How I Do It: Simplified Transcystic Antegrade-only Robotic Common Bile Duct Exploration (RCBDE)

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Background: Data consistently supports a surgery-first approach to common bile duct (CBD) stones in patients with a gallbladder via laparoscopic CBD exploration (LCBDE). LCBDE has equivalent efficacy and decreased cost as compared with cholecystectomy plus endoscopic retrograde cholangiopancreatography (ERCP). However, adoption has been low due to the technical limitations of laparoscopy. We describe a straightforward and highly reproducible robotic CBDE (RBCDE) technique.

Methods: A cystic ductotomy is made after obtaining a critical view of safety. Through a 5 mm port, a wire-ready cholangiogram catheter is secured in the cystic duct and intraoperative cholangiogram performed. Based on stone burden, small versus large, either an antegrade balloon snowplow (push stones forward) or sphincteroplasty is performed over a wire under fluoroscopy. If concern persists for retained stones, choledochoscopy is performed.

Conclusions: Our simplified antegrade-only RCBDE technique allows surgeons to consistently offer a surgery-first, single-stage approach to CBD stones in patients with a gallbladder.

Key Words: robotic surgery, robotic cholecystectomy, robotic transcystic common bile duct exploration, choledocholithiasis, common bile duct exploration

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Choledocholithiasis or common bile duct (CBD) stones occur in up to 20% of patients requiring cholecystectomy but are difficult to predict preoperatively.[1–3] The American Society for Gastrointestinal Endoscopy (ASGE) has tried to identify high-risk patients for choledocholithiasis based on clinical, imaging, and lab findings. However, data has repeatedly shown that these lab and imaging findings are not predictive.[4–6] This is troublesome, as patients are often recommended to undergo a separate endoscopic retrograde cholangiopancreatography (ERCP), which carries significant risk.[7] These ERCP's often have negative findings or findings that could have easily been managed at the time of surgery, supporting a "surgery-first" approach which significantly limits the need for additional procedure(s) (Supplemental Digital Content 1, http://links.lww.com/SLE/A461).[8]

"Surgery first" for choledocholithiasis starts with an intraoperative cholangiogram (IOC) to first confirm the presence of CBD stones. Then a CBD exploration (CBDE) can be performed, offering a single-stage intervention.[9] Laparoscopic CBDE (LCBDE) with cholecystectomy has been repeatedly shown to have equivalent safety and efficacy with decreased cost and hospital length of stay as compared with the multistaged approach with ERCP.[10–13] Despite these advantages, adoption of LCBDE has remained low, secondary to logistical challenges and lack of training.

The robotic platform lessens the barriers of LCBDE with wristed instruments and more controlled movement. However, previously reported robotic CBDE (RCBDE) techniques have been choledochoscope-driven with retrograde stone extraction, which can be impractical or perforate the duct. They also describe using a trans-CBD (choledochotomy) approach instead of transcystic (cystic ductotomy), which is intimidating to many. This paper highlights a reproducible, straightforward technique that is entirely minimally invasive, transcystic, antegrade-only (ie, all stones pushed forward into the duodenum as is done in ERCP), and fluoroscopic-guided with balloons over wires.

This manuscript describes the steps and logistics involved in our simplified RCBDE technique. This project was undertaken as a Quality Improvement Initiative. All patients gave informed consent preoperatively.

METHODS

Preoperative Workup

Patients underwent selective IOC during cholecystectomy if at risk for choledocholithiasis, as predicted via multiple risk factors. These include an obstructive liver function test (LFT) pattern, abnormal dilation of the CBD or CBD stones on imaging [ultrasound, CT, or magnetic retrograde cholangiopancreatography (MRCP)], or clinical findings of gallstone pancreatitis or cholangitis.[4] An IOC was also performed on any patient with aberrant foregut anatomy (eg, gastric bypass).

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Equipment

The cholecystectomy is performed with the DaVinci Xi Robotic platform. Cholangiography is performed with a C-arm using a wire-ready catheter system that includes a 5 or 6-Fr ureteral stent connected to a Tuohy borst adapter that is attached to short IV tubing with a 3-way stop cock.[14] For contrast, iohexoL (Omnipaque) 350 mg iodine/mL injection mixed 50:50 with saline is used. We use a wire (eg, Bentson, Boston Scientific, etc.) that is 0.035" thick with a floppy hydrophilic tip that is at least 150 cm in length. For balloons, the Boston Scientific Extractor Pro RX-S injects above retrieval balloon catheter or the 6 cm length Mustang over the wire PTA balloon dilatation catheter. Balloon diameter size is selected based on the largest stone or CBD at the greatest diameter. When choledochoscopy is required, a reusable Karl Storz 8.5 Fr video choledochoscope or a disposable ureteroscope is used.

Procedure

A standard robotic and fluoroscopic compatible operating room (OR) table is used. The patient is positioned supine with arms tucked on a nonslip pad. The OR table is maximally slid toward the head. After abdominal entry, the patient is positioned 17 degrees in reverse Trendelenburg and 7 degrees left tilt. Four 8 mm robotic ports are placed horizontally at the level of the umbilicus, with one at Palmer's point. Arm 1 contains a fenestrated bipolar, arm 2 camera, arm 3 scissors, and arm 4 prograsp (Fig. 1). The robot is docked on the patient's left, and arm joints are swung out widely, away from the midpoint between arms 2 and 3 to later accommodate a C-arm in-between these arms.

After a critical view of safety is achieved, the cystic artery is ligated and divided. The cystic duct is clipped at the gallbladder neck. A cystic ductotomy is made on the anterior wall 3-5 mm distal to the clip using scissors coming from the left with the scissor tip beveled toward the CBD to the right. This makes it easier to thread in the IOC catheter towards the CBD. A 5 mm port is placed medial to arm 2 adjacent to the umbilicus. The wire-ready cholangiogram catheter system is inserted through the 5 mm port and placed into the cystic duct, and a robotic grasper then clamps across the duct and catheter. The C-arm is brought in above the patient's head and placed centrally between arms 2 and 3, and an IOC is performed (Fig. 2). If the cholangiogram is positive—stones are seen or no filling of the duodenum appreciated—we proceed with our RCBDE algorithm (Fig. 3).

Interventions

Wire Sweep and Power Flush

The patient is first given glucagon. Next, the guidewire is threaded through the ureteral stent into the duodenum with a robotic grasper under fluoroscopic guidance using tilepro. If resistance is met, the ureteral stent is threaded over the wire more distally, and then wire entry into the duodenum is reattempted. We make three passes of either the wire alone or wire plus ureteral stent across the ampulla into the duodenum under fluoroscopic guidance. A power flush is then performed with a rapid injection of 30 mL of saline above the previous stone burden. The IOC is then reshot, and if still positive, we proceed to the next step in our RCBDE algorithm.

Balloon Snowplow

If a small stone burden is present (<3 stones and all ≤ 4 mm), we proceed with a balloon Snowplow (Fig. 4).[15] The wire is reinserted into the duodenum with excessive redundancy under fluoroscopy with tilepro. Over the wire, an Extractor Pro RX-S 9 mm/12 mm balloon is inserted into the mid-CBD. Under fluoroscopy, the balloon is inflated with air until it reaches the diameter of the CBD. Next, while injecting contrast, the balloon is pushed forward by a

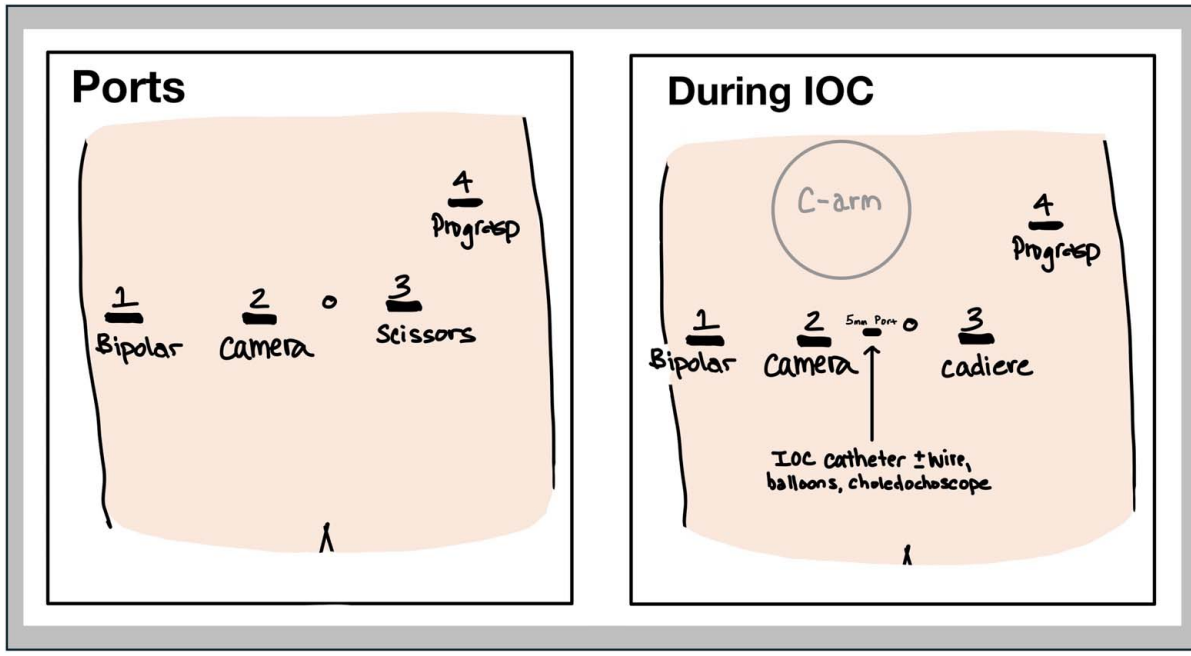

FIGURE 1. Robotic trocar placement and instruments during initial dissection and cholangiogram. IOC indicates intraoperative cholangiogram. Drawing created by author Eleah D. Porter.

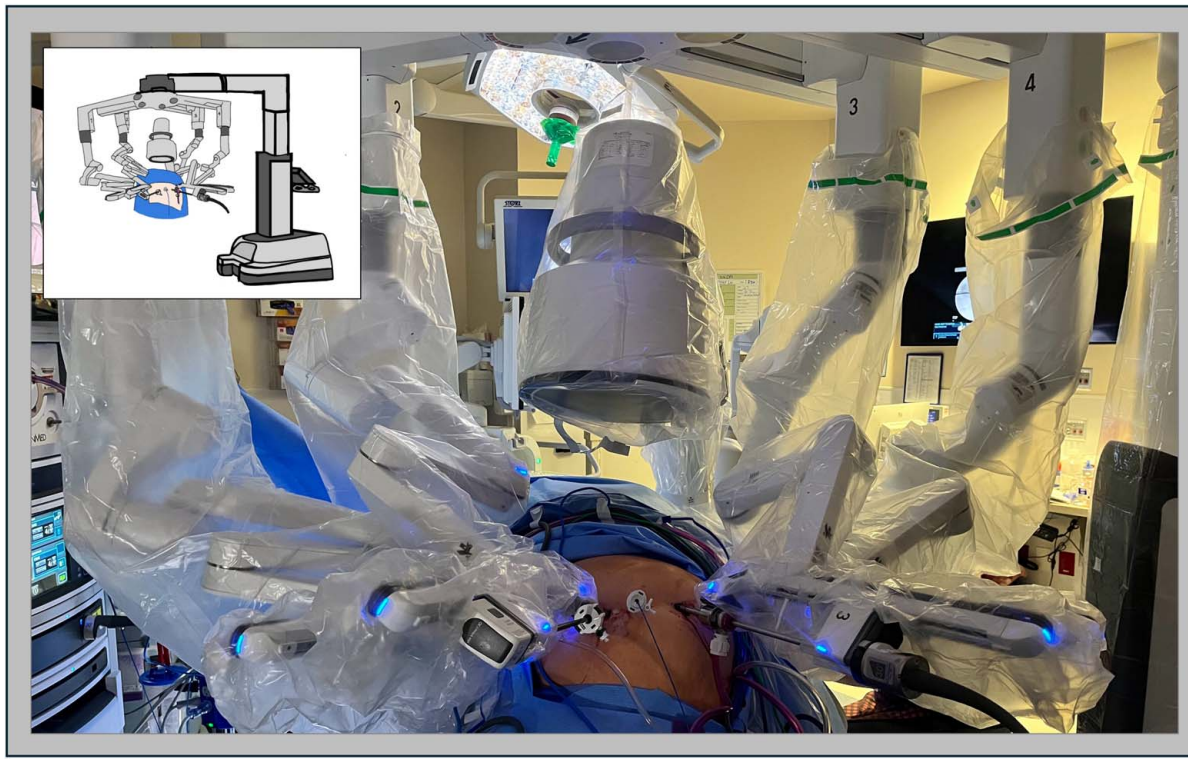

FIGURE 2. C-arm placement during cholangiogram and common bile duct exploration. Drawing created by author Eleah D. Porter. Intraoperative photos are proprietary images owned by the study team.

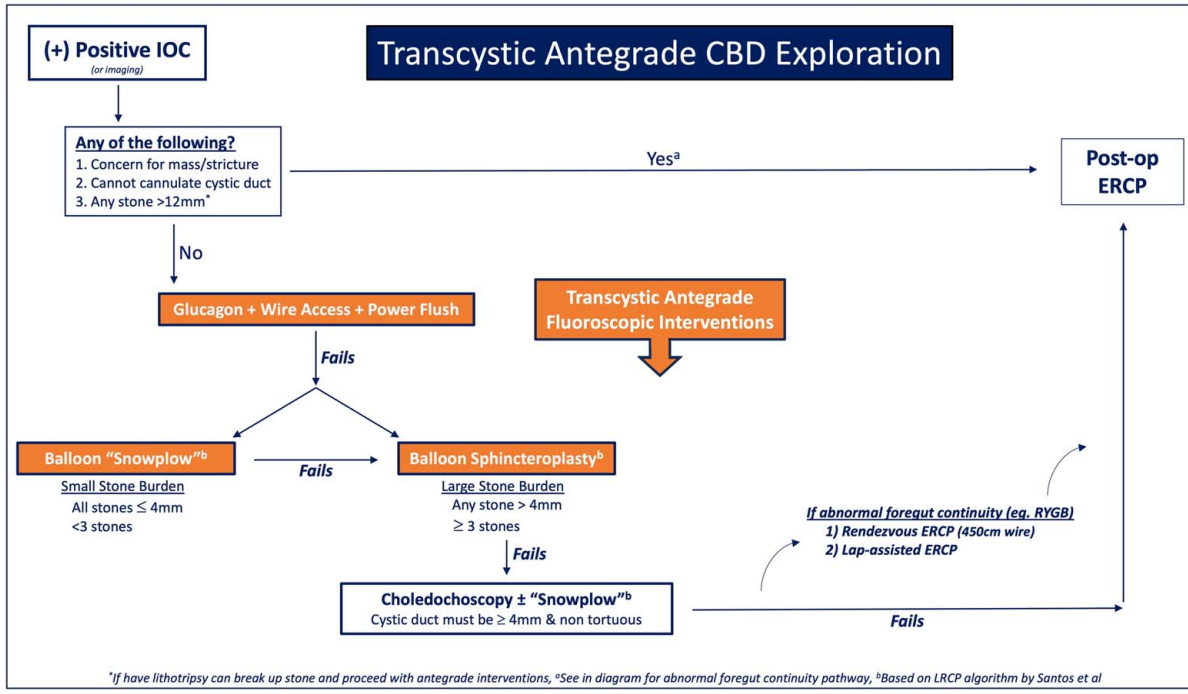

FIGURE 3. Transcystic antegrade CBD exploration intervention algorithm. CBD indicates common bile duct; ERCP, endoscopic retrograde cholangiopancreatography; IOC, intraoperative cholangiogram.

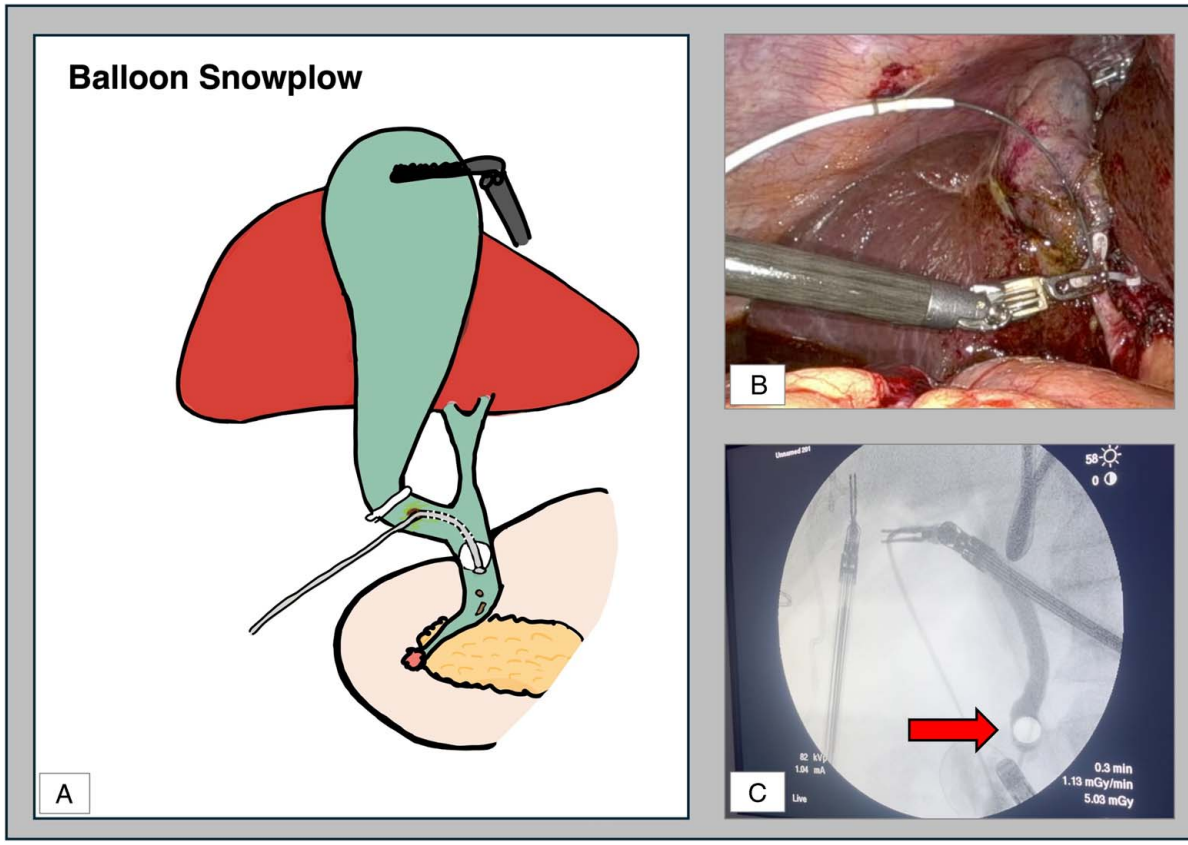

FIGURE 4. Balloon Snowplow. A, Cartoon of technique pushing stones antegrade from the common bile duct into the duodenum. B, Insertion of the Boston Scientific Extractor Pro RX-S injects above retrieval balloon catheter over the wire. C, Cholangiogram showing balloon inflated (red arrow) above stones at distal common bile duct pushing the stones antegrade into the duodenum. Drawing created by author Eleah D. Porter. Intraoperative photos are proprietary images owned by the study team.

robotic grasper under fluoroscopy, pushing CBD stones antegrade until entering the duodenum, which may require letting out small amounts of air in the balloon. The balloon is then retracted above the previous stone burden and reinflated, a 10 mL power flush of saline is administered, and a repeat IOC is performed.

Balloon Sphincteroplasty

If a balloon snowplow is unsuccessful or if there was a large stone burden initially (≥ 3 stones or any stone > 4 mm), a balloon sphincteroplasty is performed (Fig. 5). The wire is inserted into the duodenum with excessive redundancy. A Mustang over-the-wire PTA balloon dilatation catheter is selected based on the greatest diameter of the CBD or the largest stone up to 12 mm. The stone or CBD size is estimated by comparing to the 8 mm robotic instrument on fluoroscopy. The balloon is threaded over the wire using fluoroscopy and tilepro and positioned with markers across the ampulla, as described previously.[16] Once appropriately positioned, a robotic grasper clutches the balloon catheter and freezes. As the balloon is inflated, a waist sign should appear indicating proper placement across the ampullary sphincter that lasts for ~5 seconds and then disappears. The balloon is inflated to manufacturing guidelines of atmospheres of pressure for the nominal diameter effect (typically 10 atm) and a timer is set for 3 minutes. The balloon is then deflated and removed. The IOC catheter system is reinserted, and a power flush and completion IOC are performed.

Choledochoscopy

If the concern persists for retained stones and cystic duct anatomy is favorable (≥ 4 mm and nontortuous), a choledochoscopy is performed. A reusable Karl Storz 8.5 Fr video choledochoscope or a disposable ureteroscope is guided into the cystic duct over the wire into the CBD. If stones present, the choledochoscope is used to either push or grasp stones with a basket and push them antegrade into the duodenum (ie, a "Snowplow" maneuver). We specifically avoid retrograde stone removal as this can perforate the cystic duct/CBD junction. In the rare event choledochoscopy is unsuccessful, the patient is scheduled for a postop ERCP.

After the RCBDE, the C-arm and catheter system are removed, and cholecystectomy is completed.

Postprocedural Care

Patients are currently admitted for at least 1 night postoperatively. Diets are advanced and LFTs and lipase are obtained.

PRELIMINARY OUTCOMES AND DISCUSSION

Since initiating our RCBDE algorithm in March 2023, we have performed 41 cases with a $> 92\%$ success rate

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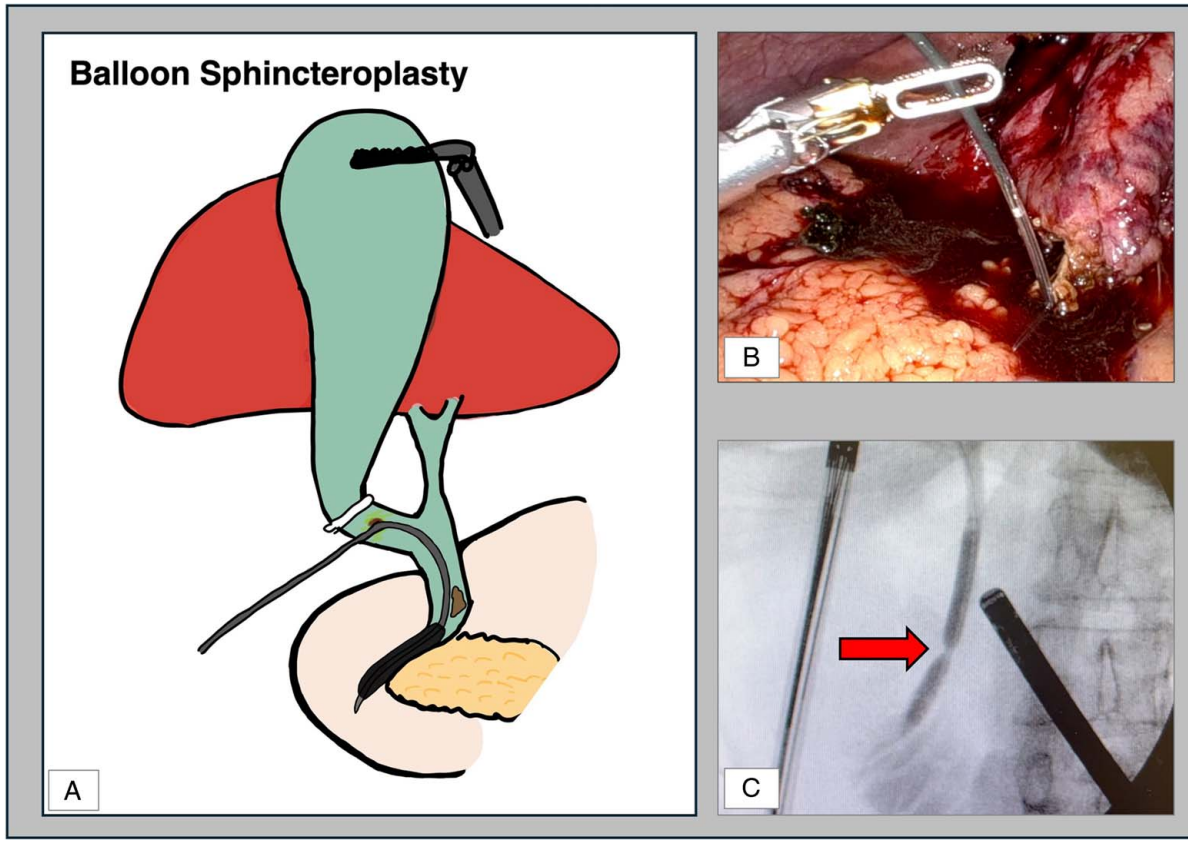

FIGURE 5. Balloon sphincteroplasty. A, Cartoon of technique dilating the ampullary sphincter to allow common bile duct stones to flow antegrade into the duodenum. B, Insertion of the Boston Scientific Mustang over the wire PTA balloon dilatation catheter into the cystic duct over the wire. C, Cholangiogram showing the "waist" sign (red arrow) at the ampullary sphincter indicating appropriate positioning for sphincteroplasty. Drawing created by author Eleah D. Porter. Intraoperative photos are proprietary images owned by the study team.

(no postop ERCP required) and only 1 complication requiring reoperation. This was a bile leak managed with a return to the operating room for a washout and endo loop placement ligating the cystic duct. While interventions were not mutually exclusive, when assessing the success rate of the step-up approach (n = 38), 13.2% (5) only required a wire sweep, 5.3% (2) were successful with a balloon snowplow, 55.3% (21) were successful with a balloon sphincteroplasty, and 26.3% (10) were successful with choledochoscopy (Table 1).

There was an initial learning curve with both robotic IOC set-up and instrumentation. The CBDE portion of the case initially took between 1 and 2 hours. However, on average after 40 cases, a robotic IOC takes 5 minutes, a step-up to balloon sphincteroplasty takes 15 minutes, and choledochoscopy takes 30 minutes.

TABLE 1. Comparison Between RCBDE Algorithm Interventions

	n (%)			
	Wire sweep and power flush (n = 6)	**Snowplow (n = 2)**	**Sphincteroplasty (n = 22)**	**Choledochoscopy (n = 11)**
Demographics				
Male sex	3 (50.0)	1 (50.0)	4 (18.2)	3 (27.3)
Age > 65	3 (50.0)	1 (50.0)	9 (40.9)	6 (54.5)
Any comorbidity	4 (66.7)	1 (50.0)	11 (50.0)	10 (90.9)
CBDE				
Large stone burden	2 (33.3)	0 (0.0)	19 (86.4)	10 (90.9)
CBDE success*	5 (83.3)	2 (100.0)	21 (95.5)	10 (90.9)
Any complication†	1 (16.7)	0 (0.0)	2 (9.1)	3 (27.3)

*CBDE success is defined as not requiring postoperative ERCP to clear stones. Of note, interventions in the table are for mutually exclusive events of only the final intervention performed.

†Complications included those after failed CBDE and subsequent ERCP-related complications.

CBDE indicates common bile duct exploration; RCBDE, robotic common bile duct exploration.

CONCLUSIONS

A simplified transcystic, antegrade-only, and fluoroscopic-guided RCBDE technique may represent a paradigm shift for CBD stone management. Advantages of our RCBDE over LCBDE include improved visualization, ability to freeze during interventions, requirement of only 1 skilled operator, and wristed instruments that more easily manipulate wire-guided equipment. Our technique mitigates the risks of previously described robotic techniques with trans-CBD entry or choledochoscope reliant retrograde stone extraction. To our knowledge, our seldinger and fluoroscopic predominant technique has never been described before. It allows the general surgeon to safely manage choledocholithiasis in a surgery-first, single-stage approach during cholecystectomy and subverts the need for separate procedures such as ERCP.

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