The successful introduction of laparoscopic cholecystectomy by Muhe in 1985 ushered in a new era of management of gallbladder and biliary disease [1]. Several trials have borne out the advantages of laparoscopy, including shorter hospitalizations, quicker return to work, decreased complications, and less postoperative pain. Despite initial skepticism, the overwhelming success of laparoscopic cholecystectomy has become a platform for an ever-expanding body of minimally invasive procedures. As technology and instrumentation have improved, so have the complexity of operations that can be performed in a minimally invasive way. This evolution also is manifest in approaches to management of choledocholithiasis.

Before the laparoscopic era, intraoperative cholangiography was performed routinely and common bile duct stones diagnosed at this time were dealt with by open duct exploration. Routine intraoperative cholangiography currently is not a part of most laparoscopic surgeons’ techniques. A selective approach to intraoperative cholangiography during laparoscopic cholecystectomy has been shown to be safe when the ductal anatomy is defined clearly and there is no laboratory or clinical evidence of common bile duct abnormalities [2]. Some investigators assert, however, that routine cholangiography should be performed for evaluation of occult stones and to improve techniques for laparoscopic common bile duct exploration if needed [3].
Significant advances in endoscopic techniques for stone removal also have occurred and are commonplace. Endoscopic retrograde cholangiopancreatography (ERCP) is a successful approach to stone clearance and proposed by many as appropriate for management of pre- and postoperatively discovered choledocholithiasis [4–13]. In addition to endoscopic sphincterotomy, an ever-widening array of endoscopic baskets, balloons, and lithotripsy devices exist for stone removal.

As experience has accrued and instrumentation improved, laparoscopic approaches to choledocholithiasis also have evolved. Such techniques include transcystic stone removal, laparoscopic choledochotomy with stone extraction, and transcystic stenting followed by postoperative ERCP. Some surgeons propose using intraoperative ERCP in combination with laparoscopy [14,15].

With the litany of advances in laparoscopy and endoscopy, much has improved regarding management of choledocholithiasis. Controversy exists, however, regarding which of the appropriate interventions should be used in different clinical scenarios. This article examines the different approaches currently available to remove common bile duct stones, with an examination of the literature supporting different approaches and the techniques involved.

**Indications for preoperative endoscopic retrograde cholangiopancreatography**

Before the advent of laparoscopy, preoperative clearance of common bile duct stones with ERCP before open exploration was uncommon. Several well-performed studies did not demonstrate any improvement in morbidity or mortality with preoperative endoscopic sphincterotomy [16–18]. One study demonstrated an increase in morbidity when preoperative ERCP with sphincterotomy was added to open cholecystectomy compared with cholecystectomy and open common bile duct exploration [18]. Largely based on these studies, preoperative ERCP with sphincterotomy was uncommon in the era of open cholecystectomy and it did not become more widespread until laparoscopic approaches to cholecystectomy appeared.

When laparoscopic cholecystectomy was introduced, preoperative ERCP was used frequently for patients suspected of having choledocholithiasis [19–23]. This strategy was in large part due to unfamiliarity of most surgeons with the advanced laparoscopic techniques necessary for common bile duct exploration coupled with the high success of endoscopic extraction, with rates of clearance approaching 90% [19–21,24]. Patients who presented with jaundice, elevated cholestatic liver function tests, a history of pancreatitis, or a dilated biliary system on radiographic imaging were considered candidates for preoperative ERCP. Even with these criteria, however, it is difficult to predict which patients have choledocholithiasis. The majority of patients who had these abnormalities did not have common bile duct
stones at the time of ERCP. Using these selective criteria, a negative preoperative ERCP is performed in 40% to 70% of patients. Most of these abnormalities were caused by transient biliary obstruction secondary to stones that subsequently passed into the duodenum [18–21,25].

Performing ERCP has clinical and financial costs and must be weighed against the likelihood of successful extraction of stones that otherwise would result in significant disease manifestation. Complications, including post-procedural pancreatitis, bleeding, infections, and perforations, are not uncommon. ERCP has an overall complication rate of 10%, serious morbidity of 1.5%, and mortality rate of less than 0.5% [19–24,26]. A recent systematic analysis of prospective studies has shown that complications continue to occur at a relatively consistent rate and that the majority of events are of mild-to-moderate severity [27]. These rates are increased in high risk, elderly patients. Laparoscopic cholecystectomy has been shown, however, to have increased morbidity in older patients and those who have pre-existing medical risk factors [28].

Additionally, the financial cost of a diagnostic ERCP is substantial. Several studies have demonstrated increased direct costs, total hospital costs, and increased length of stay in patients undergoing ERCP with sphincterotomy compared with patients undergoing laparoscopic cholecystectomy with common bile duct exploration [29–31]. Liberman and colleagues [30] conducted a retrospective study of 76 patients undergoing transcystic laparoscopic common bile duct exploration or laparoscopic cholecystectomy plus ERCP for urgent and elective management of choledocholithiasis. They found that patients undergoing laparoscopic common bile exploration for common bile duct stones, in urgent and elective situations, have markedly decreased morbidity rates, length of hospital stay, and costs compared with patients undergoing laparoscopic cholecystectomy and endoscopic sphincterotomy. The cost of treatment for patients undergoing single-stage therapy was $14,732 compared with $21,125 for patients undergoing laparoscopic cholecystectomy and ERCP with endoscopic sphincterotomy ($P<.05$).

There are indications in which preoperative ERCP should be implemented. Preoperative endoscopic drainage should be used in acute cholangitis for decompression and amelioration of sepsis [4]. A randomized trial from Hong Kong found 34% morbidity and 10% mortality rates in 41 patients who underwent endoscopic decompression compared with 66% morbidity and 32% mortality rates in patients who underwent primary surgical therapy [32].

Severe gallstone pancreatitis is another indication for ERCP with endoscopic sphincterotomy and decompression [4]. A prospective randomized control trial of urgent ERCP with sphincterotomy versus conservative management in patients predicted to have severe gallstone pancreatitis demonstrated a mortality rate of 4% in patients undergoing ERCP with decompression versus 24% in the conservative group [17]. Patients were
stratified by predicted severity of the attack, according to the modified Glasgow system. ERCP was done within 72 hours, and if common bile duct stones were identified, patients underwent sphincterotomy immediately to extract the stones. There were fewer complications in the patients who underwent ERCP than among those treated conventionally, the difference confined to those patients whose attacks were predicted to be severe compared with conventional treatment. Hospital stay also was shorter for patients who had severe attacks and who underwent ERCP and sphincterotomy than for those who received conservative treatment. Preoperative ERCP also should be considered if the diagnosis is uncertain as in cases of persistent, severe hyperbilirubinemia when stricture and neoplasm cannot be ruled out.

Two prospective randomized controlled trials have been performed to compare preoperative ERCP with sphincterotomy followed by laparoscopic cholecystectomy during the same hospital admission with single-stage laparoscopic management [4,33]. The results demonstrate equivalent success rates of duct clearance and patient morbidity for the two management options. A significantly shorter hospital stay was demonstrated with simultaneous laparoscopic cholecystectomy and common bile duct exploration. In one of these studies, Cuschieri and colleagues [4] conclude that in fit patients (American Society of Anesthesiologists physical status I and II), single-stage laparoscopic treatment is the better option, and preoperative ERCP with sphincterotomy should be confined to poor-risk patients, such as those who have cholangitis or severe pancreatitis.

Intraoperative techniques for stone removal

Laparoscopic cholecystectomy has replaced open cholecystectomy in most elective instances and surgeons have developed a significant experience with surgical techniques, including intraoperative cholangiography. As skills have improved, less reliance is placed on preoperative endoscopic sphincterotomy. Surgeons should learn techniques of laparoscopic common bile duct exploration to allow definitive management during one procedure. If successful, this also circumvents the known morbidity and cost of ERCP and sphincterotomy.

The first requirement for successful removal of common bile duct stones is a good cholangiogram that clearly identifies the biliary anatomy. Attention must be paid to evaluating the intra- and extrahepatic biliary tree, including anomalies, flow of contrast into the duodenum, and any filling defects. The technique of performing intraoperative cholangiography is important. Although accuracy of detecting common bile duct stones is high [34], anatomic variants of the biliary tree are common and have the possibility of being misread. It is imperative for surgeons to understand fluoroscopic appearances of filling defects that are secondary to stones and air bubbles or
biliary strictures. Successful performance of intraoperative cholangiography by experienced surgeons occurs in greater than 95% of cases [35,36].

Routine cholangiography is used by surgeons in elective laparoscopic cholecystectomy to varying degrees, with published reports of its use ranging from 37% to 67% in two international surveys [37,38]. In addition to cholangiography, laparoscopic ultrasound is shown effective at identifying common bile duct stones [39]. Among patients who have choledocholithiasis, however, 10% to 12% are asymptomatic and do not have alterations in liver function tests [40,41]. If not used as part of routine cholecystectomy, cholangiography should be performed in the settings of elevated liver function tests, a history of gallstone pancreatitis, or a dilated biliary system on preoperative imaging. After performance of intraoperative cholangiography, stone architecture is important. Stones should be noted for their size, location, and number to plan for successful extraction. Ultimately, clearance depends on the stone characteristics, resources available to surgeons, and surgeon expertise.

**Laparoscopic transcystic removal**

Transcystic common bile duct stone extraction is shown highly effective and has the advantage of avoiding choledochotomy and subsequent suture repair [6–8,10,12,42]. Depending on stone characteristics and surgeon experience, most cases of choledocholithiasis can be managed via the cystic duct. In a study of 300 consecutive patients discovered to have choledocholithiasis, Nathanson and colleagues [43] were able to clear two thirds transcystically, with the remainder undergoing choledochotomy. After successfully obtaining a quality cholangiogram and interpreting it correctly, access to the cystic duct and biliary system must be evaluated. Placement of an additional 5 mm trocar or a separate stab incision for catheter placement may be beneficial for manipulation of instruments and better access to the ductotomy. If the ductotomy made for the cholangiogram is too small, this may need to be extended. Once the biliary system is accessed, the first maneuver is to flush the cholangiocatheter with saline. This often is successful for small stones, approximately 4 mm or less. A greater success rate can be achieved with prior administration of intravenous glucagon, which promotes relaxation of the sphincter of Oddi, and flushing with 1% lidocaine [44]. This sequence should be performed under real-time fluoroscopic imaging.

Failure of this technique should prompt re-evaluation of stone characteristics. Mobile stones that are small enough to retrieve through the cystic duct can be removed by insertion of a wire basket, with retrograde extraction. Often, however, transcystic duct techniques require dilation of the cystic duct with balloon dilators to allow for percutaneous access and retrieval of stones. The cystic duct usually can be dilated to 5 to 7 mm, always in a controlled manner, and never should be dilated larger than the diameter of the common bile duct. Larger stones may be crushed with a lithotripsy.
device before attempts at removal. After cystic duct dilation and fracture of large calculi, additional attempts at fluoroscopic wire basket stone removal are performed. Biliary balloon catheters also can be used during transcystic explorations. The major limitation of balloon use is the potential to drag stones into the common hepatic duct, making extraction more difficult from a transcystic approach. Caution should be used with attempts at antegrade propulsion of stones into the duodenum with balloon catheters because injury, bleeding, and pancreatitis can occur at the sphincter of Oddi. If this technique is used, ampullary balloon dilatation ought to be performed first.

Some surgeons routinely use a choledochoscope via the cystic duct. A 3-mm scope can be advanced and allows for direct visualization, wire basket manipulation, and retrieval of stones. In experienced hands, this technique is successful in 80% to 90% of patients [45, 46]. An additional advantage of the choledochoscope is postprocedural surveillance to ensure complete clearance of the biliary tree. A disadvantage of this technique is difficulty in examining and extracting stones from the proximal common bile duct.

Transcystic common bile duct exploration has proved efficacious, although technically demanding and often time consuming [5–7, 23, 25, 42]. Availability of a laparoscopic cart with common bile duct exploration instruments is helpful, as this equipment is not used routinely and decreases delays and frustration when common bile duct stones are encountered. Surgical equipment companies also have created self-contained, single-use kits that are widely available. Long-term outcome data examining transcystic laparoscopic common bile duct explorations have demonstrated low rates of retained stones without stricturing of the biliary system [47].

**Laparoscopic choledochotomy**

Failure of transcystic exploration necessitates a different approach. Laparoscopic choledochotomy and common bile duct exploration is an effective technique but requires advanced laparoscopic skills, including intracorporeal suturing. Studies have demonstrated success with extracting larger stones, from 10 to 15 mm, with an associated dilated common bile duct through this approach [6, 8, 25]. Choledochotomy also is likely more successful for retrieving stones that are impacted and require lithotripsy. Choledochotomy is contraindicated in the setting of a small caliber duct, as this is more likely to stricture after exploration.

Once an appropriate cholangiogram is performed and the stone characteristics and biliary anatomy are delineated, the bile duct is exposed anteriorly by opening the peritoneum parallel to the duct. This is accomplished by dissecting from the cystic duct toward the common bile duct. Once the common bile duct is exposed, its identity can be confirmed by needle aspiration of bile. Alternatively, intraoperative ultrasound can be used, which has the advantage of also imaging the common bile duct stones. Two stay sutures
routinely are placed for traction, as in the open technique. A ductotomy is made with scissors anteriorly along the vertical axis, to avoid the vascular supply, and an opening created of 15 to 20 mm in length. This incision should be made only as long as the diameter of the largest stone. A catheter then is inserted through the lateral 5-mm trocar and the duct is irrigated. The authors prefer to use a 14-Fr red rubber catheter. Firm flushing at this point often clears the duct. A guide wire then is inserted and passed into the duodenum under fluoroscopy. A balloon catheter is fed over the guide wire and passed proximal and distal through the duct to clear the stones. Fluoroscopic imaging should be performed throughout these maneuvers. A choledochoscope then is advanced into the bile duct to confirm complete clearance of all stones and debris.

After choledochotomy, consideration is made as to whether or not a T tube should be placed. Some surgeons place them routinely, whereas others use a selective approach. If a selective approach is used, common bile duct size is the main determinant. An appropriately sized T tube, usually between 10 and 14 French, then is inserted into the common bile duct. The choledochotomy is closed with interrupted, absorbable sutures. A completion cholangiogram is performed through the T tube to confirm no filling defects and no leak from the choledochotomy. In experienced hands, success rates are high, with some reports of rates greater than 90% [48]. Morbidity rates in this large series were reported as 8% and mortality 1%. This technique is successful for larger stones in the setting of a dilated common bile duct but requires advanced laparoscopic skills. Failures of laparoscopic choledochotomy can be managed by conversion to laparotomy with common bile duct exploration or postoperative ERCP with sphincterotomy. Published reports consistently demonstrate excellent results of laparoscopic common bile duct exploration, by transcystic approach and choledochotomy. These results are, however, generally from larger centers with higher volumes and are performed by surgeons who have expertise in laparoscopy. There are few data that examine advanced laparoscopic procedures performed by less experienced surgeons [13].

What role does endoscopic retrograde cholangiopancreatography play in stone removal?

Reports vary widely, but 5% to 18% of patients undergoing cholecystectomy for gallstones have common bile duct stones. Treatment options for these stones include pre-, intra-, or postoperative endoscopic ERCP or open or laparoscopic surgery. Two prospective, randomized studies exist that evaluated intraoperative laparoscopic techniques versus postoperative ERCP with sphincterotomy for management of common bile duct stones. Rhodes and colleagues [49] in 1998 identified 80 patients discovered during intraoperative cholangiography to have common bile duct stones. These patients then were randomized to laparoscopic common bile duct
exploration or postoperative ERCP with sphincterotomy. Patients were excluded from this study if they had undergone preoperative sphincterotomy, cholangitis, or acute pancreatitis. Primary duct clearance in both treatment groups after the first attempt was 75%. Patients in the laparoscopic group who failed this initial attempt then underwent open exploration or postoperative ERCP. Those patients randomized to postoperative ERCP underwent repeat procedures as necessary for complete duct clearance. No significant differences existed in morbidity and mortality between the study groups. Hospital stay, however, was a median of 1 day (range 1–26) in the laparoscopic group compared with 3.5 days (range 1–11) in the ERCP group ($P = .0001; 95\% \text{ CI}, 1–2$).

The other prospective study was conducted by Nathanson and colleagues [43] and evaluated patients having laparoscopic cholecystectomy who had failed transcystic duct clearance of bile duct stones. In seven hospitals, after failed transcystic duct clearance, 86 patients were randomized intraoperatively to have laparoscopic choledochotomy or postoperative ERCP. Their exclusion criteria were prior ERCP, severe cholangitis or acute pancreatitis requiring immediate decompression, common bile duct diameter of less than 7-mm diameter, or if biliary-enteric bypass was required in addition to stone clearance. Total operative time was less than 11 minutes longer in the choledochotomy group (158.8 minutes), with slightly shorter hospital stays of 6.4 days versus 7.7 days. Bile leak occurred in 14.6% of those having choledochotomy. Similar rates of pancreatitis (7.3% versus 8.8%), retained stones (2.4% versus 4.4%), reoperation (7.3% versus 6.6%), and overall morbidity (17% versus 13%) were observed in the choledochotomy versus ERCP groups. The investigators recommend avoidance of choledochotomy in ducts less than 7 mm and in inflamed friable tissues that might hamper an adequate dissection. They advocate choledochotomy as a good choice for patients who have postsurgical anatomy that would impair endoscopic access or previously failed ERCP access or when long delays would occur for patient transfer to other locations for the ERCP.

In 2006, a Cochrane database review was conducted to evaluate management of common bile duct stones by four different approaches: ERCP versus open surgical bile duct clearance, preoperative ERCP versus laparoscopic bile duct clearance, postoperative ERCP versus laparoscopic bile duct clearance, and ERCP versus laparoscopic bile duct clearance in patients who had previous cholecystectomy [50]. Included for analysis were 13 trials that randomized a total of 1351 patients. Eight trials ($n = 760$) compared ERCP with open surgical clearance, three ($n = 425$) compared preoperative ERCP with laparoscopic clearance, and two ($n = 166$) compared postoperative ERCP with laparoscopic clearance. There were no trials of ERCP versus laparoscopic clearance in patients who did not have an intact gallbladder. These studies conclude that in the era of open cholecystectomy, open common bile duct exploration was superior to ERCP in achieving common bile duct stone clearance. In the laparoscopic
era, no significant difference between laparoscopic and ERCP clearance of common bile duct stones is clear. Additionally, they found that the use of ERCP necessitates an increased number of procedures per patient. Large and multiple stones found during laparoscopy may require multiple endoscopic procedures over a long course of time, with attendant risks, and may be dealt with best at the time of operation [19–23].

Intraoperative endoscopic retrograde cholangiopancreatography

Intraoperative ERCP is an effective method for dealing with common bile duct stones, especially stones found in the common hepatic or intrahepatic system [14,51]. The logistics of arranging this technique, however, limit its application. This requires the transport of endoscopic equipment, including fluoroscopy, into the operating room, and the presence of an endoscopist skilled in ERCP. Supine positioning of patients for laparoscopic surgery does make ERCP more difficult. This approach is dependent on many variables but results from certain centers have shown clearance rates of greater than 90% with minimal morbidity [51,52]. Intraoperative ERCP and sphincterotomy with simultaneous laparoscopic cholecystectomy also did not increase length of stay compared with laparoscopic cholecystectomy alone.

Some investigators have suggested antegrade transcystic passage of a sphincterotome to the ampulla guided by endoscopic visualization from the duodenum [15]. Once properly positioned, the sphincterotome cuts the sphincter under endoscopic direction, releasing stones into the duodenum. Another method involves laparoscopic transcystic passage of a guide wire into the duodenum, traversing the obstructing stone and sphincter. Once passed, an endoscopist grasps the wire with a snare, pulling the wire out through the working channel, through the patient’s mouth. A sphincterotome then is advanced over the wire through the working channel in the usual manner. Stones then can be removed endoscopically using a basket or balloon catheter. Known commonly as the “rendezvous technique,” this combined, simultaneous endoscopic and laparoscopic approach is feasible and successful although requiring significant coordination of equipment and additional personnel.

Postoperative endoscopic retrograde cholangiopancreatography

The decision to defer common bile duct stones discovered during laparoscopy to postoperative management is made by a surgeon intraoperatively. Postoperative ERCP is highly successful and the majority of stones can be dealt with endoscopically [28]. Many stones discovered in the operating room, however, turn out to be asymptomatic and routine postoperative ERCP for all common bile duct stones adds additional morbidity and mortality in addition to expense and prolonged hospital stay. A prospective, randomized study by Chang and colleagues [53] examined a series of
patients who had gallstone pancreatitis and were at high risk for persistent common bile duct stones. Their criteria included common bile duct greater than 8 mm or elevated bilirubin or amylase. Patients were randomized to routine preoperative ERCP followed by laparoscopic cholecystectomy or laparoscopic cholecystectomy with selective postoperative ERCP and sphincterotomy only if a common bile duct stone was present on intraoperative cholangiogram. They found that in patients who had gallstone pancreatitis, selective postoperative ERCP and stone extraction is associated with a shorter hospital stay, less cost, no increase in combined treatment failure rate, and significant reduction in ERCP use compared with routine preoperative ERCP.

Martin and colleagues [50] in their review of two randomized trials comparing single stage laparoscopic therapy with postoperative ERCP found that clearance rates are equal with no significant difference in morbidity and mortality. Laparoscopic trials reported shorter hospital stays, however, and insufficient data were reported for cost analysis. Postoperative ERCP is a successful technique and a reasonable option in circumstances where definitive surgical therapy, laparoscopic or open, is unavailable.

Laparoscopic transcystic drainage and postoperative endoscopic retrograde cholangiopancreatography

Retained common bile duct stones left in place after laparoscopic cholecystectomy have the potential to create complications including jaundice, cholangitis, and obstruction leading to cystic duct stump leaks. With this strategy, a surgeon is relying on the successful endoscopic management of these stones. An alternative has been suggested to more safely bridge the time from surgery to endoscopic therapy and avoid these untoward complications. One such technique is laparoscopic transcystic drainage followed by postoperative ERCP. After unsuccessful laparoscopic management of choledocholithiasis, a tube is placed transcystically into the common bile duct. After securing the cystic duct to the tube, it is externalized in a fashion similar to a T tube. Left to gravity drainage, this provides decompression of the biliary system. A wire then can be passed under fluoroscopy through this drain and into the duodenum. This facilitates endoscopic access, allowing the duct to be swept free of stones. Once the duct is cleared, the drain is capped and removed in 3 to 4 weeks, after the tract has matured.

Transcystic stenting and postoperative endoscopic retrograde choledangiopancreatography

Similar to the technique described previously, Rhodes and colleagues [9] initially described transcystic stenting and postoperative ERCP. After detection of choledocholithiasis, a 7-Fr, 5-cm biliary stent is passed over a guide wire under fluoroscopic view. This is advanced through the biliary tree and partially
into the duodenum, stenting the ampulla. Further endoscopic therapy can be performed on an elective basis, as normal biliary drainage is restored. This serves as an aide for endoscopists to identify and perform procedures, including sphincterotomy, and allows for continued internal drainage.

Summary

Choledocholithiasis is a common problem, present in 10% to 15% of patients undergoing laparoscopic cholecystectomy. As technology and experience have improved, the management of common bile duct stones has changed dramatically. Several of the approaches to managing choledocholithiasis are summarized in this article. Although few randomized trials exist, results of studies from the past 15 years have shown that single-procedure laparoscopic common bile duct exploration is safe and effective, especially when approached by a transcystic technique. Published reports consistently demonstrate excellent results of laparoscopic transcystic common bile duct exploration, with low morbidity and clearance rates of 80% to 90%. In more experienced hands, laparoscopic choledochotomy and stone extraction also are shown effective. Other techniques exist, including pre-, intra-, and postoperative ERCP and open common bile duct exploration. These approaches should be used as indicated by a particular clinical scenario. Individual surgeons must be aware of their capabilities to perform the safest successful operation and judicious use of available endoscopic techniques.

References

LAPAROSCOPIC COMMON BILE DUCT EXPLORATION


