



Choledocholithiasis—a new clinical pathway

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Abstract: The incidence of cholecystectomy in children has increased considerably since the early 1990s. Management of gallbladder disease in children must include an awareness of choledocholithiasis treatment strategies. Both endoscopic retrograde cholangiopancreatography (ERCP) and common bile duct exploration (open or laparoscopic) are accepted management techniques for choledocholithiasis. Laparoscopic cholecystectomy with preoperative or postoperative ERCP is at least a two-procedure process while cholecystectomy with laparoscopic common bile duct exploration (LCBDE) can provide definitive treatment in a single procedure under one anesthetic. Despite this, the trend over the last decade continues towards less LCBDE utilization in favor of ERCP. This trend has resulted in decreased familiarity with LCBDE by adult and pediatric surgeons and their trainees. Access to the necessary tools and education on the technical aspects can allow for successful single-stage treatment of choledocholithiasis by surgeons during laparoscopic cholecystectomy. This may include a pre-defined stepwise algorithm and understanding of all the equipment and resources necessary to perform a LCBDE. Ultimately, increased understanding of the equipment and procedural steps necessary for LCBDE will result in widened adoption of the technique and thus confer advantages to the patient such as decreased length of stay and fewer required anesthetics.

Keywords: Choledocholithiasis; laparoscopy; cholecystectomy; common bile duct (CBD)

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Introduction

The incidence of cholecystectomy in the pediatric population has increased considerably since the early 1990s. This is likely due to increased recognition of gallbladder pathology from widespread use of ultrasonography, a change in physician perception of the disease, and a rise in pediatric obesity (1-3). Comprehensive management of gallbladder disease in children and adolescents must include an awareness of choledocholithiasis treatment strategies. Both endoscopic retrograde cholangiopancreatography (ERCP) and common bile duct (CBD) exploration (open or laparoscopic) are accepted management techniques for choledocholithiasis (4-7). Laparoscopic cholecystectomy (LC) with preoperative or postoperative ERCP is at least a two-procedure process

while cholecystectomy with laparoscopic common bile duct exploration (LCBDE) can provide definitive treatment in a single procedure under one anesthetic.

The American Society for Gastrointestinal Endoscopy (ASGE) guidelines advocate for limiting the use of ERCP in suspected choledocholithiasis to only those who are at high risk for CBD stones (8). However, the ASGE criteria (including laboratory values and CBD stone visualization on right upper quadrant (RUQ) ultrasound) has proven unreliable in identifying the patients with CBD stones at time of intervention (9). Thus, if CBD stones are not found to be present during intervention, many patients will have been unnecessarily exposed to the procedural risks associated with ERCP, such as anesthetic harms and pancreatitis (10). Further, the incidence of retained or

newly passed CBD stones diagnosed on intraoperative cholangiogram (IOC) during LC after preoperative ERCP is as high as 13% (11). If these newly discovered stones cannot be extracted, then a third procedure with repeat ERCP may be indicated and add increased cost, length of stay (LOS), and anesthetic risk to the patient. As such, there is a clear need for a surgical option that eliminates the need for additional procedures. Randomized control trials comparing ERCP and LC to LCBDE and LC have shown that LCBDE and LC have equal efficacy and safety profiles with an associated decrease in hospital LOS and costs (12-21). Despite this, the trend over the last decade continues towards less LCBDE utilization in favor of ERCP (12). This trend has resulted in decreased familiarity with LCBDE by adult and pediatric surgeons and their trainees. Access to the necessary tools and education on the technical aspects can allow for successful single-stage treatment of choledocholithiasis by surgeons during LC.

LCBDE in children

While management of choledocholithiasis in children with ERCP has been shown to be safe and effective, LCBDEs have also been described (5-7,22). A few studies have specifically compared these two modalities in the typical pediatric surgery population. A study of LC + LCBDE compared to LC + ERCP in 42 children over a one-year period revealed similar operative time for both cohorts with longer LOS (15.7 *vs.* 6.6 days, $P=0.02$) and hospital cost (\$18,132 *vs.* \$12,735, $P<0.01$) in those who underwent cholecystectomy with ERCP. There was also no significant difference in morbidity (17). A recent study from the University of Michigan reviewed the management of 81 children with suspected choledocholithiasis. It was found that those patients who underwent primary LC first rather than primary ERCP had decreased LOS. Only a third of patients who first underwent primary cholecystectomy had positive IOC necessitating further intervention (23). Several other studies describe LCBDE in children. However, data is limited compared to the adult population (6,17,24).

Indications for LCBDE

LCBDE is indicated in clinical scenarios in which CBD stones are suspected from preoperative imaging [magnetic resonance cholangiopancreatography (MRCP), ultrasound or CT] or elevated liver function tests (LFTs) and are subsequently confirmed on intraoperative imaging

(IOC or ultrasound) (4,25). LCBDE may be particularly advantageous in situations in which ERCP is not easily feasible, such as in patients that have previously had enteric bypasses that prevent endoscopic intervention.

In some instances, sphincter spasm and/or sludge can masquerade as a distal obstruction without a discernible filling defect on IOC. The possibility that the obstruction is more functional than mechanical makes LCBDE preferable due to increased likelihood of clearing the duct with intravenous glucagon administration, duct flushing, or dilation of the sphincter with a balloon. This avoids the ERCP and possible sphincterotomy that would follow. This notion of sphincter spasm at the time of IOC from a functional obstruction that leads to further endoscopic intervention is noteworthy, especially for pediatric providers that place extra emphasis on limiting additional anesthesia events and radiation exposure from fluoroscopy (26). In a previously described cohort of 48 children with suspected choledocholithiasis, ten of 14 had negative findings on preoperative ERCP and twenty-eight of the 34 who had a cholecystectomy first had a negative IOC (22). This discrepancy may be attributed to this spasm/sludge phenomenon causing sphincter spasm or the spontaneous passage of obstructing stones.

Consideration for radiation exposure

Exposure to radiation with fluoroscopy occurs in both ERCP and LCBDE. Due to the perceived cancer risks associated with medical radiation exposure, special consideration should be given to the use of fluoroscopy in pediatric patients. Children are both more sensitive to the ionizing effect and typically have a longer life span over which they can develop malignancies (27-30). Determining the dose associated with a specific procedure relies on several different factors including exposure settings, length of procedure, age and weight of the patient and scaling factors (28). Often, fluoroscopy time is the chief metric reported. Yet, it is an indirect measure of radiation dose and as such is a poor indicator of exposure (29). Despite the inability to quantify the absorbed dose, surgeons should always utilize dose minimization techniques. Specifically for LCBDE, this principle includes operating the C-arm at the lowest dose setting that still allow for sufficient images, use of spot films with small adjustments rather than continuous fluoroscopy, minimizing the distance between the patient and the detector, and utilizing digital zoom rather than electronic magnification if needed. The use of

lead shielding of the patient's pelvis is also essential and should be part of the nursing portion of the checklist (31,32). Ideally, this protective lead apron would be positioned prior to draping the patient to minimize additional time and disruption to workflow. In comparing the techniques employed for LCBDE, the use of baskets to retrieve stones is likely the most fluoroscopic intensive maneuver as it requires frequent feedback for stone capture. When using any of the available LCBDE techniques, it is important to note that efficiency will decrease fluoroscopy time. One tactic to improve overall operative efficiency is employing a stepwise algorithm. Completing a LCBDE in a defined standardized fashion can improve workflow for the entire operative team (*Figure 1*). As with any surgical technique, increased experience leads to improved performance and efficiency which will in turn minimize radiation exposure.

Obstacles to adoption of LCBDE

The declining use of LCBDE arises from multiple factors including a paucity of surgical LCBDE training, lack of necessary tools, and the convenience of widely available ERCP (12,20,33). One of the most important factors in increasing adoption is to increase the simplicity of the intervention and minimizing any friction in the process—especially intraoperatively. This efficiency involves a logical, stepwise approach that facilitates the next steps (i.e., being able to perform basket retrieval through same catheter or access platform that the cholangiogram is injected through) and gives preference to employing the easiest methods/cheapest tools early over more expensive supplies and less readily available equipment. This efficiency also involves creating a central location or cart in the operating room complex to store all of the supplies. Making LCBDE easy and “pain free” to perform will ultimately lower the threshold to intervene and drive adoption among surgeons. The lower the threshold, the more attempts surgeons will make and the more experience a surgeon will gain. The end result is increased success with LCBDE and better outcomes for patients (34,35). To this end, training models have been created and validated which can accelerate skill acquisition and result in cost savings (36-40).

Skills necessary to perform LCBDE

In order to perform a LCBDE, a surgeon must:

- (I) Have access to all the necessary tools and equipment and an understanding of how to use

them;

- (II) Be able to adeptly use laparoscopic instruments and guidewires;
- (III) Perform an IOC and interpret the produced fluoroscopic image;
- (IV) Understand and be able to perform some or all of the different methods of stone clearance:
 - (i) “Power flushing” of the CBD;
 - (ii) Fluoroscopic Nitinol Basket deployment and stone retrieval;
 - (iii) “Crush and Flush” of stones using the Nitinol Basket;
 - (iv) Balloon dilation of sphincter with flushing;
 - (v) Choledochoscopy for Nitinol Basket or Laser lithotripsy deployment;
 - (vi) Endobiliary stent placement.

If LCBDE is not technically feasible, alternative options such as open CBD exploration or ERCP may be utilized. *Figure 2* displays these interventions on a continuum from easiest to most difficult to perform by the surgeon in the operating room.

Technique for performing LCBDE

Successful completion of LCBDEs requires coordination between the surgical team, operating room staff and fluoroscopy. The first step in LCBDE is ensuring the operating room is able to accommodate a C-arm for fluoroscopy and confirming that the operating room staff will have all the necessary supplies. A complete list of these supplies can be found in *Table 1*. Optimal set up also includes the capability of displaying the fluoroscopy images on the operating room screens and orienting the equipment and monitors (even a serial connection to one of the overhead monitors) to maximize the ergonomics of surgeon and intervention (*Figure 3*) (41,42). This is a seemingly minor point, but efficiency and success are predicated on creating the most favorable working conditions possible. Additionally, consideration must be given to where the second laparoscopic tower would be located for choledochoscopy, if required.

After the critical view of safety has been obtained, proceeding with CBD exploration requires transabdominal placement of 12-gauge angiocath or other style of introducer to accommodate the cholangiogram catheter (*Figure 4*). Alternatively, if an additional port is placed, laparoscopic cholangiogram forceps can be used to both introduce the cholangiogram catheter and secure it in place. An additional 5th port may also be particularly

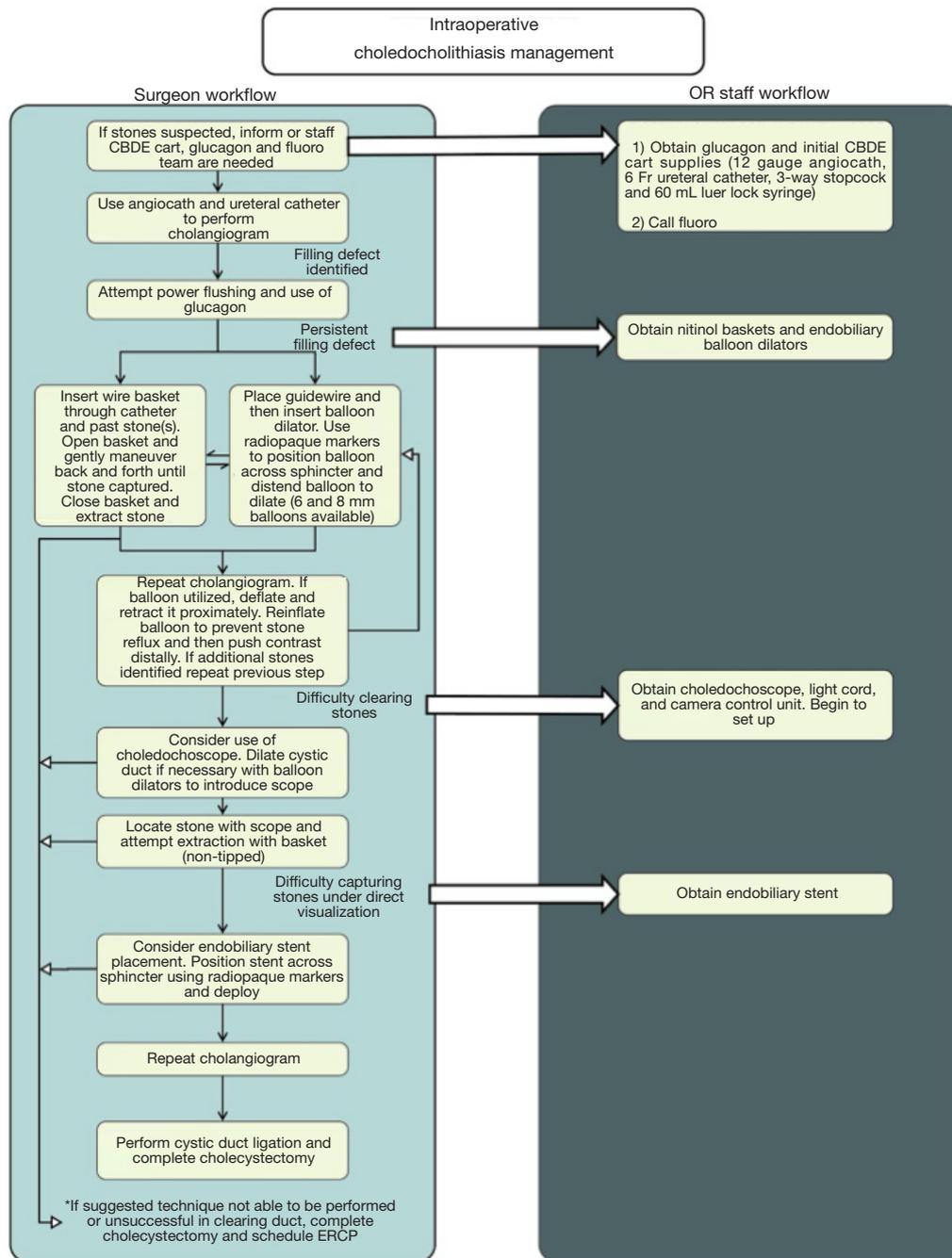


Figure 1 Intraoperative choledocholithiasis management flowsheet. A systematic stepwise algorithm for increased efficiency in the operating room. ERCP, endoscopic retrograde cholangiopancreatography.

advantageous because strategic positioning of the port will allow for a more favorable angle of insertion and direct instrumentation of the ductotomy. The trocar can guide tools such as the choledochoscope into the cystic duct with minimal to no manipulation.

A ductotomy is then made in the cystic duct with laparoscopic scissors. A transcholedochal approach can also be used, but requires intracorporeal suturing of the CBD for closure of the ductotomy. In contrast, the cystic duct stump can be closed with clips or an endoloop. Therefore, the transcystic

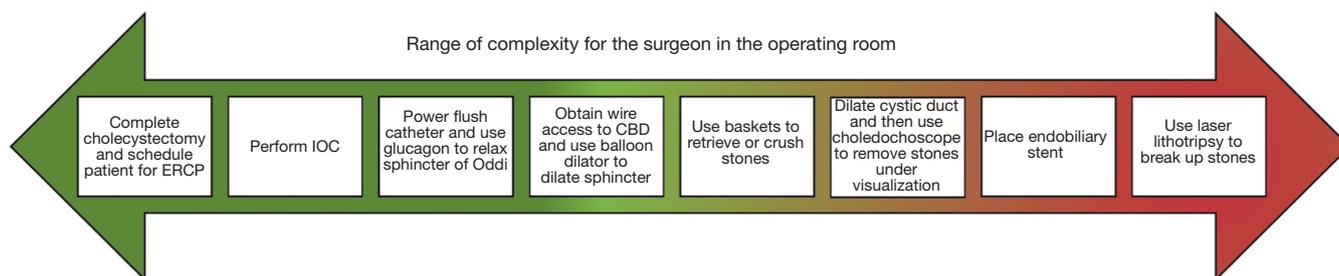


Figure 2 LCBDE complexity progression. Interventions on continuum from easiest to most difficult to perform by the surgeon in the operating room. ERCP, endoscopic retrograde cholangiopancreatography; IOC, intraoperative cholangiogram; CBD, common bile duct; LCBDE, laparoscopic common bile duct exploration.

approach may be technically less difficult to perform in comparison to the transcholedochal approach (43-45).

After the cholangiogram catheter is positioned into the duct, it must be secured in place by a clip. Specifically, use of a 6–8-Fr open-ended ureteral catheter to perform the cholangiogram rather than a 5-Fr angiogram catheter prevents occlusion with manipulation or securing clips (*Figure 5*). The ureteral/angiogram catheter should be connected to a setup that allows for flushing of contrast and saline to perform an IOC. The setup depicted in *Figure 6* using a Tuohy-Borst connector, extension tubing with a 3-way stopcock and attached syringes containing both a 50/50 saline-contrast mix and saline allows for the IOC to be performed in addition to flushing and threading of a 0.035" guidewire through one system. It should be noted that backing the ureteral catheter out of the aperture on the back end of Tuohy-Borst connector is necessary to successfully thread the wire in this setup (*Figure 7*). These small alterations in the setup will contribute significantly to procedural efficiency.

If a filling defect is then noted on the IOC (*Figure 8*), 1–2 mg of glucagon can be intravenously administered (46-52). Note that the single milligram of glucagon is just as effective as 2 mg (47). Flushing can be performed after a few minutes once the glucagon has taken effect in an attempt to clear the duct. If a filling defect persists, the surgeon has several options outlined below:

Basket extraction

A wire basket can be threaded down the cholangiogram catheter in an attempt to capture stones under the fluoroscopic guidance (4,53-55). Examples of these baskets in our described setup are depicted in *Figure 9*. Captured stones may be removed in whole from the duct or the

surgeon may employ the technique of “crush and flush”. Often, the captured stones are relatively soft and can be intentionally or unintentionally crushed or “sliced through” during basket closure. If the calculi are able to sufficiently break into smaller pieces, they then can be flushed through the sphincter of Oddi and into the duodenum. Very careful attention to completion cholangiogram is needed to confirm the fragmented stones were able to be cleared. These baskets can be used not only under fluoroscopic guidance, but also under direct visualization with use of the choledochoscope. The baskets can be passed through the working channel of the choledochoscope.

Balloon dilation

Balloon catheters are used to both dilate the cystic duct to allow entry with choledochoscope and/or enlarge the sphincter of Oddi to allow for stone passage (*Figure 10A,B*) (56-59). These balloon dilators are advanced over a wire. As such, the first step to employing this technique is placement of a guidewire into the CBD through the cholangiogram catheter. It is necessary to use fluoroscopy to ensure the floppy-tipped wire is in the duodenum. This helps to prevent mispositioning of the catheter and loss of wire access in the duct when manipulating the balloon catheter. Selection of the balloon should take into account the diameter of the CBD. In general, it is safe to dilate the sphincter up to the diameter of the CBD (e.g., 6–10 mm). Other practical issues of proper balloon selection include overall length (75 cm is a standard working length for a non-compliant balloon catheter that works best) and the length of the actual balloon (40, 80, 100 mm are common lengths). The 40-mm balloon length offers the most versatility when working within the confines of the duodenum and

Table 1 Complete list of supplies needed to perform a LBCDE

Equipment necessary to complete LCBDE	Details
Intraoperative cholangiogram	
Fluoroscopy	–
12-Fr Angiocath	–
6–8-Fr open ended ureteral catheter	–
Tuohy Borst Connector	–
60-mL Luer Lock Syringes	One containing saline and one with 50/50 saline-contrast mix
3-way stopcock	–
Extension Tubing	–
Glucagon, 1 to 2 mg	Given intravenously by anesthesia provider to relax sphincter of Oddi
Clips or Olsen-Reddick Clamp	To secure ureteral catheter at ductotomy
Stone capture with Nitinol Baskets	
Fluoroscopy and IOC setup	–
Stone retrieval baskets	Tipped baskets are more easily visualized on fluoroscopy but can damage the choledochoscope
Balloon dilation of sphincter of Oddi	
0.035" floppy-tipped guidewire ×150 cm	Balloons are advanced into CBD via Seldinger technique
Balloon dilators	6 or 8 Fr ×75 cm; 40, 80 and 100 mm are common lengths of the balloons
Rotational inflation device	–
Choledochoscopy	
Flexible choledochoscope	With a working channel in order to introduce stone retrieval baskets
0.035" floppy-tipped guidewire ×150 cm	The scope can be advanced into CBD via Seldinger technique
Second video monitor tower with a light source	Allows for simultaneous endoscopic and laparoscopic views during choledochoscopy
Pressurized bag of saline with tubing	To allow for visualization during choledochoscopy in the same fashion as cystoscopy
Atraumatic laparoscopic grasper	For intra-abdominal manipulation of the choledochoscope
Nitinol stone retrieval baskets	Advanced through the working channel
Balloon dilators	Used to dilate cystic duct if necessary to accommodate scope
Additional optional equipment	
Laser lithotripter	To fragment stones
Endobiliary stent	May be placed over wire across sphincter of Oddi if obstruction not relieved by other measures. ERCP then would be need to be scheduled postoperatively
Laparoscopic ligating loop	To close cystic duct after manipulation/exploration

LCBDE, laparoscopic common bile duct exploration; CBD, common bile duct; ERCP, endoscopic retrograde cholangiopancreatography; IOC, intraoperative cholangiogram.

navigating the cystic-common duct junction.

When positioning the balloon for sphincter dilation, it is helpful to advance it until the entirety of the balloon is in the duodenum and then inflate to the manufacturer's

specifications using a rotational inflation device (the inflation pressure to achieve the defined balloon profile diameter is found on the balloon packaging). When pulling back gently, the balloon will hub against the sphincter and



Figure 3 Optimizing efficiency in the operating room when performing LCBDE. Operating room set up during LCBDE that maximizes ergonomics with fluoroscopy images displayed on OR screens. LCBDE, laparoscopic common bile duct exploration; OR, operating room.

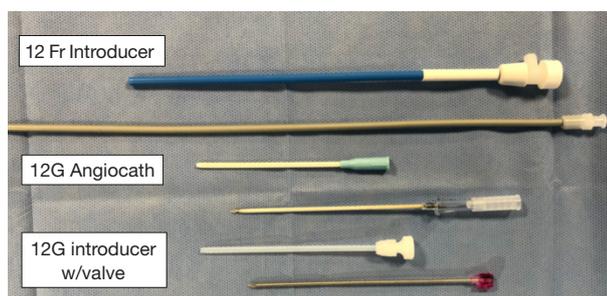


Figure 4 Examples of various introducers that can be utilized during LCBDE. LCBDE, laparoscopic common bile duct exploration.

allow for better visual and tactile feedback regarding its position. Also during fluoroscopy, either markers on the dilator or use of a 50/50 contrast/saline mix for balloon inflation can assist with positioning. Once hubbed against the sphincter, the balloon should be deflated slightly and then retracted so that it straddles the sphincter. After appropriate positioning, the balloon may be blown back up to full inflation pressure and held there for 3–5 minutes.

Following the dilation of the sphincter, the balloon is deflated and pulled back so that it now straddles the cystic duct-CBD junction. The retracted balloon is then reinflated to seal the CBD. The wire is removed so that a cholangiogram can be performed through the same wire lumen. Sealing the CBD with the balloon allows for a more pressurized system through which to flush debris and stones forward and will prevent unintended flushing of

stones proximally into the hepatic ducts. This technique is depicted in a stepwise fashion in *Figure 11*.

Choledochoscopy

Choledochoscopy allows for direct visualization of stones while attempting removal (4,53,60,61). The choledochoscope can be advanced into the CBD either over a wire by Seldinger technique or by direct instrumentation through the ductotomy. Introduction of the choledochoscope into the cystic duct may require dilation of the duct with a balloon dilator. As a general rule, avoid dilating the cystic duct or sphincter more than the diameter of the CBD (52,62). If the choledochoscope requires intra-abdominal manipulation, an atraumatic laparoscopic grasper must be used to ensure the scope is not damaged. Use of a choledochoscope requires a second video monitor system so that both the endoscopic and laparoscopic views can be seen simultaneously. A pressurized bag of saline must also be connected to the choledochoscope to allow for visualization in the same fashion as genitourinary (GU) irrigation for cystoscopy. After the stones have been located with the scope, baskets are advanced through its working channel to permit attempted stone removal under direct visualization. Once again, a completion cholangiogram should be performed to ensure stone clearance.

Endobiliary stent placement

If wire access can be obtained into the duodenum but all other stone clearance techniques have failed or are only partially successful, then placement of an endobiliary stent versus completing the cholecystectomy and post-operative ERCP should be considered. Management of CBD stones with endobiliary stents has been shown to be safe and effective (63–65). Similar to the balloon dilators, these endobiliary stents can be passed over a wire and advanced into place by identifying the associated markers on fluoroscopy. The markers should be positioned on either side of the sphincter and will allow for drainage of the ductal system as a temporizing measure. The patient will still require ERCP with sphincterotomy and removal of the stent, but with appropriate drainage of the biliary system, this can be performed on an outpatient basis if necessary. Placement of a stent during LCBDE can also aid the endoscopist during postoperative ERCP, especially in pediatric patients with a diminutive papilla that may be hard to identify and cannulate from the intestinal lumen.

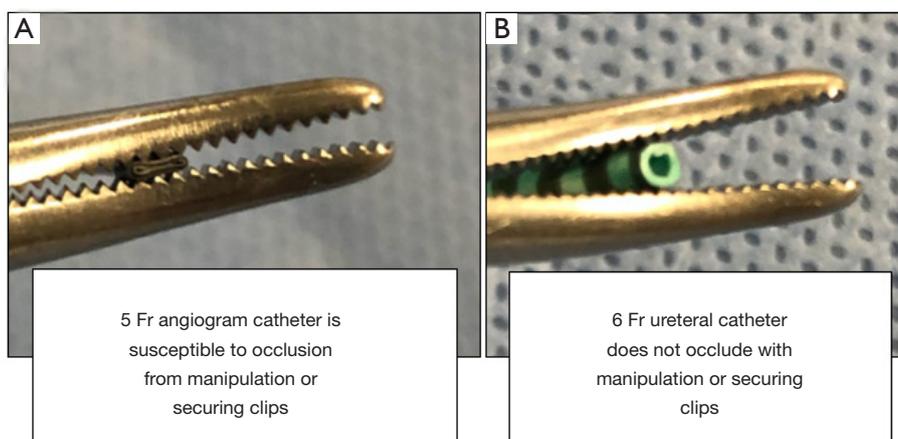


Figure 5 Angiogram catheters are susceptible to occlusion with manipulation or use of clips when performing an intraoperative cholangiogram. By contrast, a ureteral catheter does not occlude with manipulation or securing clips, thus allowing for free flow of contrast and saline. This will also allow for various other interventions to be utilized through the ureteral catheter such as the threading of a wire or use of a basket.

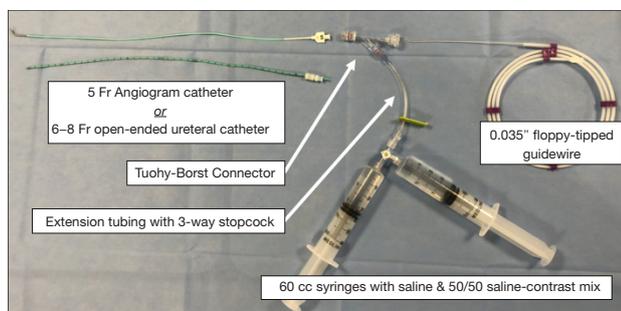


Figure 6 Initial setup for performing an intraoperative cholangiogram. Use of a Tuohy-Borst connector, extension tubing with a 3-way stopcock and syringes with saline and 50/50 saline-contrast mix along with either a 5-Fr angiogram catheter or 6-8-Fr open-ended ureteral catheter allows for flushing and subsequent threading of a guidewire without any alteration in setup or additional steps.

Laser lithotripsy

An additional adjunct to the use of the choledochoscope is laser lithotripsy (43,66). Once stones are identified under direct visualization, the laser is passed through the working channel of the scope and is used to fragment the calculi. After the stones have been broken up, the pieces are removed either by flushing into the duodenum or with nitinol basket retrieval. In most hospitals, special credentialing for the use of lasers is required. Partnering with Urology colleagues may be advantageous. Most laser

wires are designed to fit in the working channel of small cystoscopes and choledochoscopes.

Tips, tricks and troubleshooting potential problems

Mastery of any surgical technique requires instruction and repetition. When beginning to perform LCBDEs, inexperience with the described techniques can generate frustrations. Listed below are “tips and tricks” to help circumvent anticipated difficulties:

- (I) Performing an IOC with a catheter large enough to accommodate wires, balloons, and baskets allows the surgeon to immediately take the next step after a filling defect is noted. Success with LCBDE first starts with reducing the threshold for taking the next step. This is the rationale for using ureteral catheters as the IOC catheter at the outset.
- (II) When using wires, close approximation of an introducer to the ductotomy (or even entering into the cystic duct) will allow for the wire to be advanced and manipulated without inducing undue tension in the wire causing a “spring back effect” and losing wire access into the CBD. Losing wire access to the CBD is a frustrating occurrence that can be mitigated by this simple maneuver. Avoiding simple problems that add to the overall time of the procedure and surgeon frustration level will aid adoption and success rate of LCBDE.

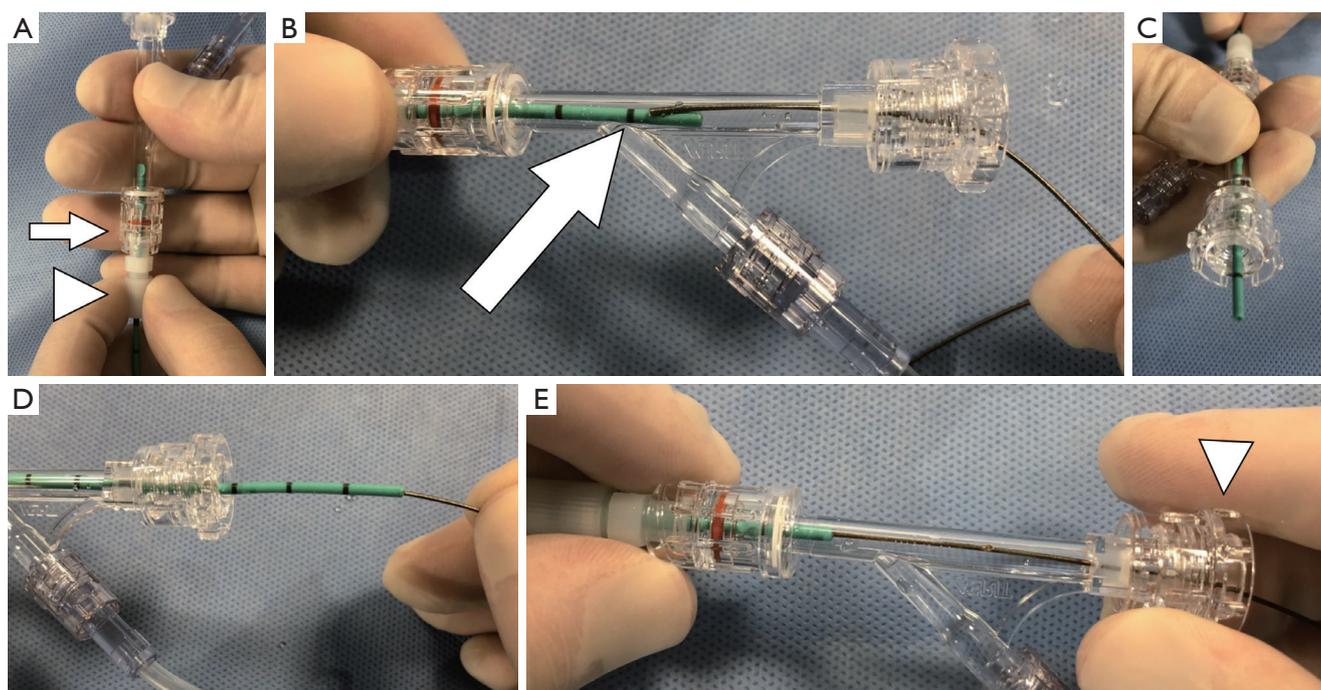


Figure 7 Wire management through the Tuohy-Borst connector. After ureteral catheter is secured to the Tuohy-Borst connector (A), if the wire is attempted to be advanced inside the connector (B), it will be difficult to direct the wire into the lumen of the catheter. In order to successfully tread a 0.035" floppy tipped guidewire into the catheter through the Tuohy-Borst connector, the catheter should be backed out through the distal port (C). This allows for easy advancement of the wire (D) and once this has been accomplished, the catheter can be re-secured in its prior position (E).

- (III) Tortuous cystic ducts can be more readily accessed with a hydrophilic guidewire that is delivered into the ductotomy with the ureteral catheter (*Figure 8*).
- (IV) Using the Touhy-Borst system allows for flushing of the catheter and removal of all the air in the system after the wire is removed. This will prevent air bubbles from entering the CBD system that may be confused for filling defects.
- (V) After successful flushing or retrieval of stones, the vigilance for retained stones should be heightened as they can be missed on completion IOC if they are pushed into hepatic duct during repeated flushing. In order to not miss these calculi, special attention should be given to the proximal portion of the ductal system during the final cholangiogram.
- (VI) When performing a transcystic LCBDE, use of an endoloop on the cystic duct stump should be considered when completing the cholecystectomy if the duct cannot be cleared.
- (VII) If numerous stones are encountered as seen in

- Figure 12* or several unsuccessful attempts have been made, it may be best to abandon LCBDE and perform completion cholecystectomy with postoperative ERCP. The corollary to this statement is that some debris can likely be left behind with little untoward effect if the main obstruction or large stone is diminished or significantly broken up. In this scenario, close follow up is a reasonable option in favor of a reflexive call for postoperative ERCP because the natural history of smaller stones is to spontaneously pass with little complication or downside (22,26,67).
- (VIII) Use intermittent low volume installation of contrast solution into the CBD during nitinol basket retrieval attempts. The benefit is an accentuation of the stone as a filling defect that can be otherwise hard to see—especially if the contrast media from earlier cholangiogram runs has been diluted by repeated flushing attempts with saline.
- (IX) Take a stepwise approach and do the quick maneuvers first. With an array of strategies and

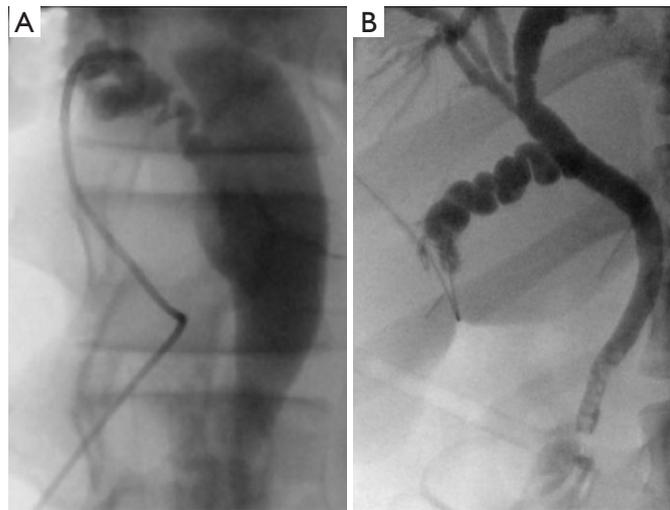


Figure 8 Intraoperative cholangiograms using ureteral stents. LCBDE was not technically possible in these two cases because of the very tortuous cystic ducts. There are distal CBD filling defects. The use of hydrophilic guidewires can often help navigate difficult cystic duct anatomy. LCBDE, laparoscopic common bile duct exploration; CBD, common bile duct.

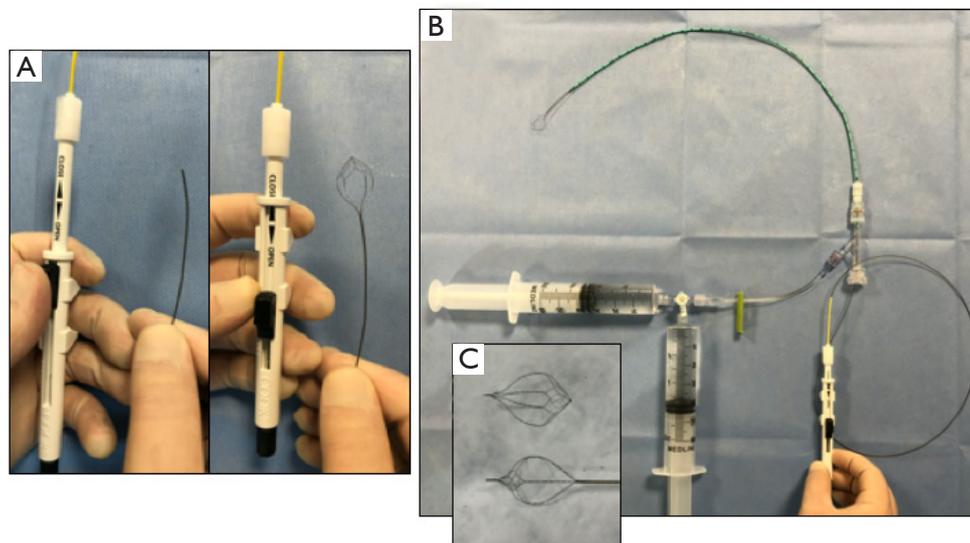


Figure 9 Example of nitinol baskets. Advancing and retracting the switch on the basket handpiece opens and closes the baskets distally (A). If the setup in *Figure 6* is utilized, the baskets can be threaded through the Tuohy-Borst connector immediately after filling defect is noted on intraoperative cholangiogram without any additional alterations to the setup (B). Nitinol baskets are available as tipped or non-tipped. The tipped baskets are more easily visualized with fluoroscopy but will damage choledochoscopes and are more prone to duct mucosal injury (C).

tools for LCBDE at the surgeon's disposal, the temptation may be to instrument the CBD at the first indication that contrast isn't passing through the sphincter of Oddi. Utilizing the larger 5–6-Fr catheters, the surgeon can apply much

more force and deliver a large stream of contrast that may succeed in breaking a spasm after the administration of glucagon. Sometimes the simplest moves are the most effective because not all that inhibits flushing is a stone.

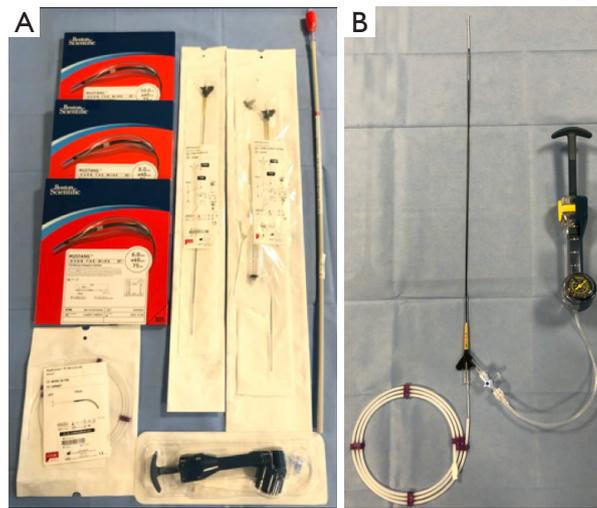


Figure 10 Balloon dilation in LCBDE. (A) LCBDE supplies needed for sphincter dilation including balloon dilators, a rotation inflation device and a 0.035" guidewire. (B) Setup for use of balloon dilator including a rotational inflation device and a guidewire. Prior to advancement of the balloon dilator over the wire, it is necessary to ensure the floppy-tipped wire is in the duodenum by use of fluoroscopy. The balloon dilator should be inflated to the manufacturer's specification noted on the balloon packaging. LCBDE, laparoscopic common bile duct exploration.

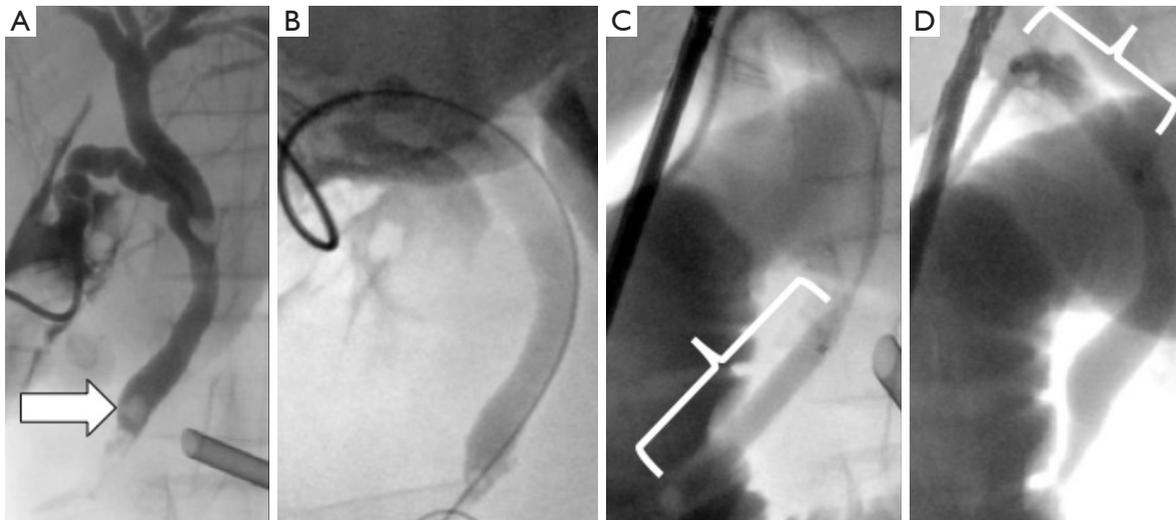


Figure 11 Fluoroscopic images depicting balloon dilator use. (A) Filling defect is noted in the distal CBD without the passage of contrast into the duodenum. (B) A floppy-tipped wire is advanced past the stone into the duodenum. (C) A balloon dilator is advanced over the wire by Seldinger technique and is pictured straddling the sphincter of Oddi. The markers on the proximal and distal ends of the balloon can be seen with fluoroscopy. After properly positioned, the balloon is inflated per the manufacturer's specifications and is held there for 3–5 minutes. (D) For completion cholangiogram, the balloon is then deflated and retracted proximally within the CBD. The balloon is then reinflated to seal the CBD. This allows for a cholangiogram to be performed through the balloon and prevents debris from being flushed proximally into the hepatic ducts. CBD, common bile duct.

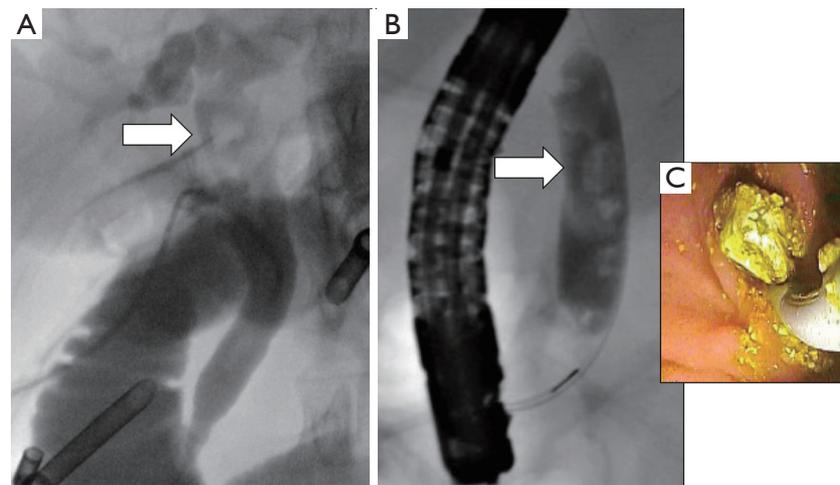


Figure 12 Considerations for abandoning LCBDE. (A) Stones found in proximal CBD that are difficult to access with the described techniques. (B) Numerous filling defects which will complicate successful clearance by LCBDE. (C) Intraluminal view of stone extraction during ERCP. LCBDE, laparoscopic common bile duct exploration; CBD, common bile duct; ERCP, endoscopic retrograde cholangiopancreatography.

Postoperative management of patients

The success rate of complete CBD stone clearance with LCBDE ranges from 74% to 97% (16,19,68). As such, the surgeon must be aware that a clean-appearing cholangiogram may be misleading and fail to reveal retained stones that require further intervention. Often, these stones are inadvertently flushed proximally into the right and left hepatic ducts and are not detected on final cholangiogram and no concerns arise until elevation in routine postoperative LFTs are noted. Yet, even these LFTs can be misleading as down trending LFTs only carry a 49% accuracy in predicting stone passage (9). One study specifically evaluating the usefulness of postoperative LFTs in predicting retained calculi status post LCBDE found no difference in laboratory trends in those who had successful LCBDE and those who had persistent choledocholithiasis. 75% of the patients who had persistent choledocholithiasis had improved LFTs while many with duct clearance had worsening LFTs postoperatively (69). Ultimately, trending labs in the postoperative period is likely unreliable. Patients should be advanced back to a regular diet and activity as would be typical of a standard postoperative LC patient.

Conclusions

Successful completion of LCBDE not only requires surgical skill but also coordination between the surgeon, operating

room staff and fluoroscopy. Thoughtful organization and systematization of the procedure will allow for improved efficiency and success. This includes a pre-defined stepwise algorithm and an understanding of all the equipment and resources necessary to perform a LCBDE. Some of the described techniques include completion and interpretation of an IOC, power flushing of the CBD, fluoroscopic nitinol basket deployment and stone retrieval, “crush and flush” of stones using the nitinol basket, balloon dilation of the sphincter of Oddi with subsequent flushing, use of choledochoscopy for nitinol basket or laser lithotripsy deployment, and endobiliary stent placement. Ultimately, increased understanding of the equipment and procedural steps necessary for LCBDE will result in widened adoption of the technique and thus better outcomes for patients.

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Footnote

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