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ORIGINAL ARTICLE

Single-Incision Laparoscopic Common Bile Duct Exploration with Conventional Instruments: an Innovative Technique and a Comparative Study

Shu-Hung Chuang · Pai-Hsi Chen · Chih-Ming Chang · Yung-Fa Tsai · Chih-Sheng Lin

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Abstract

Background Single-incision laparoscopic surgery developed rapidly in recent years. We introduce an innovative technique: single-incision laparoscopic common bile duct exploration (SILCBDE) with conventional instruments. A retrospective comparison between SILCBDE and standard laparoscopic common bile duct exploration (LCBDE) was analyzed.

Methods Thirty-four patients who underwent LCBDE for choledocholithiasis in a period of 17 months were enrolled. Seventeen standard LCBDEs and 17 SILCBDEs were attempted. Simultaneous cholecystectomies were performed.

Results The stone clearance rate was 94.1 % (16 patients) in the standard LCBDE group and 100 % in the SILCBDE group. There was no statistical difference in demographic distribution, clinical presentations, and operative results between the two groups, except the SILCBDE group had a higher rate of acute cholecystitis than the standard LCBDE group (76.5 vs. 35.3 %; $p<0.05$). One procedure (5.9 %) in the SILCBDE group was converted to a four-incision transcystic LCBDE. The complication rate was 11.8 % (two patients) in the standard LCBDE group and 5.9 % (one patient) in the SILCBDE group. The average follow-up period was 4.2 months.

Conclusion SILCBDE is as safe and efficacious as standard LCBDE in experienced hands. Choledochoscope manipulation and bile duct repair are the key skills. Long-term follow-up and further prospective randomized trials are anticipated.

Keywords Choledocholithiasis · Choledochotomy · Common bile duct exploration · Laparoendoscopic single-site surgery · Single-incision laparoscopic surgery · Transcystic

Previous Presentation The preliminary result of this study was presented at the 21st International Congress of the European Association for Endoscopic Surgery (EAES) in Vienna, Austria, 19–22 June 2013.

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Introduction

While laparoscopic cholecystectomy (LC) becomes the standard procedure to treat benign gallbladder disease since 1990s, laparoscopic common bile duct exploration (LCBDE) plays an important role in choledocholithiasis.[1,2] Single-incision laparoscopic surgery (SILS) which is also known as laparoendoscopic single-site (LESS) surgery has been applied in various fields to minimize the traumatic effects in recent two decades. Single-incision laparoscopic cholecystectomy (SILC) is the mostly published SILS to date,[3–5] and its safety, efficacy, and advantage have been verified in many studies.[6–8] However, the present documentation about applying SILS in common bile duct exploration remains rare.[9,10] We herein introduce an innovative technique: single-incision laparoscopic common bile duct exploration (SILCBDE) with conventional instruments. The procedure details were described, and a retrospective comparison between SILCBDE and standard LCBDE was analyzed.

Material and Methods

The first author in this paper developed SILC with conventional instruments in March 2010.[11] Before 2011, our mainstream strategy for choledocholithiasis was endoscopic retrograde cholangiopancreatography (ERCP) and endoscopic sphincterotomy (EST). Open common bile duct exploration was served as a salvage procedure. Since June 2011, we started to adopt LCBDE as an optional treatment for patients with bile duct stone(s). After accomplishing over 100 SILCs and 30 LCBDEs with low complication rates, we developed SILCBDE in July 2012. Then, this novel technique became the routine procedure for choledocholithiasis in our clinical practice.

From October 2011 to February 2013, 41 consecutive patients with gallbladder and bile duct stones underwent LC and LCBDE by a single surgeon at Mackay Memorial Hospital, Hsin-Chu Branch in Hsin-Chu city, Taiwan. Seven patients were excluded from this study: five patients had Mirizzi syndrome (McSherry's classification type II),[12] one patient had liver cirrhosis with portal hypertension, and one patient lost follow-up after his discharge. The remaining 34 patients were divided into two groups according to the attempted procedures. Standard LCBDEs were attempted on the first 17 patients and SILCBDEs were attempted on the other patients. There was no selection criterion to perform a standard LCBDE or a SILCBDE. Patient characteristics, clinical presentations, and operative results were recorded. Both modified APACHE II score[13] and American Society of Anesthesiologists (ASA) classification were used for the preoperative prognostic prediction. The comorbidity referred to major systemic and organ diseases. Known bile duct stone was detected by image study, either abdominal echography or computed tomography (CT) scan. Suspicious bile duct stone was verified by intra-operative cholangiography (IOC) before common bile duct exploration. Stone clearance was ensured by fiber choledochoscopy and completion cholangiography. The operative time was defined as the interval from initial skin incision to skin closure. Postoperative narcotic use was recorded as the intramuscular pethidine dose (milligrams) per kilogram of patient body weight (i.e., 1 mg/kg). The postoperative length of hospital stay (PLOS) was regarded as the duration between the day of surgery and the day of discharge. There was no readmission in this series. Any procedure which failed to be fulfilled as scheduled was considered as converted. The complications were categorized according to the Clavien-Dindo classification.[14]

The above data were analyzed with Pearson's chi-square test and Student's t test. A p value of less than 0.05 was considered statistically significant.

Surgical Technique

Standard Laparoscopic Cholecystectomy and Common Bile Duct Exploration

Besides the operative equipment for standard LC, a 5-mm fiber choledochoscope set and a portable C-arm are needed. A 10-mm 30-cm-long 30-degree laparoscope was inserted via a 10-mm infra-umbilical port for visualization. A 5-mm right flank port served as the gallbladder retraction port. In the setting of a three-incision procedure, this retraction port was replaced with a 5-mm port at the right side of the optic port through the same incision, so the infra-umbilical incision should be 15 to 20 mm in length. A 5-mm epigastrium port and a 5-mm right subcostal port served as the working ports, and the latter should be placed in alignment with the common bile duct to facilitate choledochoscope manipulation. After meticulous dissecting the Calot's triangle, the critical view of safety[15] was achieved and documented by photos. The proximal cystic duct was secured with two 5-mm endoclips. The cystic artery should be preserved to prevent cystic duct disruption due to ischemia during gallbladder retraction. A 5 (mostly used) or 6 French feeding tube was inserted into the peritoneal cavity through the right subcostal port. A small opening was made on the cystic duct to insert the feeding tube. After the tip of the feeding tube reached the common bile duct, the feeding tube was held in place by a 5-mm locked atraumatic grasper through the epigastric port. Bile duct flushing with normal saline was performed to push small or soft bile duct stones into the duodenum and to make sure no bile spillage from the cannulated site on the cystic duct. Then, IOC was performed by a portable C-arm. In case bile duct stone was suspected, we proceeded to explore the common bile duct. Transcystic approach would be adopted if the cystic duct was dilated up to 5 mm in diameter; otherwise, a choledochotomy was performed. In our experience, it was almost impossible to manipulate the fiber choledochoscope without a grasper, especially during a transcystic approach. To prevent damage to the coating, we wrapped the distal part of the 5-mm fiber choledochoscope with Steri-Strips™ (3M Corporate, St. Paul, MN, USA). Besides, we gently held and guided the fiber choledochoscope with a 5-mm atraumatic grasper. During a transcystic approach, the lateral wall of the cystic duct often needed to be opened till the junction with the common bile duct to fit the fiber choledochoscope. Forcing the choledochoscope tip to pass through a narrow opening would cause severe tissue damage. During a choledochotomy approach, a 7- to 10-mm vertical incision was made at the anterior wall of the common bile duct near the junction with the cystic duct. Any stone encountered during the choledochoscopy was retrieved with a stone basket. Impacted stone(s) could be loosened or fragmented with electrohydraulic lithotripsy. After successful removal of the bile duct stone(s), the lateral wall of the cystic duct or the choledochotomy was repaired with interrupted 4-0 absorbable sutures. The small-caliber feeding tube was inserted into the common bile duct again through the small opening on the cystic duct. Leakage test by flushing 20 ml normal saline into the feeding tube detected the small defects, and suture repair was done as needed. Then, completion cholangiogram was taken to ensure stone clearance. Both the distal cystic duct and the cystic artery were secured with 5-mm endoclips and divided. The remaining procedure was the same as that during a standard LC to detach the gallbladder from the liver bed. A closed suction drain was placed at the subhepatic space and passed through the right flank incision (right subcostal incision during a three-incision procedure). The gallbladder was placed into a retrieval bag and extracted through the infra-umbilical incision. All the fascial defects and the skin incisions were closed with sutures. The subhepatic drain would be removed in 48 h after the operation if there was no bile leakage.

Single-Incision Laparoscopic Cholecystectomy and Common Bile Duct Exploration

A 25-mm vertical para-umbilical incision at the left side was made. Three 5-mm ports and a 3-mm port were inserted through four separate fasciotomies in a vertical arrangement. We used two different brands of 5-mm ports (so that the lengths were different) in an interlaced array to reduce port collisions (Fig. 1). The 3-mm port at the second place served as the gallbladder retraction port. A 5-mm 50-cm-long 30-degree laparoscope was inserted via the lower 5-mm port for visualization. The upper and middle 5-mm ports were working ports. The procedures details were similar to those in a standard LCBDE and a SILC[11] except the following. A small-caliber feeding tube was inserted into the peritoneal cavity through the 3-mm port for bile duct flushing, IOC (Fig. 2a, b), and completion cholangiography (Fig. 2c, d). During choledochoscope manipulation (Figs. 1 and 3a, b), the atraumatic grasper passed through the upper 5-mm port and the fiber choledochoscope passed through the middle 5-mm port. During intracorporeal suturing (Fig. 3c), a 5-mm needle holder passed through the upper 5-mm port and a 5-mm curved dissector passed through the middle 5-mm port. Manipulating the instruments in vertical and anterior-posterior directions would minimize the sword fighting and obviate cross hand technique. We used monofilament absorbable sutures to facilitate tying knots. At the end of the procedure, a subhepatic closed suction drain passed through the lowermost fascial defect which was diminished by 2-0 absorbable sutures to prevent an incisional hernia. The middle 5-mm port was upgraded to a 10-mm reusable port for specimen extraction. All the fascial defects and the skin incision were closed with interrupted sutures (Fig. 3d). The subhepatic drain would be removed in 48 h after the operation as well in case of no bile leakage. Because only conventional instruments were used, the operation could be converted to a multi-incision or open procedure easily and rapidly if patient safety was doubtful.

Results

The demographic distribution and clinical presentations showed no statistical difference between the standard LCBDE group and the SILCBDE group except the latter group had a higher rate of acute cholecystitis than the former group (76.5 vs. 35.3 %; $p<0.05$) (Table 1). The bile duct stone(s) was(were) documented by preoperative image studies in five patients (29.4 %) in the standard LCBDE group and seven patients (41.2 %) in the SILCBDE group, while IOC confirmed the diagnosis in the remaining 22 patients. Stone removal was fulfilled by transcystic route in seven patients (41.2 %) in the standard LCBDE group and two patients (11.8 %) in the SILCBDE group, while choledochotomy was performed in the remaining 25 patients (Table 2). The stone clearance rate was 94.1 % (16 patients) in the standard LCBDE group and 100 % in the SILCBDE group. Three patients (17.6 %) in the standard LCBDE group and one patient (5.9 %) in the SILCBDE group had a pathologic diagnosis of complicated cholecystitis (gangrene and/or empyema). There was no statistical difference between the two groups in operative time, estimated blood loss, pethidine dose, and PLOS. One procedure (5.9 %) in the SILCBDE group was converted to a four-incision transcystic LCBDE which was the only conversion in this series. No procedure was converted to an open operation.

There were five complications that happened to three patients in this study (Table 2). The difference in the complication rates was statistically insignificant between the two groups (11.8 % in the standard LCBDE group and 5.9 % in the SILCBDE group). One patient in the standard LCBDE group developed a self-limited minor bile leak and an infected subphrenic collection which was managed with percutaneous pigtail drainage and intravenous antibiotics. According to the Clavien-Dindo classification,[14] this complication was classified as grade IIIa. The other patient in the standard LCBDE group developed a minor bile leak which stopped on the third postoperative day (Clavien-Dindo classification grade II). Both of them underwent choledochotomies. One patient in the SILCBDE group had dense adhesions at the cystocholedochal junction (frozen Calot's triangle), and the procedure was converted to a standard LCBDE at an early stage to facilitate a retrograde cholecystectomy and a transcystic bile

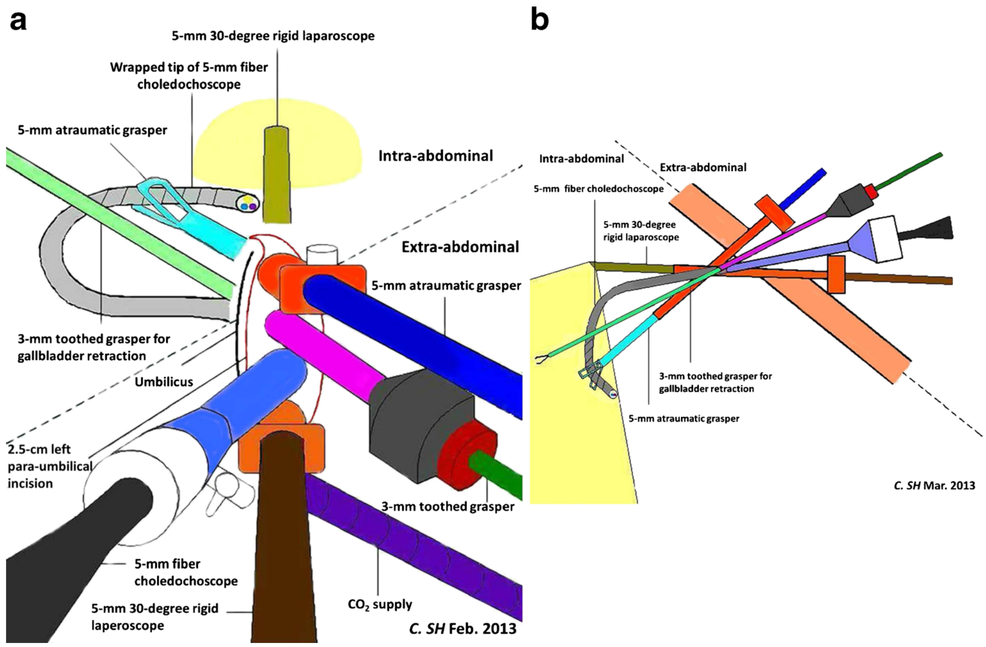

Fig. 1 Drawings of choledochoscope manipulation during a SILCBDE. **a** Front view. The intra-abdominal parts of the instruments were dyed with light colors. **b** Lateral view from the patient's right side

duct exploration. He developed a minor bile leak which stopped on the fourth postoperative day and a self-limited duodenal ulcer hemorrhage which responded to intravenous proton pump inhibitor therapy and blood transfusion (Clavien-Dindo classification grade II). The average follow-up period in this study was 4.2 months (0.5–15 months).

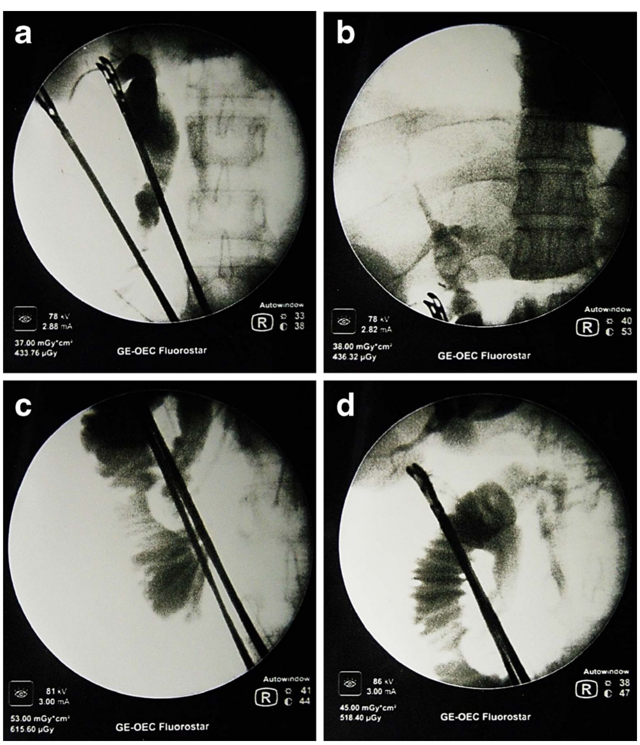

Fig. 2 IOC. **a**, **b** Transcystic cholangiograms showed multiple stones in the bile duct and poor visualization of the duodenum. **c**, **d** Completion cholangiograms showed no residual bile duct stone and no bile leakage

Discussion

SILS or LESS surgery has been applied in various fields worldwide in recent two decades, and most of the results were promising.[3–5] As common bile duct exploration has been introduced for more than 100 years, LCBDE became an effective but technique-demanding procedure for choledocholithiasis in the laparoscopic era. However, documentation about applying SILS in common bile duct exploration remains rare.[9,10] In our experience, there are two major obstacles to a SILCBDE: choledochoscope manipulation and bile duct repair. In a standard LCBDE, the fiber choledochoscope passes through the right subcostal port to reach the bile

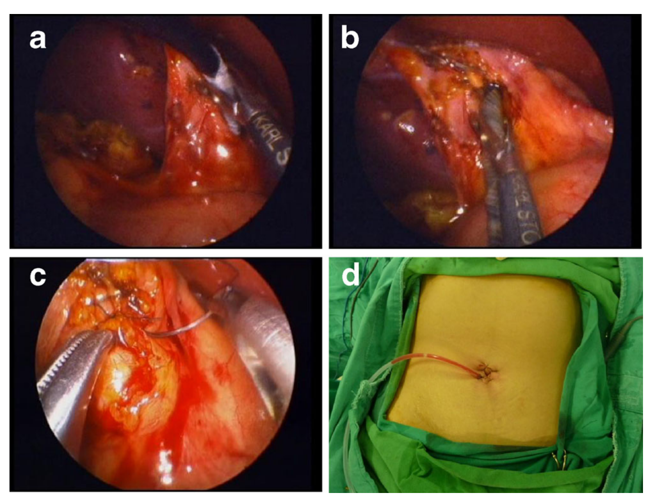

Fig. 3 Photographs of SILCBDE. **a** Choledochoscope manipulation during a distal exploration of the bile duct. **b** Proximal exploration of the bile duct. **c** Primary closure of choledochotomy. **d** Closed para-umbilical incision with a subhepatic drain in place

Table 1 Patient characteristics and clinical presentations

	Standard LCBDE (n=17)	SILCBDE (n=17)	p
Age (years)	46.6±15.4	46.1±15.3	0.930
Gender (M/F)	7:10	7:10	1.000
Body mass index (kg/m^2)	25.97±3.26	24.46±3.55	0.207
Modified APACHE II score, n (%)			0.310
0–5, low risk	16 (94.1)	17 (100)	
6–9, intermediate risk	1 (5.9)	0	
10–11, high risk	0	0	
ASA classification, n (%)			0.147
1	1 (5.9)	5 (29.4)	
2	13 (76.5)	11 (64.7)	
3	3 (17.6)	1 (5.9)	
≧4	0	0	
Comorbidity, n (%)	5 (29.4)	4 (23.5)	0.697
Previous abdominal operation, n (%)	5 (29.4)	5 (29.4)	1.000
Jaundice, n (%)	8 (47.1)	11 (64.7)	0.300
Acute cholecystitis, n (%)	6 (35.3)	13 (76.5)	0.016*
Pancreatitis, n (%)	3 (17.6)	0	0.070
Acute cholangitis, n (%)	4 (23.5)	1 (5.9)	0.146
WBC count ≧11,000 mm^3, n (%)	4 (23.5)	1 (5.9)	0.146
Abnormal liver function tests, n (%)	15 (88.2)	16 (94.1)	0.545
Common bile duct diameter (mm)	9.35±3.00	9.54±2.64	0.847
Known bile duct stone, n (%)	5 (29.4)	7 (41.2)	0.473
Suspicious bile duct stone, n (%)	12 (70.6)	10 (58.8)	0.473

LCBDE laparoscopic common bile duct exploration, *SILCBDE* single-incision laparoscopic common bile duct exploration, *ASA* American Society of Anesthesiologists, *WBC* white blood cell

*p<0.05

duct in a right angle. This facilitates distal and proximal explorations of the bile duct. In contrast, the fiber choledochoscope passes through the (para-)umbilical port to reach the bile duct in a SILCBDE. It is almost impossible to insert the choledochoscope into the bile duct in a sharp angle without grasper guidance. However, the fiber

Table 2 Operative modifications and results

	Standard LCBDE (n=17)	SILCBDE (n=17)	p
Bile duct exploration route, n (%)			0.052
Transcystic	7 (41.2)	2 (11.8)	
Choledochotomy	10 (58.8)	15 (88.2)	
Completion cholangiogram, n (%)	17 (100)	15 (88.2)	0.145
Stone clearance, n (%)	16 (94.1)	17 (100)	0.310
Number of stone extracted	1.4±0.8	2.4±3.6	0.274
Gallbladder pathology, n (%)			0.008*
Gangrene/empyema	3 (17.6)	1 (5.9)	
Acute inflammation	3 (17.6)	12 (70.6)	
Mild acute/chronic inflammation	11 (64.7)	4 (23.5)	
Operative time (min)	237±59	261±71	0.292
Estimated blood loss (ml)	31.2±57.6	28.8±45.9	0.896
Pethidine dose (mg/kg)	0.959±1.292	0.687±0.514	0.424
Post-operative length of hospital stay (days)	4.8±2.5	3.7±1.5	0.117
Conversion, n (%)			0.310
Standard LCBDE	–	1 (5.9)	
Open LCBDE	0	0	
Complication, n (%)	2 (11.8)[a]	1 (5.9)[b]	0.545

LCBDE laparoscopic common bile duct exploration, *SILCBDE* single-incision laparoscopic common bile duct exploration

*p<0.01

[a] One was minor bile leak and infected subphrenic collection; the other was minor bile leak

[b] Minor bile leak and self-limited duodenal ulcer hemorrhage

choledochoscope is so delicate that grasping may damage its coating. Therefore, we wrapped the choledochoscope tip with Steri-Strips™ (3M Corporate, St. Paul, MN, USA) and used an atraumatic grasper to avoid the damage (Figs. 1 and 3a, b). Only partial Steri-Strips™ would enter the bile duct during the choledochoscopic bile duct exploration, so the entire Steri-Strips™ could be easily removed from the bile duct in case of distal sloughing. Once sloughing of the Steri-Strips™ was detected (even minimum), we renewed it immediately. During distal exploration of the bile duct in a SILCBDE, the choledochoscope reaches the bile duct in an inverted U curve (Fig. 3a). The operator should manipulate the choledochoscope tip in or out the bile duct with the atraumatic grasper. Pushing in or pulling out the choledochoscope in a wrong direction may cause laceration at the choledochotomy. During a proximal exploration of the bile duct, the choledochoscope reaches the bile duct in a straight line (Fig. 3b). The operator can push in or pull out the choledochoscope easily without grasper guidance.

Traditionally, the choledochotomy was closed on a T-tube which passed through the right subcostal incision. That means SILCBDE is essentially infeasible. However, many recent studies documented the safety and the advantages of primary bile duct closure without T-tube drainage.[16,17] We performed primary closure after choledochotomy in the majority of our patients since we began to adopt LCBDE for choledocholithiasis in June 2011. During a SILCBDE, bile duct repair via a single incision became a challenging problem. We found inserting ports in a vertical array could minimize the collisions in horizontal movements. Manipulating a needle holder and a curved dissector in vertical and anterior–posterior directions made tying knots easier (Fig. 3c). Monofilament absorbable sutures were preferable. Practicing this skill in a training box before applying it to a human being is strongly recommended. To avoid bile leakage, we closed the choledochotomy with interrupted suturing (1 mm per stitch). The following leakage test detected small defects, and suture repair would be performed as needed. In case small-diameter (less than 6 mm) or severely inflamed bile duct, which has been considered as a contraindication for chodedochotomy, was identified before bile duct exploration during a SILCBDE, transcystic approach or postoperative ERCP with EST will be adopted. If postoperative bile duct narrowing is concerned after a choledochotomy performed in a SILCBDE (this situation was not encountered in this study), the procedure should be converted to a standard LCBDE to facilitate T-tube drainage.

According to the 2010 Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) guideline for the clinical application of laparoscopic biliary tract surgery,[18] introduction of new instruments, access devices, or new techniques should be done with caution. We followed this guideline strictly in the clinical practice. Before developing a SILCBDE in July 2012, we had accomplished over 100 SILCs and 30 LCBDEs to pass through the learning curves. The complication rates were low. Because only conventional instruments were used in a SILCBDE, this economical procedure could be easily and rapidly converted to a multi-incision or open operation for safety concerns. We emphasized a low threshold for conversion, as the 2010 SAGES guideline recommended.

The SILCBDE group had an insignificantly longer operative time than the standard LCBDE group (261±71 vs. 237±59 min; $p=0.292$) (Table 2). Although the difference may reach statistical significance if the sample size is large enough, it is too early to make the conclusion. We are still in the learning curve to perform a SILCBDE. Besides, the SILCBDE group had a higher rate of acute cholecystitis than the standard LCBDE group (76.5 vs. 35.3 %; $p<0.05$) (Table 1), and removing an acute inflamed gallbladder was more time consuming. The long operative time in our series can be explained by the high rate of acute cholecystitis (55.9 %, overall), routine leakage tests, and completion cholangiograms after bile duct repair, and the time-consuming portable C-arm. In our hospital, patients with complicated choledocholithiasis tended to be referred to the general surgeons. Otherwise, ERCP and EST followed by elective LC would be arranged. Because ERCP and EST cannot solve the problem of concomitant acute cholecystitis, one-stage laparoscopic surgery (LC and LCBDE) is more suitable for these complicated situations.[19] As a fragile cystic duct would hinder a transcystic bile duct exploration, the low rate of transcystic route (26.5 %, overall) could be mainly explained by the high rate of acute cholecystitis (55.9 %, overall) in our study. Another reason was not using balloon dilatation, which has been introduced to facilitate a transcystic approach.[20] We emphasize the importance of routine leakage tests and completion cholangiograms after bile duct repair. In our experience, reinforced repair of the bile duct after a positive leakage test was often necessary. We believe this can decrease bile leakage rate and obviate a major leak. The fact that we only had three patients with minor bile leak in this series supports our opinion. In the past, postoperative T-tube cholangiography detected retained bile duct stones and fiber choledochoscopy removed the stones through the T-tube tract in most cases. Nowadays, primary closure of the bile duct becomes the preferred procedure. Two latest meta-analyses concluded that primary closure of the bile duct is superior to T-tube drainage in terms of overall postoperative complications, operative time, and postoperative hospital stay in laparoscopic choledochotomy.[16,17] Documentation of stone clearance by a completion cholagiogram becomes reasonable and minimizes the rate of retained bile duct stones. The high stone clearance rates (94.1 % in the standard LCBDE group and 100 % in the SILCBDE group) in our study support our claim. The portable C-arm is inconvenient to set up for cholangiography during an operation, and keeping sterilization is a big problem.

Intraoperative fluoroscopy seems to be a better solution, and it can save much operative time.[2,21]

The SILCBDE group had a shorter PLOS than the standard LCBDE group (3.7±1.5 vs. 4.8±2.5 days; $p=0.117$) in this study, but the difference failed to achieve statistical significance. The postoperative narcotic dose was also insignificantly lower in the SILCBDE group than that in the standard LCBDE group (0.687±0.514 vs. 0.959±1.292 mg/kg; $p=0.424$). However, this study is only our preliminary report. A retrospective study with small sample size is the limitation. As the safety and efficacy of SILCBDE has been addressed, we would proceed to pass through the learning curve of this novel technique. Subsequent prospective randomized trials are anticipated to clarify the potential benefits of SILCBDE other than the cosmetic advantage.

Conclusion

According to our study, SILCBDE with conventional instruments is as safe and efficacious as standard LCBDE for choledocholithiasis in experienced hands. Choledochoscope manipulation and bile duct repair are the key skills. Before applying this novel technique in clinical practice, a surgeon must be proficient in both SILC and LCBDE. A low threshold for converting the procedure should be maintained for patient safety. The potential benefits of this novel technique other than the well-known cosmetic advantage need further investigation. Long-term follow-up and larger prospective randomized trials are anticipated.

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