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A Review of the Techniques, Current Status and Learning Curves of Laparoscopic Bile Duct Exploration

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Laparoscopic cholecystectomy is of one the most common general surgical operations performed today. Concomitant choledocholithiasis occurs in roughly 10-20% of patients with symptomatic gallstones. Laparoscopic bile duct exploration (LBDE) offers a single-stage minimally-invasive solution to the management of choledocholithiasis. LBDE may be performed either via the transcystic route or via laparoscopic choledochotomy. A number of strategies to improve success are available to the surgeon to help in the problem of complicated choledocholithiasis, these range from simple maneuvers to the use of laser or mechanical lithotriptors. With the advances in laparoscopic surgery, it is also possible to handle complex surgical conditions such as Mirizzi syndrome or recurrent pyogenic cholangitis laparoscopically, even though these have yet to be accepted as standard of care. Following laparoscopic choledochotomy, options for closure include: primary closure, closure over a T-tube, and closure over an endobiliary stent. T-tube placement has been associated with increased operating time and hospital length of stay compared to primary closure, with no significant differences in morbidity. Based on the available literature, LBDE appears comparable to ERCP with regards to procedural efficacy and morbidity. LBDE remains relevant to the general surgeon and is best viewed as being complementary to endoscopic therapy in the management of choledocholithiasis.

Key Words: Laparoscopic bile duct exploration, Transcystic, Choledochotomy, Choledocholithiasis

INTRODUCTION

Laparoscopic cholecystectomy is one of the most common general surgical operations performed today. Of those undergoing laparoscopic cholecystectomy, concomitant choledocholithiasis occurs in roughly 10-20% of patients with symptomatic gallstones.[1] Various strategies are available to manage the patient with choledocholithiasis and an intact gallbladder.[2] Open common bile duct exploration remains the gold standard for duct clearance, but several minimally-invasive options in various single- or two-stage configurations exist, depending on local expertise and experience with laparoscopic or endoscopic techniques.[3] This review seeks to explore the current state of laparoscopic bile duct exploration (LBDE) as an intervention at the time of laparoscopic cholecystectomy, and its relevance as a technique to clear the duct as a single-stage procedure when choledocholithiasis is encountered intraoperatively.

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Evolution of CBD Exploration

With the advent of laparoscopic cholecystectomy, the management of concomitant choledocholithiasis became less straightforward compared to the era of open surgery. Preserving a minimally-invasive approach to choledocholithiasis classically involved a two-stage approach involving either pre or post-operative endoscopic retrograde cholangiopancreatography (ERCP). However, with the advancement in surgical technique and technology, the single-stage approach in the form of LBDE at the time of cholecystectomy became more widely adopted.

LBDE has been reported in the literature since as early as the 1990s.[4-6] The initial experience with LBDE mostly consisted of relaxing the sphincter of Oddi with intravenous glucagon and flushing the duct through with saline and simple transcystic exploration of the bile ducts using techniques similar to those used with ERCP. Further development of more sophisticated and dedicated equipment and the dissem-

ination of advanced laparoscopic skills such as suturing facilitated direct exploration of the bile ducts via laparoscopic choledochotomy.[4-9] These various techniques are not discrete, but rather exist on a continuum depending on the presented anatomy and stone characteristics, and which technique to employ, either alone or in succession, is left to the discretion of the operating surgeon.

Indications for LBDE

The most common indication for LBDE is in situations where ERCP has failed or is contraindicated. These may be in patients who have altered gastrointestinal (GI) anatomy precluding straightforward ERCP, such as post gastrectomy with Roux-en-Y reconstruction. Using standard techniques, experienced endoscopists can achieve deep cannulation in 85-90% of cases, and this may be increased with various techniques including pre-cut sphincterotomy and the double-wire technique.[10] Factors cited for failed ERCP depend on the degree of difficulty and experience of the endoscopist. Another common indication for LBDE is in incidental choledocholithiasis in patients undergoing routine laparoscopic cholecystectomy with intra-operative cholangiography (IOC). While the utility of routine versus selective IOC is still debated, undoubtedly the increased use of IOC would lead to increased rates of LBDE. Furthermore, in centers where there is limited access to ERCP, a single-stage LBDE procedure would be the procedure of choice.

Contraindications to LBDE would include the presence of severe cholangitis where operative morbidity and mortality would be high without prior biliary decompression either by ERCP or percutaneous trans-hepatic biliary drainage (PTBD). Furthermore, patients not suitable for laparoscopy or surgery due to significant cardiopulmonary impairment may benefit from endoscopic clearance of choledocholithiasis as a definitive procedure. Increased age cannot be seen as a contraindication for LBDE. Recent literature suggests that LBDE, specifically laparoscopic transcystic bile duct exploration (TCE), in the elderly is just as safe and effective in the elderly as in a younger cohort.[11,12]

Setup

A suggested setup for LBDE is presented here (Fig. 1) and generally follows that from a routine cholecystectomy. The patient is placed in reverse Trendelenburg and a standard 4-port placement is utilized with an optional fifth port, which may be placed on the left of the falciform ligament if laparoscopic choledochotomy is being performed.

The operating surgeon generally stays on the left side of the patient (as does his assistant), with the laparoscopic stack and choledochoscope screen (if utilized) opposite on the patient's right. If fluoroscopically-guided, the C-arm should enter on the patient's left (surgeon side) with the monitor placed opposite.

Intra-operative Cholangiography (IOC)

The performance of IOC is considered the most basic 'biliary' intervention at the time of laparoscopic cholecystectomy, and paves the way to performing more advanced procedures such as transcystic exploration of the bile ducts. This confirms the presence of choledocholithiasis and demonstrates the biliary anatomy. Indeed, with the performance of routine IOC, incidental ductal stones are found in as many as up to 10% of cases.[14] In academic centers, the regular performance of IOC also facilitates the training of residents to perform this procedure, and eventually step-up to the performance of more complex laparoscopic biliary interventions.[14]

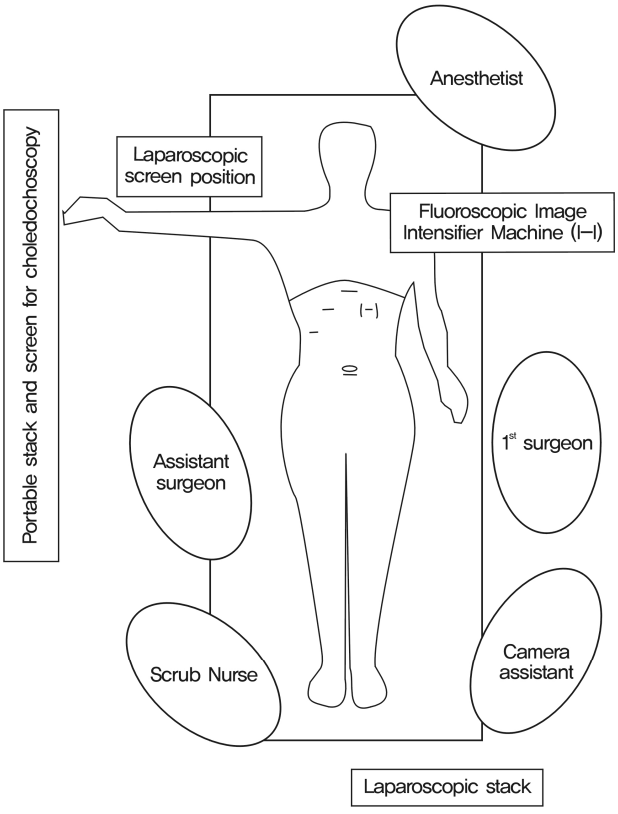

Fig. 1. Suggested operating room setup for LBDE.

Transcystic Bile Duct Exploration (TCE)

Upon identification of stones in the common bile duct, an assessment is made with regards to the number and size of stones, and the relative course and caliber of the cystic duct and common bile duct. If the stones are small enough to attempt flushing through the ampulla of Vater (into the duodenum), this may be facilitated by the intravenous administration of glucagon (to relax the sphincter of Oddi) followed by flushing with several boluses of saline. Nonetheless, this simple technique carries the theoretical risk of impacting stone(s) at the sphincter.

TCE may be performed under fluoroscopic and/or choledochoscopic guidance. Depending on local access to a choledochoscope, TCE may be performed solely under fluoroscopic guidance. The author's preference is the use of the Nathanson transcystic bile duct stone exploration set (Cook Medical, Bloomington, Indiana, USA). Otherwise, use of a 3 or 5-mm choledochoscope, with or without an accessory working channel, may facilitate duct exploration under direct vision. The choledochoscope may be introduced via the right subcostal or epigastric trocar (depending on anatomy and preference) and if necessary, gently manipulated with a rubber-tipped grasper to prevent damage to the choledochoscope. Repeat access to the ducts may be facilitated by use of a guidewire introduced following cholangiography and use of the Seldinger technique. Introduction of the choledochoscope via a fairly proximal incision in the cystic duct carries the risk of impaction at the spiral valves (of Heister), in which case a separate dochotomy at a more distal site (closer to its junction with the common bile duct) may be made to facilitate access into the common bile duct. Proximal access (to the common hepatic duct) is generally difficult in TCE due to the angulation of the entry of the cystic duct into the common bile duct.

Once access into the common bile duct is achieved, stones may be extracted via a variety of techniques. These include the use of a variety of Dormia-type baskets and Fogarty catheters. If available, and ductal anatomy permits, laser or mechanical lithotripsy may also be employed to assist with stone clearance. After performance of a final cholangiogram or exploration with the choledochoscope to ensure clearance of stones from the duct, surgical clips are applied distally to the cystic duct and the duct ligated per routine cholecystectomy.

Laparoscopic choledochotomy

The decision to explore the bile ducts via a direct choledochotomy may also be made depending on ductal anatomy and stone characteristics. This may follow on from failed transcystic exploration or from the outset e.g. if a small or aberrant cystic duct is present. The common bile duct is identified and the tissue surrounding it anteriorly cleared to allow an incision to be made. Generally, a longitudinal incision is made in the common bile duct (transverse incisions have also been used), which may be performed using laparoscopic scissors or diathermy.[15] Depending on operator preference, stay sutures may be placed laterally on the choledochotomy.

Similar to TCE, a 5-mm choledochoscope is maneuvered into the choledochotomy and exploration is undertaken. Stones are cleared from the common duct (in similar fashion) and direct choledochoscopy performed proximally up to the second or third-order hepatic ducts. The choledochotomy is then closed using absorbable sutures either primarily, over a T-tube or a laparoscopically-deployed endobiliary stent. In patients without prior sphincterotomy, the passage of the 5-mm choledochoscope into the duodenum to document distal bile duct clearance can be difficult and risk trauma to the ampulla. The performance of a check cholangiogram via the cystic duct after closure of the choledochotomy is useful to document radiological clearance of the biliary tree, to check for leakage of the choledochotomy repair site and to ensure there is no significant narrowing at the site of repair. Bile ducts less than 10 mm in size should be closed with interrupted sutures with larger ducts usually tolerating continuous closure with monofilament absorbable sutures.

Patient Selection – TCE versus Choledochotomy

A guideline (Table 1) suggesting the factors influencing the approach for bile duct exploration i.e. transcystic exploration versus choledochotomy has been proposed by Petelin (2003) and modified slightly by Puhalla et al. (2015), the main difference being a recommendation to avoid choledochotomy in patients whose common bile ducts were smaller than 10 mm (cf. 6 mm).[7,13] The authors prefer a "TCE-first" approach where feasible as recovery from TCE is very similar to laparoscopic cholecystectomy alone without the added risk of biliary leak or stricturing from choledochotomy.[8]

Strategies to Improve Success

A number of situations may pose technical challenges to

Table 1. Factors influencing the approach for LBDE

Factor	Transcystic exploration	Choledochotomy
Single stone	+	+
Multiple stones	±	+
Stones <6 mm	+	+
Stones >6 mm	-	+
Intrahepatic stones	-	+
Cystic duct diameter <4 mm	-	+
Cystic duct diameter >4 mm	+	+
CBD <10 mm	+	-
CBD >10 mm	+	+
Cystic duct entrance - lateral	+	+
Cystic duct entrance - posterior	-	+
Cystic duct entrance - distal	-	+
Inflammation - mild	+	+
Inflammation - marked	+	-
Suturing ability - poor	+	-
Suturing ability - good	+	+

the surgeon e.g. large stones contained within relatively small ducts. A number of strategies may be employed to overcome these difficulties in an attempt to improve the success rate of LBDE.

A Fogarty balloon or even angioplasty balloons may be used to gently dilate the cystic duct to facilitate stone retrieval when utilizing the transcystic approach, the caveat being that this should best be avoided in smaller cystic ducts (sized 4 mm or less). Intravenous glucagon (1 mg) may be administered to relax the sphincter and allow free flow of contrast material into the duodenum. This may also permit the flushing of small stone fragments and debris. As mentioned above, a cystic dochotomy too far away from its junction with the common bile duct may impede stone retrieval or instrument passage through the spiral valves. Carrying the dissection closer to the junction may facilitate transcystic exploration and potential conversion to a choledochotomy if indicated. Furthermore, in cases where the stone has migrated above the cystic duct insertion, a closer incision to the cysto-hepatic junction may allow manipulation of the bile duct exploration catheter and baskets or 3-mm choledochoscope up the biliary tree. During advancement of the basket catheter, avoidance of deployment beyond the ampulla is advised to avoid ampulla trauma and thus resulting in post-operative pancreatitis.[13]

Prior to performing the actual choledochotomy, distending the bile duct with a push of saline may make this task easier and safer, by minimizing risk of damage to its posterior wall.[13] In the case of impacted or large stones, the use of lithotripsy (mechanical or Holmium laser) may be used to facilitate stone extraction. Finally, the performance of a check cholangiogram after choledochoscopy may minimize the rate of retained stones.

Complicated Choledocholithiasis

We consider complicated choledocholithiasis to be present in patients who have failed or are unsuitable for ERCP e.g. post Roux-en-Y gastrectomy. This complex group may also include patients with altered anatomy due to pathology such as Mirizzi's syndrome or those with recurrent pyogenic cholangitis (RPC).

For patients who have failed preoperative ERCP or those in whom ERCP is precluded, an attempt at LBDE is reasonable, and indeed recommended to avoid an open procedure, if the operating surgeon is trained in said techniques. In those whom TCE have failed, several options are available to the surgeon depending on the diameter of the common bile duct. In patients with dilated common ducts (greater than 10 mm), a choledochotomy (laparoscopic or open) is a reasonable and feasible option, particularly if ERCP is precluded. In patients with common ducts smaller than 10mm, if only small stones(s) are present, they maybe expectantly followed up with an early post operative MRCP as some of these filling defects may be either artifactual or pass spontaneously. Post operative ERCP can then follow at a later date if needed. If ERCP was already know to have failed or precluded preoperatively, every attempt should be made to confirm and retrieve these stones. This may involve a careful choledochotomy and direct exploration laparoscopically with interrupted closure with fine absorbable monofilament sutures 5/0 or 6/0. However, if fairly large stones are present, an anterograde endobiliary stent may be deployed as a temporizing measure and bridge to post-operative ERCP. Lastly, if such capability is available, intra-operative ERCP may be attempted. This may be done using a lap-endoscopic rendezvous technique to facilitate cannulation and improve success rates.

With the advances in laparoscopic surgery, attempts at the laparoscopic management of more complex problems such as the involvement of Mirizzi's syndrome have also been reported and may be attempted even though this cannot as yet be recommended as standard practice.[16-18] A systematic review into the laparoscopic management of Mirizzi's syndrome pooled a total of 124 patients and found that the laparoscopic approach was successful in 73 patients (59%),

the remaining 41% were converted to laparotomy for completion of the procedure.[18] However, including only those studies that provided information on subtype of Mirizzi's, it should be noted that the majority, 68 of 84 patients (81%) were Mirizzi type 1.[18]

Similarly, the laparoscopic management of RPC has also been reported but due to individual variation in the pattern of this complex disease, the surgical approach is best individualized depending on the patient's disease characteristics and operator experience.[19-21] This heterogenous group often has concomitant hepatolithiasis and require repeated ERCP or PTBD, and ultimately biliary bypass with consideration of hepatectomy depending on disease characteristics.[20,21]

Closure Following Laparoscopic Choledochotomy

The options for closure following laparoscopic choledochotomy are: primary closure, closure over a T-tube, and closure over an endobiliary stent.[2] Each option having its own benefits and risks. Primary closure avoids the morbidity associated with a T-tube or stent, and thus potentially an additional procedure. However, if there is a risk of retained stones, or periampullary oedema causing biliary obstruction, this can put strain on the choledochotomy repair with subsequent danger of breakdown and biliary peritonitis.

T-tube placement allows for good external drainage and a decompressed biliary tree following surgery. Further biliary intervention may also be undertaken via the T-tube tract should the need arise. Disadvantages of this approach include difficulty in the laparoscopic placement of T-tubes, the need for patients to manage and care for an external drain tube following surgery, and the morbidity associated with T-tubes.[22] A Cochrane review in 2013 comparing the practice of closure over a T-tube against primary closure of a choledochotomy in laparoscopic surgery found no evidence of benefit for the routine use of T-tubes following laparoscopic choledochotomy.[22] A total of three trials were included in their analysis (295 participants) however the authors noted that all three had a high risk of bias.[22] The authors found no significant difference in serious morbidity (11.3% in the T-tube group versus 6.1% in the primary closure group; RR 1.86, 95% CI 0.87-3.96) between both groups. However, operating time and hospital stay was significantly longer in the T-tube drainage group compared with the primary closure group, on average 21 minutes longer for operating time and 3.2 days for length of stay. Most recently, a meta-analysis of all studies comparing primary ductal closure and T-tube drainage after LBDE showed significant advantage of primary ductal closure with decreased incidence of post-operative bile peritonitis, operative time, duration of hospitalization and median hospital stay.[23]

Lastly, placement of an anterograde endobiliary trans-papillary stent (Cotton-Leung 7-9, Cook Medical) is a useful technique which also facilitates post-operative ERCP in the case of known remnant stones post-exploration. It can generally be performed fairly quickly, adding little time to the operative procedure. However this effectively commits the patient to another procedure for stent removal with the concomitant risk of recurrent stones, stent complications and pancreatitis.[24] Studies comparing endobiliary stenting with T-tube show lower procedure related complications, shorter hospital stay, and increased patient satisfaction with endobiliary stenting.[25-27]

Learning Curves

For surgeons who perform IOC fairly routinely, transcystic exploration of the common bile duct can be seen as a fairly natural extension of that skill set. This is especially true with surgeons who have experience with ERCP. With laparoscopic choledochotomy incorporating the laparoscopic place-

Table 2. Studies documenting the learning curve for LBDE

Study	Total no. of cases described	Practice type	Overall clearance rate	Type of LBDE	Estimated learning curve	Methodology
Zhu et al. (2015)	708	Hospital unit	98%	TCE only	250 cases	Cumulative sum (CUSUM) quantitative assessment of operating time
Lien et al. (2005)	82	Hospital unit	83%	Choledochotomy with T-tube	40 cases	Anecdotal; conversion rate
Keeling et al. (1999)	120	Series from two consultant firms	89%	Both	40 cases	Clearance rate

ment of a T-tube, it has been shown that the learning curve is generally overcome only after 40 cases.[28,29] Nonetheless, through the use of a training model and simulators, coupled with dedicated proctoring by experienced surgeons, this number is likely to be reduced.[28,30] Nonetheless, achieving mastery of this seemingly facile procedure may take a lot longer. Going beyond procedural efficacy and morbidity, a retrospective study at a Chinese unit suggested that it may take a unit up to 250 cases in order to surpass the learning curve, based on operating time analysis.[31] A summary of the experience from these studies is presented in Table 2.

Outcomes

A 2013 Cochrane review on the surgical versus endoscopic management of bile duct stones reported an overall rate of retained stones of 4-9% for LBDE.[3] This comprises a heterogenous mix of patients who had both TCE and laparoscopic choledochotomy. In general, while it is accepted that open common bile duct exploration is the gold standard, the outcomes from LBDE and ERCP (whether performed as a one- or two-stage procedure) are thought to be comparable.[3] However, a recent trial (performed after the Cochrane review) randomised 104 patients to either LBDE or intra-operative ERCP and found a statistically significant difference in the rate of retained stones (42 versus 15%), favouring intra-operative ERCP.[32] Nonetheless, criticisms of this study include: (1) the LBDE arm of this trial consisted mostly of TCE and there was a fairly low overall choledochotomy rate, (2) the fact that both arms of the study may not have been equal given that the interventionists in the intra-operative ERCP group may be more experienced with their procedure than the interventionists in the LBDE group, and (3) the study was limited only to acute presentations and included a fairly large proportion of patients with cholangitis. As an intervention, intra-operative ERCP requires a fair amount of logistical support and is probably better viewed as an alternative strategy to failed TCE intra-operatively.[32]

The Cochrane review also did not find any significant differences in comparing morbidity between LBDE and the various ERCP approaches.[3] Nevertheless, while ERCP is well-known to be associated with its fair share of morbidity i.e. pancreatitis, bleeding and perforation, LBDE as a procedure is not without its risks.[33] While TCE is generally not associated with risks or morbidity greater than that for laparoscopic cholecystectomy, laparoscopic choledochotomy is widely accepted to have a higher risk of bile leak post-operatively, on top of the potential from stent or T-tube related morbidity, depending on closure technique.[2,8]

CONCLUSION

LBDE is a useful skill for the general surgeon to possess and allows a fairly quick single-stage solution to the problem of choledocholithiasis. LBDE is best viewed as being complementary to endoscopic therapy, with the best option for patients and providers dependent on each institutions resources and capability. TCE is fairly straightforward and does not require much additional training on top of the skill set required for IOC and basic endoscopy. On the other hand, laparoscopic choledochotomy and complicated choledocholithiasis, should probably best be attempted by surgeons experienced with complex laparoscopic hepatobiliary procedures for optimal outcomes.

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