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Laparoscopic Common Bile Duct Exploration

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Abstract. Laparoscopic cholecystectomy has become the procedure of choice for laparoscopically skilled surgeons when dealing with both chronic and acute cholecystitis. When choledocholithiasis is encountered in the treatment of these patients the skilled laparoscopist has several treatment options available to treat the patient in one stage and avoid the morbidity of endoscopic sphincterotomy. Although still controversial, laparoscopic common bile duct exploration has been shown to be safe, applicable, and cost-effective in the treatment of choledocholithiasis. This report details several laparoscopic treatment alternatives for choledocholithiasis.

The modern treatment of choledocolithiasis began during the late 1880s with the introduction of cholecystectomy. At that time common bile duct (CBD) stones were forced distally through the ampulla, proximally out the cystic duct stump, or crushed to facilitate spontaneous passage. Thorton and Abbe changed treatment standards in 1889 when they described choledochotomy and direct removal of stones. During the late nineteenth and early twentieth centuries intraoperative management of CBD stones was guided by the subjective clinical experience of the operating surgeon until the introduction of intraoperative cholangiography by Mirizzi in 1937 [1]. With the advent of cholangiography negative common bile duct exploration (CBDE) rates fell from around 50% to 6% [2]. The incidence of retained CBD stones also decreased from 25% to approximately 11%. Although not popularized until the late 1970s, the introduction of the rigid choledochoscope by McIver in 1941 further reduced the incidence of retained calculi [3]. A significant advance in the treatment of retained stones occurred in 1974 with the introduction of endoscopic sphincterotomy (ES) [4, 5]. With a success rate of 95%, morbidity of 15%, and mortality of 1%, skilled endoscopists changed the significance and treatment of retained calculi.

With the introduction of laparoscopic cholecystectomy in 1989, the surgical approach to patients with biliary disease changed. Preoperative endoscopic retrograde cholangiography (ERC) became the standard of care for patients suspected of having CBD calculi to avoid open CBDE. During this period postoperative ES increased because of decreased utilization of intraoperative cholangiography. Postoperative ES then became the treatment of choice in patients with CBD calculi documented intraoperatively or discovered later postoperatively.

Now that surgeons are more experienced in laparoscopic techniques, less reliance is placed on ES for the treatment of CBD stones. Surgeons can learn the various techniques of laparoscopic CBDE to treat their patients in one session. As laparoscopic suturing skills have developed, so has the technique of laparoscopic choledochotomy. The most frequently used approach, however, is transcystic common bile duct exploration (LTCBDE). Many transcystic approaches have been developed including biliary balloon catheters, lavage, and trolling with wire baskets. Dilation of the cystic duct allows biliary endoscopy, antegrade sphincterotomy, lithotripsy, catheter placement, and stone retrieval with wire baskets under direct visualization.

Indications

Indications for LTCBDE include filling defects on intraoperative cholangiography (CBD stones) and possible tumor. Contraindications to LTCBDE are common hepatic duct stones, a small friable cystic duct, 10 or more stones, and stones larger than 1 cm. Indications for choledochotomy include unsuccessful LTCBDE, need for biliary lithotripsy, and contraindications to LTCBDE. The contraindication to laparoscopic choledochotomy is a small-diameter common duct that might be narrowed during closure.

Laparoscopic Choledochotomy

Laparoscopic choledochotomy is an excellent technique when the CBD is dilated ($>$ 8 mm), for single or multiple stones, for common hepatic stones, or when lithotripsy is required. It is contraindicated in small ducts owing to the risk of stricture at the choledochotomy site, which depends in part on the laparoscopic suturing skill of the surgeon. Advantages of this technique are that stones can be irrigated or milked out of the CBD and larger-diameter choledochoscopes can be used. These larger scopes (3.3 mm or more) can be flexed in two directions for examining the hepatic ducts and accommodating larger, stronger wire baskets through their larger working channels. The choledochotomy also

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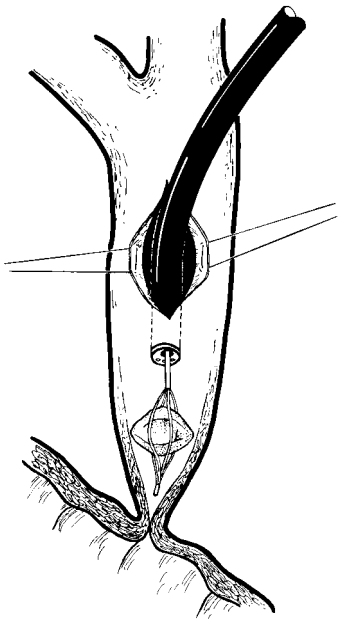
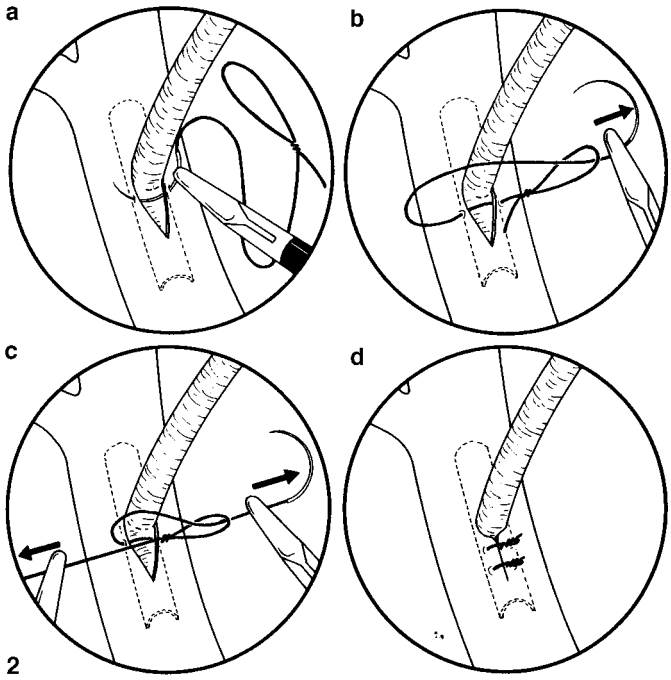


Fig. 1. Laparoscopic choledochotomy. Stones are retrieved using a choledochoscope and wire basket.

allows placement of a T-tube for decompression and postoperative access for cholangiography or retrieval of retained stones. The drawbacks of this technique are that a T-tube is required and laparoscopic suturing skills are necessary to close the choledochotomy.

The choledochotomy is made before the gallbladder is removed so the gallbladder can be used to elevate the liver, keeping the CBD under tension. The anterior surface of the CBD is exposed using blunt dissection. Stay sutures are sometimes preferred to tent up the CBD, facilitating an incision on its anterior surface. The choledochotomy is made below the junction of the cystic duct and CBD. To minimize the suturing required for closure, the incision should be made no larger than the largest of the stones to be retrieved. A choledochoscope is then inserted into the CBD at a right angle, and the scope is turned after entering. The CBD is irrigated with warmed saline to provide distension and better visualization. Crossing the stay sutures around the endoscope provides better distension of the common duct if visualization is a problem. An irrigating biliary balloon catheter or wire basket can be used to remove stones in most patients (Fig. 1). Occasionally, biliary lithotripsy is necessary to remove impacted stones.

When a drainage procedure is not indicated, a latex T-tube (10F–14 Fr) is placed in the duct. The entire T-tube is brought into the abdominal cavity after it is fashioned with a long and short end. The back side of one of the limbs can be removed and a guidewire inserted through the side with the intact back wall and brought out through the main long side arm to facilitate insertion. The T-tube is then positioned in the CBD with its long end oriented distally, and it is pushed cephalad. The first stitch is placed immediately adjacent to the tube as it exits the CBD to lessen the possibility of accidental dislodgment during suturing. The second is placed at the distal end of the choledochotomy. These two sutures can then be gently tented upward to facilitate placement of the remaining stitches. The choledochotomy is closed with interrupted 3-0 Vicryl (Ethicon, Somerville, NJ, USA) lubricated with mineral oil (Fig. 2). Sometimes placement of an additional trocar in the patient's right side facilitates suturing and



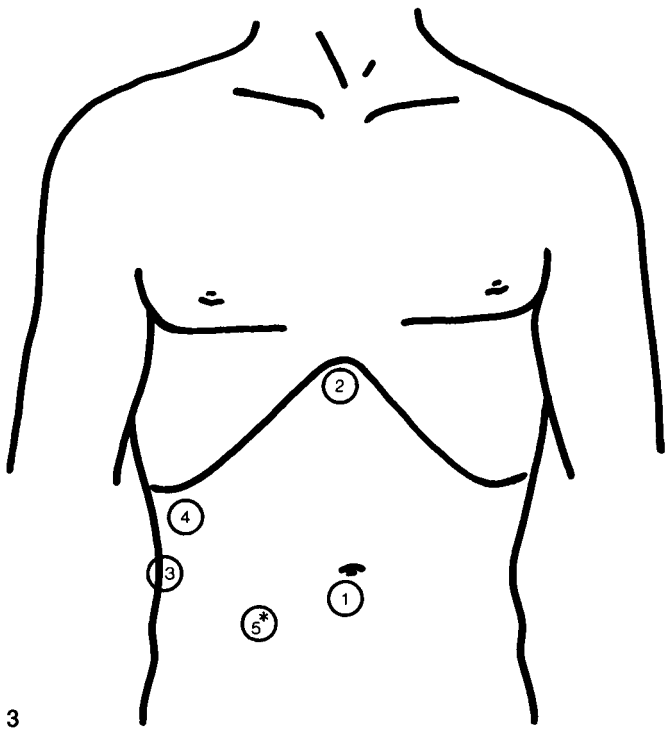


Fig. 2. Laparoscopic choledochotomy. **a.** First stitch is placed after tube is pushed cephalad. **b.** Needle is brought through slip knot loop. **c.** Lubricated slip knot is tightened down. **d.** Secured T-tube with second stitch in place.

Fig. 3. Trocar placement for laparoscopic common bile duct exploration. **1.** 10 mm (laparoscope); **2.** 5 mm (working port); **3.** 5 mm (cephalad gallbladder retraction); **4.** 5 mm (grasper, guidewire, balloon, choledochoscope); **5*.** 5 mm (optional).

Table 1. Results of laparoscopic common bile duct exploration.

Study	Year	Total cases	Transcystic techniques		Choledochotomy		Total successful clearance		Mortality	
			No.	%	No.	%	No.	%	No.	%
Petelin [6]	1991	22	20	91	1	5	19	86.4	0	0
Shapiro [7]	1991	16	15	94	1	6	16	100	0	0
Hunter [8]	1992	20	20	100	0	0	17	85	0	0
Petelin [9]	1993	77	75	97	2	3	74	96.1	1	1.3
Fielding [10]	1993	21	20	95	1	5	17	81	0	0
Fletcher [11]	1993	12	12	100	0	0	8	66.7	0	0
DePaula [12]	1994	119	107	90	12	10	108	90.8	1	0.84
Phillips [13]	1994	120	111	93	9	8	112	93.3	1	0.83
Dion [14]	1994	59	18	31	41	69	52	88.1	0	0
Ferzli [15]	1994	24	13	54	11	46	24	100	0	0
Phillips [16]	1995	129	123	95	6	5	116	90	1	0.77
Rhodes [17]	1995	114	79	70	35	30	108	95	0	0
Franklin [18]	1995	104	0	0	104	100	102	98	1	0.9
Huang [19]	1996	40	0	0	40	100	35	88	0	0
Lezoche [20]	1996	100	63	63	33	33	95	95	1	1
Carroll [21]	1996	133	123	93	10	7	121	91	1	0.75
Giot [22]	1997	92	76	83	30	33	76	82	2	2
Drouard [23]	1997	161	82	51	101	63	152	94	0	0
Millat [24]	1997	236	116	49	92	39	208	88	1	0.4

manipulation of the T-tube (Fig. 3). The T-tube is then brought through the abdominal wall, and completion cholangiography can be performed. Placing a catheter with a balloon that can occlude the duct proximally and distally to perform cholangiography before sewing in the T-tube can avoid the need to repeat the entire process if a retained stone is detected.

Results with this technique have been excellent. Drouard et al. have performed 101 procedures with a 96% success rate. The morbidity rate was 7%, and there were no mortalities (Table 1). In many centers laparoscopic choledochotomy is frequently performed in patients who have undergone unsuccessful LTCBDE. Because these cases are most difficult, the higher complication (11–17%) and retained stone (8–22%) rates are not surprising.

Laparoscopic Transcystic Duct CBDE

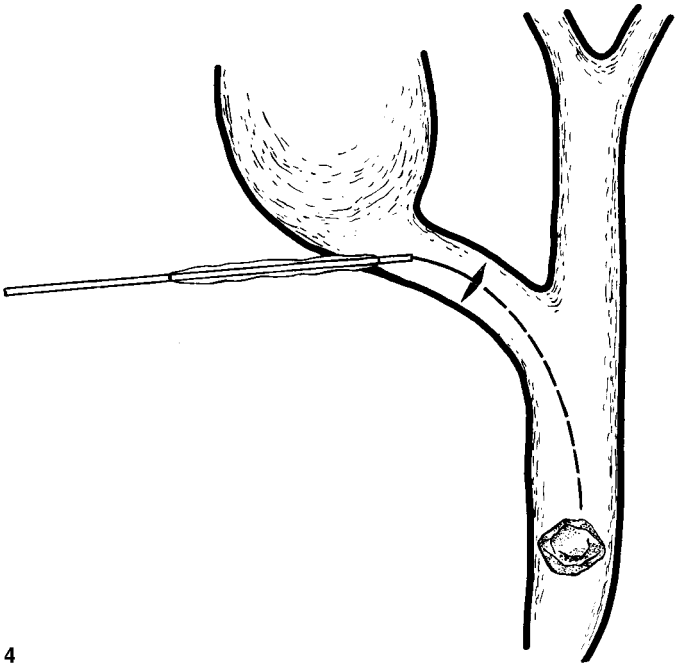
The transcystic duct technique offers an excellent approach to CBD stones while avoiding a choledochotomy and the difficulty of suturing laparoscopically. Nearly all transcystic duct techniques of CBDE involve dilation of the cystic duct with balloon dilators (preferred) or sequential graduated ureteral bougies. Balloon trolling of the CBD, ampullary balloon dilation with lavage, fluoroscopically guided wire basket stone retrieval, and transcystic endoscopically assisted sphincterotomy can occasionally be performed laparoscopically via the cystic duct without the need for dilation. Remember that large stones may be too big to remove through a strictured cystic duct.

Flexible biliary endoscopy with wire basket retrieval of calculi is our preferred technique. Additional safety is provided by this technique because wire basket manipulations and stone capture are performed under direct vision. It allows the surgeon to "clear" the CBD informally prior to the completion cholangiogram and inspect the CBD visually if tumor is a possibility. This method is applicable in 80% to 90% of cases. Contraindications to LTCBDE include multiple stones (more than eight), common hepatic duct stones, and a small fragile cystic duct. A major technical limitation is that the endoscope cannot be passed into the proximal bile ducts in most cases. Large stones ($>$ 9 mm) can be removed if lithotripsy is used to fragment the stone.

LTCBDE is performed as follows. Intraoperative cystic duct fluorocholangiography is performed to check for the presence of stones. The length, diameter, and tortuosity of the CBD and the insertion point of the cystic duct are evaluated as well. Trocar location must allow parallel insertion of the endoscope into the cystic duct. This is best accomplished by placing the most medial right upper quadrant trocar in as lateral a position as possible (Fig. 3).

To enter the larger portion of the cystic duct, the cystic duct should be dissected to within 1 cm of its junction with the CBD. A new incision is made in the cystic duct 1.5 cm from the CBD, and a floppy-tipped 0.035-inch hydrophilic guidewire is inserted through a balloon dilating catheter and advanced into the CBD (Fig. 4). If there is any resistance or question regarding the location of the guidewire, fluoroscopy can be performed. The balloon dilating catheter (4 cm long distal balloon with an outer diameter of 6 mm) is then inserted over the guidewire, and the cystic duct is gently dilated. The dilating balloon's outer diameter should never exceed the inner diameter of the CBD. A LeVeen syringe with pressure gauge is used to inflate the balloon inside the cystic duct until the appropriate pressure for the selected balloon is achieved (usually 12 mmHg) (Fig. 5).

After careful dilation of the cystic duct, a bidirectional flexible choledochoscope (2.7 mm outside diameter) is introduced into the cystic duct and manipulated down the common bile duct while warm irrigation is infused. The scope must have a 1.2-mm working channel for irrigation and basket insertion. When the first stone is identified, a straight four-wire 2.4F Segura basket is inserted to capture the stone and withdraw it via the cystic duct along with the endoscope (Fig. 6). Choledochoscopy is performed until no stones remain and the ampulla can be seen but not necessarily traversed. If tiny stones or debris remain, they can be flushed into the CBD with warm irrigation in most cases. An effort to pass the scope into the proximal hepatic ducts can be made but is usually unsuccessful.



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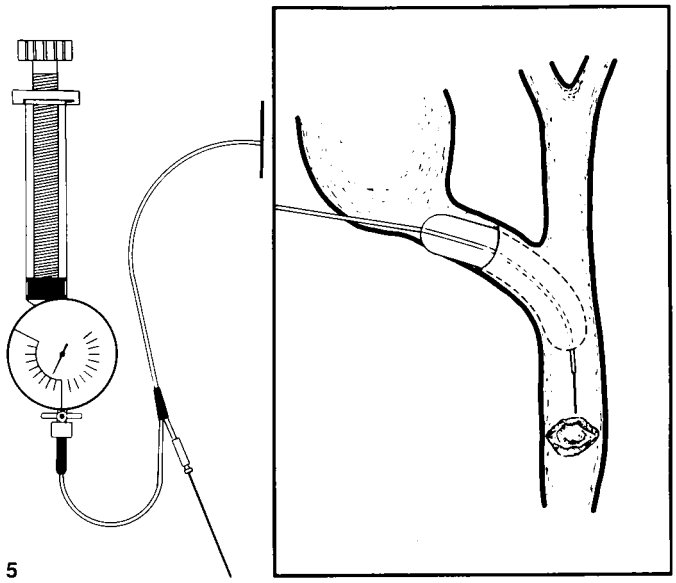

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Fig. 4. Positioning of guidewire prior to advancing balloon dilating catheter.

Fig. 5. Balloon pressure is monitored with a LeVeen syringe during cystic duct dilation.

A completion cholangiogram should always be obtained. A cystic duct drainage tube can be left in place if there are equivocal findings. This tube can be used postoperatively for repeat cholangiography and radiologic treatment of retained stones if necessary. The cystic duct must be closed with Endoloops (Ethicon), as clips may slip off the thinned duct.

Fluoroscopic Wire Basket Stone Removal

Fluoroscopic wire basket stone removal has the advantage of not requiring a flexible choledochoscope. As a result, its cost is less but it is successful in only approximately 60% of patients. Special helical wire baskets with flexible leaders are necessary to avoid CBD injury. The basket is placed in the CBD via the cystic duct. It is advanced under fluoroscopic guidance into the distal CBD as contrast material is injected. The basket is deployed, the stones are captured, and they are then removed through the cystic duct (Fig. 7). The advantage of not needing to dilate the cystic duct is offset by the potential difficulty of removing the basket and entrapped stone through a nondilated cystic duct.

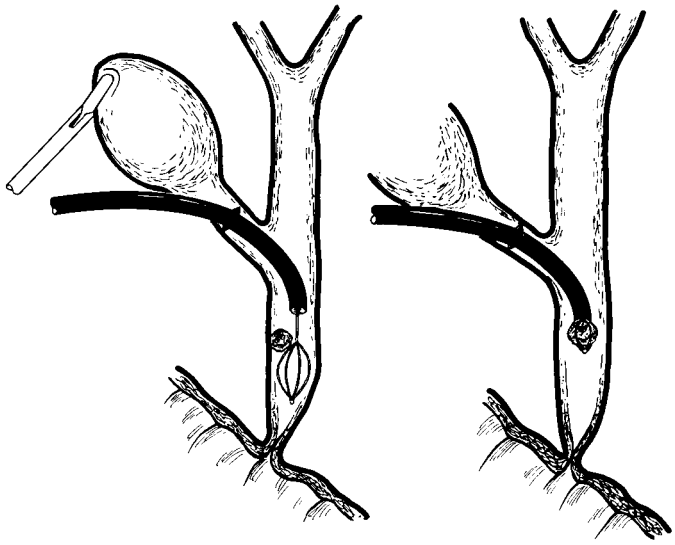

Fig. 6. Wire basket stone retrieval is performed under direct vision.

This technique is not as successful as other transcystic techniques, and it can lead to an impacted basket that requires choledochotomy for its retrieval. However, it can be a simple and successful technique in those patients with a few small stones whose diameters do not exceed the inner diameter of the cystic duct.

Biliary Balloon Catheter Stone Retrieval

Biliary balloon catheter stone retrieval is especially useful in patients with a dilated cystic duct. A biliary balloon catheter is passed via the cystic duct into the duodenum blindly or under fluoroscopic guidance. The balloon is gently inflated and withdrawn, modulating the pressure in the balloon. This technique is frequently successful via choledochotomy but has the risk of pulling a stone into the proximal ductal system out of reach of an endoscope when performed via the cystic duct.

Ampullary Balloon Dilation

Ampullary balloon dilation is a controversial technique that can be used when an endoscope cannot be inserted into a small, friable cystic duct. Stones < 4 mm in diameter and debris that does not clear after glucagon administration and lavage are the most common indications.

After the administration of 1 mg intravenous glucagon, a hydrophilic guidewire is inserted via the cystic duct and passed into the duodenum under fluoroscopic guidance. A balloon-dilating catheter is chosen, with the proper outer diameter based

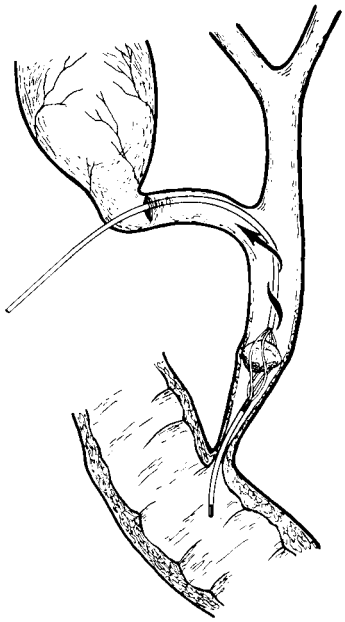

Fig. 7. Helical stone basket with a flexible tip for fluoroscopic stone extraction.

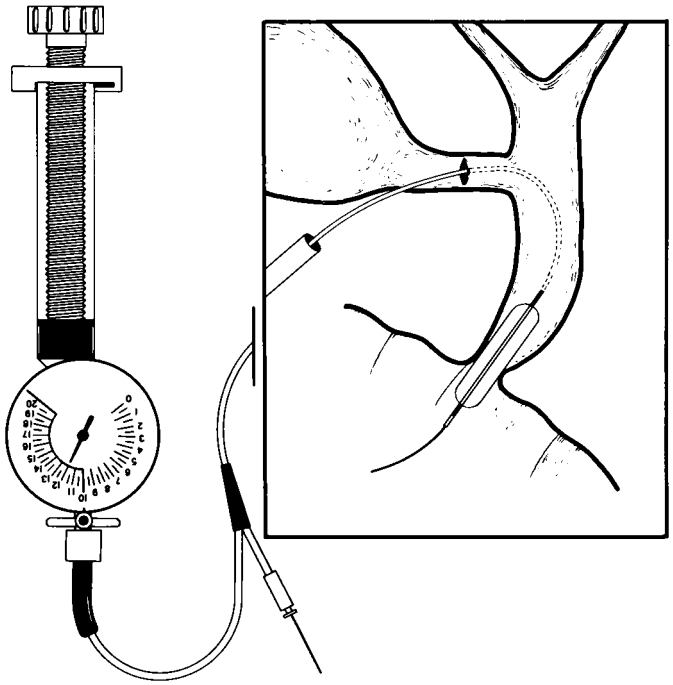

Fig. 8. Balloon dilation of the ampulla.

on the inner diameter of the CBD. The balloon catheter is advanced over the guidewire until its radiopaque markers span the ampulla. Using a LeVeen syringe, the balloon is slowly inflated with contrast so as to be visible on fluoroscopy (Fig. 8). The ampulla is dilated only to the diameter of the largest stone or a maximum of 12 mmHg pressure. The balloon is left inflated for 3 minutes, deflated, and withdrawn. Forceful irrigation into the cystic duct with warm irrigating fluid is performed, and a completion cholangiogram is obtained. This technique is highly successful with small stones (< 4 mm) and debris. Postoperative hyperamylasemia occurs in approximately 25%, and serious pancreatitis can occur. This technique should be considered only when the sole alternative is ES.

Cystic Duct Catheter Technique

The cystic duct catheter technique was reported by Fitzgibbons et al. [25]. A ureteral catheter is inserted via the cystic duct and positioned in the duodenum. The catheter can then be used to assist with guidewire placement and postoperative EC. If stones are present, guidewire-assisted ES can be performed.

Antegrade Transcystic Sphincterotomy

DePaula et al. and Zucker's group have treated a number of patients with antegrade transcystic sphincterotomy and have had good results [12, 26]. A gastroscope must be inserted via the mouth to observe the papillotome orientation. This technique may be a safe way to obtain adequate biliary drainage laparoscopically, but it is time- and equipment-intensive.

Procedure-Related Complications

Most complications can be detected at the time of operation by direct visualization or completion cholangiography. Complications include cystic duct stump avulsion, perforation of the cystic duct or other extrahepatic bile duct, persistent cholangitis due to lack of CBD decompression, delayed stricture due to mechanical or thermal injury, retained stones, and pancreatitis. Careful attention to technique and proper patient selection can avoid these problems.

LTCBDE has a morbidity rate of 5% to 10%. The mortality rate is $< 1\%$ and is due mostly to co-morbid pulmonary and cardiac disease. Laparoscopic choledochotomy has a 5% to 18% morbidity rate and a mortality similar to that of LTCBDE. Many surgeons perform LTCBDE as their first choice and use laparoscopic choledochotomy only in the most difficult cases (about 10%), which helps explain why the incidence of complications is higher with laparoscopic choledochotomy.

Discussion

Laparoscopic CBDE has demonstrated its safety, applicability, and cost-effectiveness. The experiences of DePaula, Petelin, Phillips, Franklin, and Millat have shown that the approach is applicable in more than 85% of cases and successful in 85% to 95%. Major complications occur in fewer than 10% of cases, but they include complications associated with laparoscopic cholecystectomy (LC). In our series of 188 patients undergoing LTCBDE two procedure-related complications were experienced, one death ($< 1\%$) in a patient over age 65, and no mortality in patients under age 65. Outcome analysis of open CBDE, LTCBDE, and ES has shown that patients less than 65 years of age do better with LTCBDE. When over 65 years, comparable outcomes are expe-

rienced between patients undergoing LTCBDE and those having ES plus LC.

LTCBDE has many advantages over preoperative or postoperative ES in the treatment of CBD stones. When we compared our patients undergoing LC + LTCBDE (urgent or elective) to those having LC plus ES, we found that patients undergoing LTCBDE have markedly decreased morbidity, length of hospital stay, and cost. The higher cost of perioperative ES is primarily due to the longer hospitalization (12.4 days vs. 6.9 days) and higher morbidity (41% vs. 12%) when compared to LTCBDE [27].

Preoperative prediction of choledocholithiasis is an ongoing problem. A retrospective review of 420 patients who underwent routine intraoperative cholangiography (IOC) looked at potential predictors of choledocholithiasis. A history suggestive of CBD stones had the highest positive predictive value, but it was only 45% [28]. This inability to predict the presence of CBD stones accurately contributes to the higher cost of ES because approximately 50% of patients subjected to preoperative ES are found not to have CBD stones [27]. Thus for each patient undergoing preoperative ES and stone retrieval, another is exposed to potential morbidity unnecessarily. Preoperative ES should be reserved for patients with serious illness, suspected malignancy, or advanced age.

Postoperative ES is an appropriate minimally invasive treatment modality for CBD stones in centers where LTCBDE is not performed and in patients over age 65. In this older group of patients, concomitant illness increases the risk of surgical procedures, thereby favoring ES despite its associated morbidity (bleeding, perforation, pancreatitis). In younger patients, LTCBDE and even open CBDE have lower morbidity and mortality rates than ES. The long-term effects of sphincterotomy in young patients are not yet well known, but a stricture rate of up to 20% has been reported.

The best approach to the detection and treatment of patients with choledocholithiasis is the routine use of IOC and subsequent laparoscopic CBD exploration when indicated. Laparoscopic choledochotomy requires more skill to close the CBD but is an excellent approach to multiple, proximal, or impacted distal stones. Choledochoscopy via the cystic duct may be the safest and most efficacious (90%) approach to the CBD. However, fluoroscopic wire basket retrieval is also effective (60%) in many cases. Placement of a cystic duct tube allows postoperative treatment of retained stones via guidewire-assisted ES, chemical dissolution, or radiologic tube tract extraction. Transampullary biliary tube stents also provide an adjunct to facilitate postoperative ES.

With appropriate instrumentation, education, and training, surgeons can become less reliant on ERC except in situations where it has proved efficacy: suspected malignancy, prohibitive medical illness, worsening pancreatitis, severe obstructive cholangitis. Continued technologic innovation can accelerate the application of these laparoscopic approaches to the CBD, making them the primary treatment modalities in most patients.

Résumé

La cholécystectomie laparoscopique est devenue le procédé de choix pour les cholécystites aiguës et chroniques pour les chirurgiens rompus en chirurgie laparoscopique. Lorsqu'une lithiase de la voie biliaire principale est découverte, le chirurgien laparoscopiste entraîné en techniques laparoscopiques avancées a plusieurs alternatives pour traiter le patient en un seul temps, tout en évitant la morbidité de la sphinctérotomie endoscopique. Bien qu'encore controversé, l'exploration de la voie biliaire principale par voie laparoscopique est sûre, réalisable et coût- efficace dans le traitement de la lithiase de la voie biliaire principale. Cet article détaille les alternatives laparoscopiques du traitement de la lithiase de la voie biliaire principale.

Resumen

La colecistectomía laparoscópica se ha convertido en el procedimiento de elección para el cirujano laparoscopista experto en el manejo de la colecistitits, tanto crónica como aguda. Confrontando un paciente con colédocolitiasis, el laparoscopista consumado posee varias opciones que le permiten el tratamiento en una sola fase y evitan la morbilidad de la esfinterotomía endoscópica. Aunque todavía controvertida, la exploración laparoscópica del colédoco ha demostrado ser un procedimiento seguro, aplicable y costo-efectivo en el tratamiento de la colédocolitiasis. El presente informe detalla las diferentes alternativas en el tratamiento de la colelitiasis.

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