heavily calcified and not easy to fragment unlike biliary stones (Chap. 13).

Case Concluded

At the next ERCP, the stent was removed and the cholangiogram again showed a smooth narrowing in the distal CBD. At this point, given the persistent narrowing of the CBD, the decision was made to use intraductal ultrasound (IDUS) to evaluate the possible stricture. A guidewire was placed into the intrahepatics, and the Olympus 20 MHz over-the-wire ultrasound probe (Fig. 5.7a, b) revealed a long cystic duct which was parallel to the CHD, contained a large stone (Mirizzi's syndrome), and merged into the CBD just a few centimeters above the ampulla (Video 5.1). The stone was visualized with the Spyglass system (Boston Scientific, Marlborough, MA) and fragmented with EHL using the Nortech Autolith ® system (Northgate Technologies Inc., Elgin IL). The cystic duct, CHD, and CBD were swept free of stone fragments. Final cholangiogram showed no residual stricture or stone (Fig. 5.8).

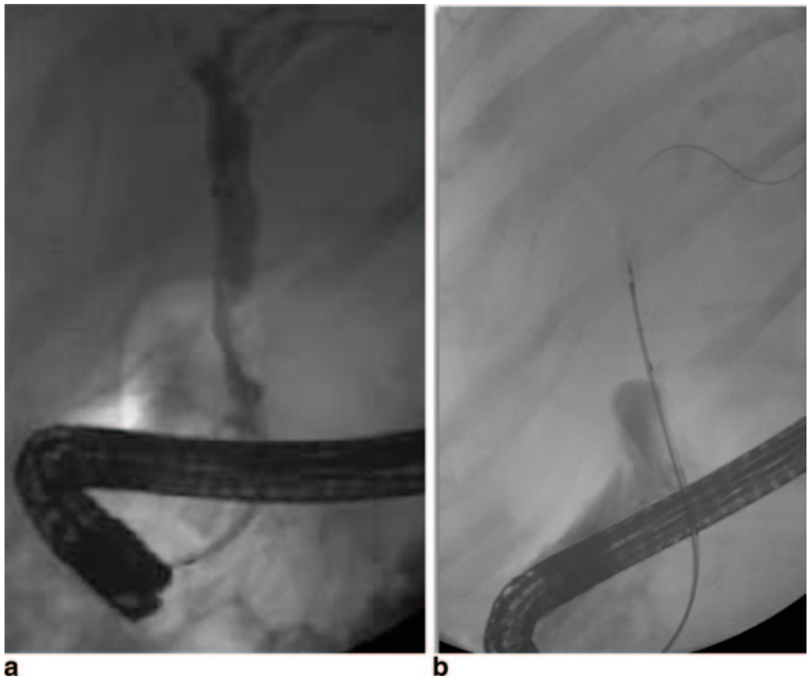

Fig. 5.7 **a**. Third ERCP with persistence of distal narrowing in bile duct. **b**. Over-the-wire 20 MHz ultrasound probe advanced deep into the biliary tree

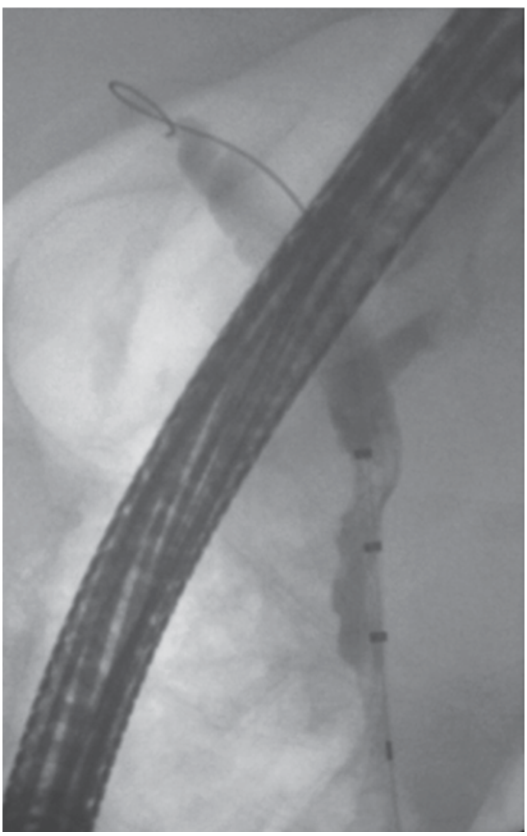

Fig. 5.8 Final cholangiogram with stone fragment removed and distal stricture resolved

Is There a Role for Intraductal Ultrasound (IDUS) in Clearing the Bile Duct?

A mini-ultrasound probe ranging from 12 to 30 MHz over a guidewire can be introduced into the bile duct to evaluate for choledocholithiasis. Several studies have evaluated the role of IDUS in detecting choledocholithiasis missed on cholangiography during ERCP [44, 45]. IDUS is particularly useful for visualizing small stones (<8 mm) in the setting of a dilated bile duct (>12 mm) when such stones may be missed on cholangiogram [46]. Residual choledocholithiasis after EST and basket/balloon extraction was detected by IDUS in 40% of patients [47]. IDUS is also useful for ensuring complete duct clearance after lithotripsy and stone extraction [48, 49]. The clinical significance of detecting these small (usually less than 4 mm) residual CBD stones by IDUS is unclear. Thus, when there is suspicion for CBD stones based on preprocedure imaging that cannot be visualized during a cholangiogram, especially in the setting of a dilated CBD, IDUS can be used to evaluate for small stones. Occasionally in situations as illustrated in the case when there is a linear narrowing of the CBD especially around the cystic duct, an IDUS can be used to exclude Mirrizi's syndrome. We do not use IDUS to ensure complete duct clearance after lithotripsy as any small fragments should pass spontaneously through the wide open papilla.

When Should Biliary Stenting Be Considered?

Biliary stenting provides biliary drainage in situations where there is incomplete duct clearance due to difficult stones as a temporizing measure or as a more definitive solution in patients with limited life span when comorbidities and advanced age preclude aggressive techniques of duct clearance. When used as a temporizing solution in the elderly population prior to definitive endoscopic or surgical therapy, there is a complication rate of 10% compared to greater than 50% when used as a definitive treatment. Approximately one out of 5 patients died of infectious biliary complications when stents were used as definitive therapy, and thus this treatment option should only be used in very select patients with short life expectancy [50]. Temporizing stents have been placed for short duration (2–6 months) in patients with large stones (>2 cm) and multiple stones (>3 stones) to help fragment the stones. A decrease in stone burden by greater than 50% was observed following stent placement for 2–6 months [51, 52]. Single or multiple stents of the straight or pigtail variety may be used. Although most of the experience to date has been with plastic stents, fully covered self-expandable metal stents have also been used successfully in the management of complex biliary stones [53]. Due to the cost and risk of complications associated with metal stents, they cannot be advocated for the management of biliary stones at this time.

When Should Nonendoscopic Modalities Be Considered for Removal of CBD Stones?

Cholecystectomy is recommended for most patients with cholelithiasis after ductal clearance by ERCP given the low morbidity of laparoscopic cholecystectomy [54]. Laparoscopic cholecystectomy should be performed ideally within 2 weeks of ductal clearance by ERCP to minimize the risk of recurrent choledocholithiasis, biliary colic, gallstone pancreatitis, and cholecystitis [55–57]. A randomized clinical trial showed a higher risk of recurrent biliary events with some necessitating emergency surgery when laparoscopic cholecystectomy was delayed (6–8 weeks) compared to early surgery (within 72 h) following EST for CBD stones [58].

An alternative to preoperative ERCP is laparoscopic CBD exploration (LCBDE) for removal of CBD stones following cholecystectomy. It can be considered a one-step operation when IOC demonstrates CBD stones which can be removed in the same setting if technical expertise in this modality is available. Randomized clinical trials comparing LCBDE with ERCP (preoperative or postoperative) for stone removal have shown comparable technical success, morbidity, and mortality [59–62]. It can also be used in cases of prior failed ERCP, lack of local endoscopic expertise, or in the setting of altered anatomy like Roux-en Y reconstruction with long limbs when the success rate for ERCP is low. Given the high success rate of ERCP (unless precluded by altered anatomy), we prefer postoperative ERCP to CBD exploration for stone removal at our institution. Percutaneous removal of extrahepatic duct stones has been described via an indwelling T-tube or percutaneous transhepatic route with success rates of ~90% although with a risk of hemorrhagic complications (hemobilia) and death [63]. This is rarely ever employed to remove extrahepatic duct stones given the length of time it takes for the tract to mature (~4–6 weeks) and the potential hemorrhagic complications and death.

What is the Role of ERCP in Intrahepatic Duct Stones?

Hepatolithiasis or intrahepatic duct stones are more common in East Asia compared to the Western population. These stones are frequently multiple and associated with strictures. Etiologies typically include postoperative biliary strictures, primary sclerosing cholangitis, and recurrent pyogenic cholangitis. They often present with recurrent cholangitis and sepsis. Long-standing hepatolithiasis may lead to secondary biliary cirrhosis, hepatic lobe atrophy, and intrahepatic cholangiocarcinoma. Patients with multiple stones confined to one lobe of the liver are often managed by surgical resection of the involved liver with or without a bilioenteric anastomosis. Greater rates of stone clearance were achieved with hepatectomy (83 %) compared to nonoperative modalities like percutaneous removal (64 %) or ERCP (43 %) [64]. In the same study, during median follow-up of 8 years, a nonsignificant trend of lower recurrence rates and cholangitis were seen with hepatectomy compared with nonoperative management [64].

Endoscopic therapy of hepatolithiasis is difficult due to the recurrent nature of the disease requiring multiple interventions and the presence of multiple stones, concomitant intrahepatic strictures, peripheral stone impactions, and duct angulations [30]. Peroral cholangioscopy with lithotripsy can be used for difficult stones that cannot be extracted using a balloon or basket [32]. The success rate for endoscopic removal of intrahepatic stones (64 %) is lower than for extrahepatic stones [65]. Care should be taken to avoid injection of an atrophied hepatic lobe during ERCP due to the high risk of infectious complications. Percutaneous cholangioscopy with lithotripsy is technically successful in up to 85 % of patients. Both endoscopic and percutaneous treatment carry a high rate of recurrence and/or cholangitis of 22–63 % [66]. Consequently, endoscopic or percutaneous methods of stone removal may be employed in patients with limited stone disease, bilateral liver involvement where surgery is not feasible, and recurrent stones after surgery.

Recurrent or Inoperable Stones

Up to 10 % of patients who have undergone EST and stone extraction will develop recurrent CBD stones, because either the gallbladder was not removed or new stones formed within the CBD in the absence of a gallbladder [67]. In these patients, 57 % had juxtapapillary diverticula, and most of these stones were pigmented stones that do not benefit from ursodiol or antibiotics for preventing recurrence. Other risk factors for recurrent choledocholithiasis include dilated CBD to greater than 15 mm, angulated bile duct, biliary stricture, and papillary stenosis, which all predispose to biliary stasis. A regular schedule of liver function tests or ERCP at defined intervals is indicated. Annual ERCP to clear the bile duct led to decreased rates of cholangitis in a small study of patients with at least two occurrences of choledocholithiasis [68]. Surgical bypass with choledochoduodenostomy for recurrent stones refractory to endoscopic therapy is not routinely recommended due to high morbidity (10–28 %) including cholangitis, sump syndrome, bile leak and up to 5 % mortality [69–72].

In patients who are unable to undergo cholecystectomy due to significant comorbidities, endoscopic transpapillary gallbladder stenting (ETGS) can be considered as an alternative to surgery. A prospective study of this patient population using double pigtail stents for ETGS in symptomatic gallbladder disease was technically successful in 23 of 29 patients (79 %) and provided long-term patency (median stent patency 760 days) without needing scheduled stent exchanges [73]. This is a technically demanding procedure, as negotiating the tortuous cystic duct is difficult and greatly influenced by the endoscopist's experience [74].

Conclusion

The majority of bile duct stones are cholesterol stones in the Western population. Due to the risk of complications including cholangitis, sepsis, and secondary biliary cirrhosis associated with choledocholithiasis, even stones in asymptomatic patients should be extracted if feasible. MRI and EUS have good accuracy in detecting choledocholithiasis, when there is an intermediate probability of harboring a bile duct stone. Most stones smaller than 10 mm can be removed with EST and balloon or basket extraction. Stones between 10 and 15 mm can be retrieved after EST with or without balloon dilation of the papilla and balloon or basket extraction. During stone removal using a basket, it is prudent to have a rescue lithotripter system available due to the risk of stone or basket impaction, which can have significant repercussions if not resolved. Several endoscopic modalities are available for extraction of difficult stones including ESLBD, mechanical lithotripsy, electrohydraulic lithotripsy, and laser lithotripsy. Stones measuring 15–20 mm can be removed with ESLBD or lithotripsy. Stones greater than 20 mm in size generally require lithotripsy. In patients with significant comorbidities that preclude surgical or aggressive endoscopic therapy, biliary stenting with plastic stents can be used as a temporizing solution for biliary drainage. IDUS has a role in the detection of small stones, particularly in a dilated bile duct, where such stones may be missed on cholangiogram. Up to 10 % of patients will have recurrent stones after endoscopic extraction and cholecystectomy, and these patients may benefit from a regular schedule of follow-up liver tests or ERCP at defined intervals.

Key Points

- Suspected choledocholithiasis should be further investigated and once confirmed, stones extracted to minimize the risk of complications. Management is determined by risk stratification for the likelihood of common bile duct (CBD) stones using clinical parameters, liver tests, and imaging.
- Patients with symptomatic cholelithiasis at intermediate risk of choledocholithiasis can undergo (a) preoperative confirmatory imaging (EUS/MRCP) followed by ERCP as indicated or (b) IOC followed by LCBDE or postoperative ERCP if needed, depending on local availability, expertise, patient characteristics, and preference.
- Uncomplicated stones can be successfully extracted with a balloon or basket after endoscopic sphincterotomy. Large stones (15–20 mm) can be removed with ESLBD or lithotripsy (ML/EHL/LL). Stones >20 mm generally require lithotripsy.
- Because stone or basket impaction is a potential complication with significant repercussions if not resolved, it is prudent to have a rescue lithotripter system available when performing stone extraction with a basket.
- IDUS is particularly useful for visualizing small stones (<8 mm) within a dilated bile duct (>12 mm) when such stones may be missed on cholangiogram.
- Biliary stenting acts as a temporizing measure in cases of incomplete stone extraction or severe acute cholangitis. Occasionally, it can provide a definitive solution in patients with limited life span when comorbidities and advanced age preclude aggressive techniques of duct clearance.
- LCBDE offers an alternative to ERCP when local expertise is available in cases where (a) IOC shows choledocholithiasis, (b) prior ERCP has failed or (c) Roux-en Y reconstructions with long limbs make the success rate for ERCP low.
- Hepatectomy should be considered for hepatolithiasis in surgically fit patients with heavy unilateral intrahepatic stone burden, especially with concomitant biliary strictures and/or lobar atrophy. Percutaneous or endoscopic therapy can be offered in select situations, but carries a higher risk of recurrence, incomplete stone removal, and cholangitis.
- In patients with recurrent choledocholithiasis, a regular schedule of liver function tests with ERCP at defined intervals is preferable to surgical bypass (choledochoduodenostomy) given the relatively high morbidity and mortality associated with the latter.

Video Caption

Video 5.1 ERCP with electrohydraulic lithotripsy and balloon extraction of stone fragments from the common hepatic duct, CBD, and cystic duct

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