ELSEVIER

Surgery for Obesity and Related Diseases ■ (2021) 1–14

SURGERY FOR OBESITY AND RELATED DISEASES

ASMBS Guidelines/Statements

Biliopancreatic access following anatomy-altering bariatric surgery: a literature review

Pavlos Papasavas, M.D.[a,*], Salvatore Docimo, Jr., D.O.[b], Rodolfo J. Oviedo, M.D.[c], Dan Eisenberg, M.D.[d], for the American Society for Metabolic and Bariatric Surgery Clinical Issues Committee

[a]*Division of Metabolic and Bariatric Surgery, Hartford Hospital, Hartford, Connecticut*
[b]*Division of Bariatric, Foregut, and Advanced GI Surgery, Stony Brook Medicine, Stony Brook, New York*
[c]*Department of Surgery, Houston Methodist, Houston, Texas*
[d]*Department of Surgery, Stanford University and Palo Alto VA Health Care Center, Palo Alto, California*

Received 11 September 2021; accepted 19 September 2021

The American Society for Metabolic and Bariatric Surgery (ASMBS) issues the following literature review for the purpose of enhancing quality of care in bariatric surgery. This publication examines the currently available literature regarding how to access the biliopancreatic system following bariatric surgery procedures. The intent of issuing such a review is to provide an objective summary of current literature that examines the advantages and disadvantages of the various existing techniques to access the excluded gastrointestinal (GI) tract. The review may be revised in the future should additional evidence become available. This review is not intended to serve as training, a standard of care, or scientific consensus. It is the responsibility of professionals to determine the appropriate patient plan of care.

Several bariatric surgery procedures alter the proximal gastrointestinal system anatomy rendering access to the ampulla of Vater for endoscopic retrograde cholangiopancreatography (ERCP) challenging. These procedures include Roux-en-Y gastric bypass (RYGB), single-anastomosis gastric bypass (SAGB), biliopancreatic diversion (BPD), BPD with duodenal switch (BPD-DS), and single-anastomosis variations of the duodenal switch (SADS). The major challenge for the endoscopist is the length of the small bowel that needs to be traversed to reach the ampulla of Vater. There are many indications for an ERCP following bariatric surgery including common bile duct stones, sphincter of Oddi dysfunction (SOD), benign or malignant biliary strictures, complications of cholecystectomy, and pancreatic diseases among others. The most common indication is choledocholithiasis. The incidence of gallstone formation following RYGB ranges from 28%–71%, with most studies reporting an approximate incidence of 30% [1–3]. In the general population, the risk of patients with incidental gallstones developing biliary symptoms averages 1%–2% per year [4]. As many as 10% of individuals with biliary stone disease may present with choledocholithiasis [5]. Studies have shown that the common bile duct dilates following RYGB, and patients may develop SOD symptoms [6,7]. The mechanism of this change is unclear. Although ERCP is the most common endoscopic procedure performed that requires access to the excluded portion of the GI system, other endoscopic procedures may be necessary including biopsies, resection of benign or malignant tumors, endoscopic ultrasonography (EUS), and drainage of pancreatic pseudocysts.

Various techniques have been developed to overcome the technical difficulties associated with performing an ERCP on patients with surgically altered anatomy due to bariatric surgery. Close collaboration between the bariatric surgeon and the endoscopist (who is often a gastroenterologist) is important in determining the best approach to access the excluded GI tract.

The purpose of this paper is to review the literature on the available techniques to access the biliopancreatic system following bariatric surgery and report on their outcomes. These techniques can be broadly categorized into:

*Correspondence: Pavlos K. Papasavas, M.D., Hartford Hospital, 80 Seymour Street, Hartford, CT 06106.
E-mail address: pavlos.papasavas@hhchealth.org (P. Papasavas).

https://doi.org/10.1016/j.soard.2021.09.011

1. Device-assisted enteroscopy ERCP (DAE-ERCP)
2. Laparoscopic-assisted/transgastric ERCP (LA-ERCP)
3. Gastrostomy-assisted ERCP
4. Endoscopic ultrasound directed transgastric ERCP (EDGE)
5. Trans-enteric approaches
6. Surgical bile duct exploration
7. Trans-biliary approaches

Device-assisted enteroscopy ERCP

Device-assisted enteroscopy, also known as "deep endoscopy," is a technique that allows for the deep insertion of an endoscope into the small bowel for mucosal evaluation. The use of a pediatric colonoscope to perform ERCP in nonbariatric patients with Roux-en-Y anatomy was first reported by Gostout and Bender in 1988 [8]. The endoscope traverses the Roux limb, through the jejunojejunostomy, and into the biliopancreatic limb. The currently available techniques of DAE-ERCP are categorized into:

- Double-balloon enteroscopy (DBE)
- Single-balloon enteroscopy (SBE)
- Spiral enteroscopy (SE)

Double-balloon enteroscopy

DBE was developed in 2001 to facilitate evaluation of the small bowel [9]. The DBE system consists of an endoscope with a working length of 200 cm and a flexible overtube made of polyurethane. Affixed to the end of the endoscope are 2 latex balloons – one attached to the end of the scope and a second to the overtube. The balloons can be filled with air or emptied using a pump system. Timed inflation and deflation of the balloons aids the advancement and pleating of the previously traversed small bowel and deep evaluation of the intestine [10]. The scope can be introduced into the gastrointestinal tract via the mouth or anus. For entry into the mouth, a fasting of 12 hours is recommended. On average, 230 cm beyond the ligament of Treitz and 135 cm proximal to the ileocecal valve are the insertion depths for oral and anal insertion sites, respectively [11].

Single-balloon enteroscopy

SBE utilizes similar technology as DBE; however, only 1 balloon is located at the tip of the overtube. When the balloon is inflated and the scope is withdrawn, the previously traversed bowel is pleated onto the overtube allowing the endoscope to be advanced further into the lumen of the small bowel. The balloon is then deflated and the overtube is advanced to the end of the scope and the process is repeated. The standard length of the scope is 200 cm.

Spiral enteroscopy

SE converts the rotational energy of the spiral into a linear force that pulls the intestine onto the enteroscope. It uses a rotating overtube that pleats the small bowel onto the overtube and allows deep advancement of an enteroscope [12]. Potential advantages of SE over DBE or SBE include relative ease of use, better endoscope control, and perhaps a shorter learning curve [13].

Performing ERCP after reaching the duodenum via deep enteroscopy is more challenging due to the need to cannulate the major papilla from a caudal approach and the lack of an elevator and other ERCP accessory devices compatible with long-length enteroscopes [14]. Intestinal perforation is the most common serious complication and can occur at any point along the intubated intestinal tract. The injury can happen owing to tears from traction or barotrauma from a closed loop system [15].

Literature summary

In a retrospective cohort study by Emmett and Mallat, 14 patients with a history of RYGB underwent DBE at a single institution [16]. The ampulla was reached in 85% of patients, of whom 80% had successful cannulation of the ampulla. The mean time of the procedure was 99 ± 48 minutes. No complications were noted.

In a retrospective cohort study by De Koning et al. performed at a single institution, 65 patients underwent SBE, and 30 underwent DBE following RYGB [17]. The average age was 58 ± 2 years. Patients were divided into 3 groups based on their anatomy: short limb (<50 cm) with bilioenteric anastomosis, as in Whipple pancreaticoduodenectomy and liver transplantation; short limb (<50 cm) with intact papilla, as in total gastrectomy; and long limb (>100 cm) with intact papilla, as in Scopinaro biliopancreatic diversion and gastric bypass. Cannulation of the ampulla was successful in 74% of cases. The success rate was significantly higher in short-limb as compared with long-limb Roux-en-Y with intact papilla (80% versus 58 %; $P = .04$). The overall adverse event rate was 8%, with 10% occurring in DBE and 8% in SBE procedures ($P = .7$). Three cases of retroperitoneal free air were treated conservatively with antibiotics. Four patients developed post-ERCP pancreatitis. One patient developed a subcapsular liver hematoma due to a guidewire perforation requiring surgical drainage.

Shimatani et al. performed the largest single-institution retrospective cohort study of DBE [18]. The study evaluated 311 patients with an average age of 67.3 ± 14.6 years. The most common patient anatomy was Roux-en-Y reconstruction in 203 patients, followed by pancreaticoduodenectomy in 44 patients. The success rate of reaching the papilla or surgical anastomosis was 97.7% (304 of 311). Diagnostic success, such as performing an ERCP, was 96.4% (293 of 304). Therapeutic success when indicated was 97.9% (277 of 283). The overall incidence of adverse events was

10.6% (33 of 311 patients; 95% confidence interval [CI]: 7.1%–14.0%); 32 patients (97%) were treated successfully without surgical intervention. There was 1 mortality in a patient with a perforation requiring emergency surgery. Microperforations, recognized by escaped air, occurred in 6 patients and a mucosal laceration in 1 patient. According to the reconstruction technique, the adverse event rate was highest in patients with Billroth-II reconstruction (23.1%; 9 of 26 patients), followed by Roux-en-Y reconstruction (10.3%; 21 of 203 patients).

Inamdar et al. performed a systematic review and meta-analysis of studies involving SBE in patients with a history of RYGB, hepaticojejunostomy, or Whipple procedure [19]. Enteroscopy success was defined as success in reaching the papilla and/or biliary anastomosis. Diagnostic success was defined as obtaining a cholangiogram. Procedural success was defined as the ability to provide successful intervention, if appropriate. A total of 15 studies were included and 461 patients were evaluated. The enteroscopy success rates ranged from 55%–100% with a pooled success rate of 80.9% (95% CI, 75.3%–86.4%). The diagnostic success rate ranged from 41%–100% with a pooled success rate of 69.4% (95% CI, 61.0%–77.9%). The procedural success rate ranged from 27%–93% with a pooled success rate of 61.7% (95% CI, 52.9%–70.5%). A total of 32 adverse events in 489 procedures were noted (mean: 6.5%; 95% CI, 4.7%–9.1%). Adverse events were noted in 8 of the 15 studies. Major adverse events included pancreatitis (n = 11), bleeding (n = 2), perforation (n = 4), and death from an embolic stroke unrelated to the ERCP (n = 1).

In a multicenter study by Shah et al., 63 of 129 patients had RYGB anatomy [20]. The success rate of reaching the ampulla with SE, SBE, and DBE was 73%, 73%, and 87%, respectively, with an overall rate of 76%. The success rate of ERCP with SE, SBE, and DBE was 62%, 59%, and 67%, respectively, with an overall rate of 62%. No perforations were reported in the RYGB cohort.

Lennon et al. reported on 34 consecutive patients who underwent 54 ERCP procedures using SBE-ERCP or SE-ERCP [21]. Eighteen procedures (8 SBE-ERCP and 10 SE-ERCP) were performed on 12 patients with a history of RYGB. The diagnostic yield was 40% for SE-ERCP and 37.5% for SBE-ERCP, with an overall rate of 38.9%. There were no adverse events with SE-ERCP. One patient in the SBE-ERCP (unclear if the patient was in the RYGB group) had a perforation at the site of the balloon sphincteroplasty which was managed conservatively.

In a retrospective study by Ali et al., 35 patients with RYGB anatomy underwent SE-ERCP [22]. Twenty-eight of 35 procedures were performed on patients with RYGB for obesity, 4 in patients with Roux-en-Y hepaticojejunostomy, and 3 in patients with gastrectomy and Roux-en-Y reconstruction. The success rate for reaching the papilla was 86%. Cannulation success in patients in whom deep cannulation of the desired duct was indicated was 100% (28/28 cases, including 24 cases with native papilla). Therapeutic ERCP success in patients requiring therapeutic intervention was 100% (28/28). No adverse events were noted.

Skinner et al. published a systematic review to evaluate the endoscopic and ERCP success rates of DBE, SBE, and SE [23]. The study yielded 23 studies that met inclusion criteria: prospective or retrospective, feasibility, observational or comparative studies, in which DAE was performed to diagnose and/or treat biliary or pancreatic diseases. A total of 679 patients (age range 2–91 yr) with altered postsurgical anatomy underwent 945 procedures. The endoscopic procedures were performed for a variety of pancreaticobiliary disorders that required therapeutic intervention, such as sphincterotomy, precut papillotomy, anastomotic strictureplasty, stone removal, stent insertion, stent replacement, and balloon dilation. The study described the success of enteroscopy and ERCP in patients with Roux-en-Y gastric bypass, specifically: the success of intubating the afferent limb and identifying the papilla of Vater was successful in 80% of patients (230 of 286) and the ERCP was successful in 70% (187 of 266) of patients. The endoscopic and ERCP success rates in patients with RYGB anatomy for DBE, SBE, and SE were 88.1%, 76.1%, 50%, and 78.9%, 100%, 38.9%, respectively. Across all studies, 32 adverse events were described during 945 procedure (3.4%), including cholangitis (n = 1), pancreatitis (n = 11), bleeding (n = 3), perforation (n = 13), and death to an embolic stroke (n = 1). Six of the 13 (46.1%) perforations required surgical intervention.

Skinner et al. performed a retrospective cohort study evaluating the use of DBE in the treatment of obscure gastrointestinal bleeding in patients with RYGB anatomy [24]. The altered anatomy included RYGB (n = 6), pylorus sparing Whipple (n = 5), and Roux-en-Y gastrojejunostomy (n = 1). DBE was performed a total of 17 times on 12 patients (7 men and 5 women with a mean age of 55 yr; range 36–70 yr). In 10 of 12 cases, the bleeding site was identified with DBE. In 9 cases bleeding occurred at the anastomotic site: jejuno-jejunal (n = 6), hepatico-jejunal (n = 2), and gastro-jejunal (n = 1). In 1 case, the bleeding source was a nonanastomotic lesion in the afferent limb. In 1 patient thermal energy was applied near a submucosal surgical clip which caused a small-bowel perforation requiring emergent surgery.

Table 1 summarizes selective studies on the topic of DAE-ERCP.

Laparoscopic-assisted/transgastric ERCP

LA-ERCP is one of the most common approaches worldwide for minimally invasive access to the biliary tree in patients with an anatomically excluded stomach as seen in RYGB [25]. This technique was first described by Peters et al. in 2002 and involves laparoscopic identification of

the gastric remnant, an anterior gastrotomy, and placement of a 15-mm port into the stomach [26]. The port is held in place with a purse-string suture around the port or anchoring transfascial sutures. Placing a bowel clamp on the biliopancreatic limb or performing the ERCP with carbon dioxide instead of air minimizes bowel distention. A variation of this technique is the direct advancement of the duodenoscope through an abdominal wall defect and insertion into the gastric remnant with attention to avoid leakage into the peritoneal cavity by using a purse-string suture to secure the gastric wall around the scope. In the case of concomitant cholecystectomy there is the option of passing a guidewire through the cystic duct to the ampulla for a rendezvous technique.

The LA-ERCP technique offers the advantage of using a standard side-viewing duodenoscope with the caveat that the angle of approaching the papilla may be different due to the supine position of the patient. At the conclusion of the ERCP, the gastrotomy on the gastric remnant is closed either with the hand-sewn or the stapling technique. If clinically indicated, a gastrostomy tube can be left in place for future access to the pancreatobiliary system.

Literature summary

In a study by Saleem et al., 15 patients underwent LA-ERCP with successful biliary sphincterotomy in 14 and pancreatic sphincterotomy in 2 [27]. Of note, 3 patients underwent concomitant cholecystectomy, and 3 patients repair of an incidental internal hernia. One patient suffered ileal perforation on postoperative day 3, requiring a laparotomy to repair. Several small series have described a high success rate of LA-ERCP [28–38].

Ponsky et al. described LA-ERCP for SOD in 9 patients with a history of RYGB who presented with a dilated common bile duct and abdominal pain [7]. Six patients (66.7%) presented with abnormal liver enzymes, and 4 (44.4%) with an earlier episode(s) of acute pancreatitis. Eight (88.9%) patients experienced cessation of abdominal pain following LA-ERCP. The proposed theory of the development of SOD after RYGB is the transection of the hepatic branch of the vagus nerve during the creation of the gastric pouch leading to "ampullary achalasia". This is one of the few series in the literature that deals exclusively with SOD rather than choledocholithiasis in RYGB patients.

In a systematic literature review by Banerjee et al., 26 eligible studies (6 prospective and 20 retrospective) comprising 509 transgastric ERCP cases were included [39]. No randomized controlled trials were included. Access to the excluded stomach was achieved laparoscopically in 58% of cases, via open surgery in 6%, by antecedent placement of a percutaneous gastrostomy tube (with laparoscopic or open technique or by interventional radiology) in 33%, and with endoscopic ultrasound-assisted percutaneous gastrostomy placement in 3%. Laparoscopic conversion to open technique occurred in 10 cases. Successful ductal cannulation was achieved in 98.5% (95% CI: 97.24–99.75, range 90%–100%). Subgroup analysis revealed that successful biliary cannulation/ERCP completion occurred in 29 of 29 (100%) of the open surgical cases, 293 of 296 (98.9%) of laparoscopic cases, 15 of 16 (93.8%) of EUS-facilitated cases, and 163 of 169 (96.4%) of G-tube–assisted cases. There were no deaths. There was a 14% rate of adverse events, with 83% of them related to the creation of the gastrostomy (with gastrostomy site wound infection being the most common) and the rest to the ERCP (with post-ERCP pancreatitis being the most common). Because of the inclusion of many gastrostomy-assisted ERCP cases, and the use of the term "gastrostomy" to describe both the temporary port placement in the gastric remnant during LA-ERCP and the conventional G-tube placement, it is difficult to determine the true incidence of complications related to the LA-ERCP technique. There were 3

Table 1
Device-assisted enteroscopy ERCP

Author	Yr	Study design	Single versus multi-center	No.	SBE	DBE	Spiral	Reached ampulla	Clinical success	Adverse events
Inamdar	2015	Systematic review and meta-analysis	Multi	461	461	0	0	81%	62%	6.5%
Skinner	2014	Systematic review and meta-analysis	Multi	286*				80%	70%	3.4%
Ali	2018	Retrospective cohort study	Single	35	0	0	35	86%	100%	None
Shah	2013	Retrospective cohort study	Multi	63†	22	15	26	76%	62%	N/A
De Koning	2016	Retrospective cohort study	Single	73‡	65	30	0	N/A	74%	8%
Shimatani	2016	Retrospective cohort study	Single	311	0	311	0	98%	96%	10.6%
Skinner	2014	Retrospective cohort study	Single	12§	0	17	0	N/A	N/A	8.3%
Lennon	2012	Retrospective cohort study	Single	12‖	8	0	10	38.9%	N/A	N/A
Emmett	2007	Retrospective cohort study	Single	14	0	14	0	85%	80%	None

ERCP = endoscopic retrograde cholangiopancreatography; SBE = Single balloon enteroscopy; DBE = Double balloon enteroscopy; N/A = data not available; RYGB = Roux-en-Y gastric bypass.

* 286 of 679 patients had RYGB anatomy.

† Sixty-three of 129 patients had RYGB anatomy.

‡ Seventy-three patients underwent 95 procedures.

§ Twelve patients underwent 17 procedures.

‖ Twelve of 34 patients had RYGB anatomy and underwent 18 procedures.

gastrostomy-related perforations (.5% of total cases), with only 1 attributed to the trocar placement during the LA-ERCP and the other 2 due to dilation of a previously placed G-tube. Many subsequent studies have quoted this 14% rate of complications to advocate the use of endoscopic techniques to perform ERCP.

A retrospective single-center case series by Grimes et al. presented the experience from 41 patients who underwent 85 transgastric ERCP procedures over 10 years (2004–2014) [40]. Most of the initial ERCP procedures were LA-ERCP (38 of 41) with 3 via a percutaneous gastric tube. The majority of the repeat ERCP procedures were via a gastrostomy tube tract (40 of 44) and 4 procedures via LA-ERCP. The conversion rate to open technique was 4.8%. The rate of selective cannulation of biliary and/or pancreatic ducts for initial LA-ERCP, initial gastrostomy-assisted ERCP, repeat LA-ERCP, and repeat gastrostomy-assisted ERCP was 95%, 68%, 100%, and 93%, respectively. The overall rate of selective cannulation was 93%. The follow-up period was 15 months, and the overall complication rate was 19%. Most of the complications (88%) were associated with accessing the gastric remnant in patients with a gastrostomy tube in place, including 1 duodenal bulb perforation, which required operative intervention, and 3 injuries to the posterior gastric wall one of which required repair with endoscopic clips. ERCP-related complications were noted in 2 of 85 (2.4 %) of cases comprised of 2 duodenal perforations during precut sphincterotomy which were managed non-operatively. Only 2 patients (2.4%) required reoperative intervention, one for an abdominal wall abscess and one for a duodenal perforation.

A systematic review and meta-analysis by da Ponte-Neto et al. described and compared 23 studies on LA-ERCP versus enteroscopy-based ERCP after RYGB [25]. LA-ERCP comprised most of the studies (n = 14), compared with SBE-ERCP (n = 5) and DBE-ERCP (n = 3). The papilla identification rate was 97% by LA-ERCP, 88.1% by SBE-ERCP, and 84.3% by DBE-ERCP. Successful papilla cannulation rates were 95.7% for LA-ERCP, 62.2% for SBE-ERCP, and 82.2% for DBE-ERCP. The complication rates were 18.0%, 9.9%, and 2.0% for LA-ERCP, SBE-ERCP, and DBE-ERCP, respectively. The authors concluded that LA-ERCP is associated with a higher success rate but also a higher complication rate compared with SBE-ERCP and DBE-ERCP.

A systematic review and meta-analysis by Aiolfi et al. included 13 observational cohort studies published 2009–2017 on LA-ERCP and gastrostomy-assisted ERCP [41]. Choledocholithiasis was the most common indication. This large study included 850 patients who underwent 931 procedures. There were 90% biliary and 10% pancreatic clinical indications. Same-day ERCP was achieved in 703 cases (75.5%), while a staged ERCP was performed in 228 (24.5%) after maturation of the gastrostomy tract. The rate of conversion to open technique was 8%. The reported success rate of ERCP was 99%, and the overall complication rate was 14.2%, with a 3.1% ERCP-related morbidity.

In one of the largest multi-center retrospective series by Abbas et al., 579 patients from several US tertiary referral centers and 1 Brazilian institution underwent LA-ERCP for biliary (89%), pancreatic (8%), or combined (3%) pathology from 2005–2016 [42]. The number of procedures performed per year increased noticeably after 2011, reflecting the increased adoption of this technique. Concomitant cholecystectomy was performed in 21% of the cases, and a gastric tube for possible future intervention was placed in 17% of the cases. The conversion rate to open technique was 5%. The overall procedural success rate was 98%. The papilla was successfully reached in 99% and the desired duct cannulated in 98% of the cases (bile duct cannulation: 99%; pancreatic duct cannulation: 91%). The median total procedure time was significantly longer in patients with a history of open (n = 123) versus laparoscopic RYGB (181 versus 147 min, $P = .009$). There was an 18% rate of adverse events, with 10% related to laparoscopy, 7% to ERCP alone, and 1% to both. The novelty of this study is that it made a distinction between laparoscopy-related versus ERCP-related adverse events. Viscus perforation occurred in 5 of 579 patients (.8%). Two patients had sphincterotomy-related duodenal perforations, and 3 patients had laparoscopy related (2 colonic and 1 gastric remnant perforation). One patient with perforation died of multiorgan failure. Placement of a G-tube and conversion to open laparotomy were factors associated with higher laparoscopy-related adverse events. Patients who had G-tube placement at the end of the LA-ERCP had a higher overall laparoscopy associated adverse events (17% versus 9%, $P = .03$) mostly due to G-tube site infection (6%), gastric entry site leak (4%), and all-cause laparoscopy-associated bleeding (7%).

Table 2 summarizes selective series on the topic of LA-ERCP.

Gastrostomy-assisted ERCP

Gastrostomy-assisted ERCP uses a gastrostomy tube as the primary route of accessing the excluded portion of the GI tract in patients with RYGB anatomy. A gastrostomy tube is placed using a variety of techniques:

- laparoscopic gastrostomy
- open gastrostomy
- device-assisted endoscopy to reach the gastric remnant followed by percutaneous placement of a gastrostomy tube
- EUS-guided access of the gastric remnant followed by percutaneous placement of a gastrostomy tube

The gastrostomy tube is typically left in place for 5–14 days to allow maturation of the tract. On the day of the transgastric ERCP or other intervention, the gastric tube is removed and the gastrocutaneous tract is dilated to allow

Table 2
Laparoscopic-assisted/transgastric ERCP

Author	Yr	Study design	Single- versus multi-center	No.	Technical success	Clinical success	Adverse events
Aiolfi	2018	Systematic review and meta-analysis	Multi	850	98%	98%	10.6% laparoscopy-related (bleeding, perforation, gastric site leak, other), 7.2% ERCP related (pancreatitis, bleeding perforation, other)
Banerjee	2017	Systematic review	Multi	509	98.5%	98.5%	14% total (83% gastrostomy related, 17% ERCP related)
Falcão	2012	Prospective cohort study	Multi	23	100%	100%	4% pancreatitis
Abbas	2018	Retrospective cohort study	Multi	579	98%	98%	18% total (10% laparoscopy, 7% ERCP, 1% both)
Bowman	2016	Retrospective cohort study	Multi	15	100%	100%	20% total (7% incisional hernia, 13% infection)
Snauwaert	2015	Retrospective cohort study	Multi	23	100%	100%	No complications reported
Mohammad	2019	Retrospective cohort study	Single	32	100%	100%	3% pancreatitis
Frederiksen	2017	Retrospective cohort study	Single	29	100%	100%	36% total (bleeding, hematoma, intra-abdominal abscess), 7% pancreatitis, 7% perforation
Lim	2017	Retrospective cohort study	Single	50	100%	100%	9% pancreatitis
Grimes	2015	Retrospective cohort study	Single	41	93%	Not reported	19% total (88% access, 12% ERCP), 4.7% additional intervention
Gutierrez	2009	Retrospective cohort study	Single	30	100%	100%	13% total (infection, leak, pancreatitis), 3% pancreatitis
Habenicht Yancey	2018	Retrospective case series	Single	16	94%	Not reported	6.2% pancreatitis
Ponsky	2017	Retrospective case series	Single	9	100%	100%	No complications reported
Richardson	2012	Retrospective case series	Single	13	100%	100%	No complications reported
Saleem	2012	Retrospective case series	Single	15	100%	100%	6.7% ileal perforation, no endoscopy complications
Bertin	2011	Retrospective case series	Single	22	100%	Not reported	4.5% retroperitoneal perforation, 4.5% abdominal wall hematoma, 4.5% bile leak
Lopes	2009	Retrospective case series	Single	10	90%	Not reported	20% pancreatitis, 10% pneumothorax

ERCP = endoscopic retrograde cholangiopancreatography.

the passage of the endoscope. A variation of this technique includes the placement of a gastrocutaneous covered metal stent. Upon completion of the endoscopy, the stent is removed, and a gastrostomy tube is left in place.

Literature summary

In a case series by Martinez et al., 6 patients with RYGB anatomy underwent a gastroduodenoscopy via a percutaneous G tube either placed at the time of previous surgery or by interventional radiology [43]. The tract was dilated to either a 20- or 24-Fr caliber. A pediatric duodenoscope or a slim gastroscope was introduced through the gastrocutaneous fistula tract to perform the procedure. A percutaneous gastroduodenoscopy was performed in all 6 patients, with a percutaneous ERCP done in 3 patients. Cannulation of the common bile duct was not successful in 1 out of the 3 patients who had ERCP.

In a study by Shaikh et al., 38 RYGB patients underwent percutaneous gastric remnant G tube placement for a variety of indications including 1 patient in need of ERCP [44]. The technical success rate was 95%. Insufflation of the gastric remnant was performed via clear window (n = 35), transhepatic (n = 5), and transjejunal (n = 1) routes. Five patients developed complications including tube dislodgement requiring surgery or replacement by radiology, abdominal pain, upper gastrointestinal bleeding, and cellulitis. This technique has been used to perform an ultrasound-guided cyst-gastrostomy in a RYGB patient who developed a pancreatic pseudocyst [45].

Law et al. described 5 patients who underwent single-session antegrade ERCP for SOD [46]. Using a balloon endoscope, the gastric remnant was accessed, T-fasteners were placed percutaneously around the intended gastrostomy site, and after the tract was dilated a fully covered self-expandable metal stent was deployed and expanded. Upon completion of the ERCP, a 26-Fr gastrostomy tube was left in place. The median procedure time was 97 minutes. Biliary sphincterotomy was successful in all patients. Three patients (60%) required prophylactic pancreatic duct stents, one of which required subsequent removal at the time of PEG removal. Sphincterotomy-induced perforation was suspected in 1 patient and was treated by placement of a fully covered biliary stent. A 2-stage variation of this technique has been described with placement of a PEG using

single-balloon–assisted enteroscopy and performance of antegrade ERCP following dilation of the mature tract 2 weeks later [47].

In another study by Schwartz et al., 17 patients who underwent gastrostomy-assisted ERCP (G-ERCP) for SOD were compared with 21 patients who underwent transduodenal sphincteroplasty (TS) for the same indication [48]. Eight patients (5 in G-ERCP and 3 in TS) required a second procedure after initial treatment failure. Resolution of symptoms after initial therapy was seen in 41% of G-ERCP and 67% of TS ($P = .190$), respectively, and overall after 35% and 64% of procedures performed ($P = .042$). Thirty-day morbidity was similar between G-ERCP and TS (29% versus 10%; $P = .207$). The authors concluded that TS is more effective than G-ERCP in treating SOD symptoms.

In a study by Kedia et al., 6 patients with RYGB anatomy underwent EUS-guided placement of a 16-Fr gastric tube by distending the gastric remnant using a 19G needle through the gastric pouch [49]. Antegrade ERCP was successful by replacing the gastrostomy tube with a transcutaneous fully covered metal esophageal stent after a mean of 5.8 days. Two patients (33%) had localized percutaneous endoscopic gastrostomy (PEG) site infections that were managed with oral antibiotics.

In a study by Attam et al., 10 patients with RYGB anatomy underwent EUS-guided access of their gastric remnant using an 18G needle through the gastric pouch or the Roux limb [50]. Following percutaneous placement of a 20-Fr peel-away sheath, gastric anchors, and eventually a 15-mm laparoscopic trocar, a single session ERCP was successfully performed in 9 of 10 patients. In 1 patient, percutaneous access of the gastric remnant was deemed unsafe. At the completion of the ERCP, a 20-Fr gastric tube was left in place.

Endoscopic ultrasound directed transgastric ERCP

EDGE was first described by Kedia et al. in 2014 [51]. Several other terms have been used to describe the procedure, including EUS-TG, EUS-GG-ERCP, and GATE (gastric access temporary for endoscopy). An endoechoscope is advanced to the gastric pouch or the Roux limb, distal to the gastrojejunal anastomosis, and the gastric remnant is accessed using a 19-gauge aspiration needle. A solution of contrast is injected to confirm the location and to distend the gastric remnant. A wire is advanced through the needle and used as a guide to create a fistulous tract that is then dilated with a 4-mm balloon. A lumen-apposing metal stent (LAMS) is deployed with the distal flange into the gastric remnant and the proximal flange into the gastric pouch or Roux limb. The lumen of the metal stent is then expanded to 18 mm with a dilating balloon. ERCP is performed during the same or subsequent session, after the tract matures and dislodgement of the LAMS is less likely. Following ERCP, the LAMS is left in place if future access to the biliary system is required. A large metal snare is used to remove the LAMS, and closure of the fistula is achieved with a variety of techniques including endoscopic suturing, approximation with clips, ablation of the fistula tract to promote healing by secondary intent, or placement of a double pigtail stent across the tract to facilitate closure. This technique has been used to address gastric outlet obstruction of the gastric remnant in patients with malignancy, and Roux limb obstruction due to technical errors [52,53].

Literature summary

In a study by Wang et al., 10 patients underwent EDGE with 100% technical success [54]. Three patients had a gastrogastric LAMS and 7 patients had a jejunogastric LAMS. Nine patients underwent ERCP (7 of 9 as a single session) and 1 underwent patient resection of a duodenal mass. Two patients experienced adverse events; 1 patient developed bleeding at the J-G access site that was treated with epinephrine and exchange of the double pigtail stent with a LAMS for tamponade and another patient had dislodgement of his LAMS during advancement of the duodenoscope that was corrected endoscopically. In 7 patients with follow-up, the LAMS was removed, and a plastic double pigtail stent was placed to facilitate closure. In subsequent endoscopy, 5 of 7 patients were found to have a closed access tract and a spontaneously expelled stent and in 2 patients the stent was endoscopically removed, and closure of the tract was confirmed later. The authors offer a decision algorithm on a single session EDGE (all cases with gastrogastric LAMS, and emergency cases with jejuno-gastric LAMS).

In a study by Tyberg et al., 16 patients underwent EDGE in 2 academic centers in the United States [55]. Technical success was 100% and clinical success was 91%. Four patients had ERCP during the index procedure and 1 case was aborted due to jejunal perforation. Stent dislodgement occurred in 3 patients and was addressed with repositioning of the stent in 2 and placement of a bridged fully covered stent in 1 patient. Ten patients underwent removal of the LAMS and closure of the fistula endoscopic suturing in 7 patients (70%) and with an over-the-scope clip in 20%. In 1 patient, the fistula tract was left to close by secondary intention. Eight of the 10 patients underwent imaging to confirm fistula closure following LAMS removal; two had a persistent leak on imaging and was scheduled to undergo repeat closure. The mean weight change from LAMS insertion to removal was negative 2.85 kg.

In a more recent study, Tyberg et al. reported their experience with EDGE at 1 institution by a single experienced operator [56]. Technical success, defined as the successful creation of the fistulous tract, was achieved in all patients. The median procedure time was 54.5 minutes (range: 31–88 min). Seventeen patients had a gastrogastric LAMS

and 2 patients had a jejunogastric LAMS. Clinical success was achieved in 18 of 19 patients; one patient had a jejunal perforation during the advancement of the duodenoscope through the LAMS and the case was aborted. Five patients had the EUS or ERCP performed during the same session as fistula creation and 14 were separated by 2–3 weeks. Five patients had a persistent fistula after closure; 4 were successfully closed with a second round of suturing; 1 patient required several procedures for fistula closure due to a concurrent gastrojejunal surgical anastomotic stricture. Four patients (21%) developed complications: bleeding (n = 2), jejunal perforation (n = 1), and pancreatitis (n = 1).

In a study by James and Baron, 19 patients underwent EDGE with a reported technical and clinical success in all patients [57]. The true technical success was 95%; EDGE was attempted in 20 patients but in 1 patient the gastric remnant could not be identified by EUS. Eight patients had a gastrogastric LAMS and 11 patients had a jejunogastric LAMS. Stent malposition occurred in 6 patients and was managed by rescue maneuvers including the use of a fully covered metal esophageal stent. One-session ERCP was performed in 4 patients. Stents were removed after a mean time of 182 days. Argon plasma coagulation was applied to promote fistula closure in 12 patients. Upper GI series to assess fistula closure was obtained in 11 patients at a mean of 182 days following stent removal. One persistent fistula with an associated weight gain of 5.6 kg, was identified and closed endoscopically with an over-the-scope clip. Mean cohort weight gain of 1.7 kg (SD, ±8.6 kg) from their preprocedure weight.

Chiang et al. compared the transgastric with the transjejunal EDGE approach in 66 patients who underwent EDGE at 7 academic institutions (published abstract) [58]. Technical success was achieved in 92% of patients. Thirteen complications (19.6%) occurred at the time of placement: bleeding (7.6%), LAMS malposition (4.5%); LAMS migration (4.5%); perforation (1.5%); and pancreatitis (1.5%). Ten of 13 complications occurred in the transgastric access group. Multivariate regression showed that the access route was not a significant predictor for technical success or complications. The authors concluded that transjejunal access is as safe as the transgastric approach.

In a meta-analysis by Dhindsa et al., 124 patients from 4 studies who underwent EDGE were compared with 939 patients from 18 studies who underwent LA-ERCP, and 205 patients from 5 studies who underwent BE-ERCP [59]. The technical success of EDGE was comparable to LA-ERCP and superior to BE-ERCP (95.5%, 95.3%, and 71.4%, respectively; $P = .01$ EDGE versus BE-ERCP; $P = .001$ LA-ERCP versus BE-ERCP). The clinical success of EDGE was comparable to LA-ERCP and superior to BE-ERCP (95.9%, 92.9%, and 58.7%, respectively; $P = .001$ EDGE versus BE-ERCP; $P = .009$ LA-ERCP versus BE-ERCP). Pooled rates of post-ERCP pancreatitis and perforation were comparable between the groups but the rate of bleeding was lower with BE-ERCP versus EDGE and LA-ERCP (1.5%, 6.6%, and 3.7%, respectively; $P = .04$). The rate of stent migration with EDGE was 13.3%.

In a study by Kedia et al., 29 EDGE procedures were compared with 43 LA-ERCP procedures at 4 tertiary centers [60]. In the EDGE group, the ERCP was performed following fistula maturation for 3–4 weeks, and the LAMS was removed at the conclusion of the ERCP if no other intervention was anticipated or later as a 3-stage procedure. In the LA-ERCP group, the ERCP was performed on the same day in 51% of patients, a gastric tube was placed for future access to the biliary system. The technical success of accessing the excluded stomach via EDGE and LA-gastrostomy was 96.5% and 100%, respectively. Successful therapeutic ERCP was achieved via EDGE and LA-gastrostomy in 96.5% and 97.7% of patients, respectively. Four of 43 (9.3%) of LA-ERCP cases required conversion to an open surgical technique. In each group, there was 1 case of failed ERCP, and each case required surgical common bile duct exploration. The adverse event rate for EDGE was 24% and for LA-ERCP 19%. Of interest, 23 of 27 patients with gallbladder in situ underwent cholecystectomy at the time of LA-ERCP, whereas 11 of 15 patients with gallbladder in situ underwent cholecystectomy after the EDGE procedure. This brings into question the benefit of EDGE in patients who may require a cholecystectomy. The overall weight change after EDGE was a loss of 3.0 kg at an average 28-week follow-up period.

In a study by Bukhari et al., 30 EDGE procedures were compared with 30 BE-ERCP (single- or double-balloon technique) procedures at 5 tertiary centers [61]. The technical success rate was significantly higher in the EDGE versus the BE-ERCP group (100% versus 60.0%). The total procedure time was significantly shorter in the EDGE group. Eight patients underwent ERCP at the time of fistula creation. Two patients (6.7%) experienced stent migration that was addressed endoscopically. Half of the EDGE patients underwent closure of the fistula with endoscopic suturing or over the scope clip and half underwent application of argon plasma coagulation or no attempt to close. Closure of fistula was confirmed with a variety of endoscopic or radiographic techniques in 76% of patients at 6–8 weeks following removal of LAMS. There was 1 persistent fistula following endoscopic suturing closure that was addressed successfully with an over-the-scope clip. Adverse events developed is 2 patients in the EDGE group (intraprocedural bleeding that was managed conservatively with blood transfusion, and persistent fistula as described above) and 3 patients in the BE-ERCP group (post-ERCP pancreatitis, post-ERCP cholangitis, and small-bowel perforation that required operative intervention).

In a study by Amateau et al., 14 patients with prior RYGB had EUS-guided endoscopic gastrointestinal anastomosis for a variety of reasons, including intractable malnutrition

(n = 8), ERCP access (n = 3), iatrogenic obstruction or discontinuity (n = 2), persistent marginal ulcer (n = 1) [62]. Some of these patients had hostile abdomens with enterocutaneous fistulae or complicated open surgeries. Five patients had stent removal, and all but 1 patient had patent tracts at follow-up. There was only 1 procedural stent dislodgement. This series illustrates that unless there is a method applied to close the fistula tract following LAMS removal, the tract may remain patent.

Persistence of the gastro-gastric fistula that is created as part of the EDGE may lead to chronic abdominal pain, weight regain, acid reflux, poor glycemic control, and anastomotic ulcers based on the RYGB literature [63–65]. The current literature on EDGE provides short-term follow-up data that support the use of an endoscopic intervention to close the iatrogenic fistula. Long-term studies are required to assess the risk of development of a chronic fistula.

With the emergence of new techniques, several studies have proposed an algorithm on how to choose the appropriate technique to access the excluded anatomy [66, 67]. Table 3 summarizes selective studies on the topic of EDGE, and Table 4 summarizes selective comparative studies.

Trans-enteric approaches

Mergener et al. described 2 cases of intraoperative transjejunal ERCP to access the pancreatic duct following previous surgical interventions [68]. The first patient was a woman aged 34 years with RYGB anatomy and a history of a transduodenal sphincteroplasty and pancreatic septoplasty to address multiple episodes of pancreatitis who required ERCP for recurrent pancreatitis. The proximal jejunum was accessed through a midline incision and a duodenoscope was placed into an enterotomy, 20 cm proximal from the ligament of Treitz. The endoscope was advanced in a retrograde fashion to the duodenum and a needle knife sphincterotomy was performed to address the stenosed pancreatic duct orifice. The second patient was a woman aged 35 years with a history of a duodenojejunostomy for intestinal malrotation and duodenal atresia in need of ERCP. An intraoperative transjejunal ERCP was performed, and a duodenal web was incised to release entrapment of the minor papilla.

In a case report by Chahine et al., a woman aged 56 years with a history of a duodenal switch developed a bile leak following an open cholecystectomy due to a right hepatic duct injury [69]. The patient underwent a laparoscopic assisted ERCP and stent placement by inserting a duodenoscope through an enterotomy in the exteriorized second loop of jejunum. A second ERCP, using the same technique, was performed 2 months later to remove the stent and this time it was complicated with an intraoperative jejunal perforation that was repaired at the time of the procedure.

Dalmonte et al. described a patient with a history of an antecolic RYGB in need of ERCP due to choledocholithiasis [70]. The authors chose a transjejunal approach for the ERCP using a forward-viewing colonoscope. A 7-Fr x 7cm biliary stent was placed to facilitate a needle-knife sphincterotomy. The stones were extracted, and the stent was removed.

Surgical bile duct exploration

Surgical exploration of the biliary system can be performed via a transcystic approach at the time of cholecystectomy or via a common bile duct exploration using an open, laparoscopic, or robotic-assisted technique. Choledochoduodenostomy is an option for patients with primary choledocholithiasis.

In a study by Fuente et al., 11 (19.2%) of 57 patients were diagnosed with choledocholithiasis during intraoperative cholangiogram and were treated with laparoscopic transcystic common bile duct exploration [71]. The procedure was successful in 90.9% (n = 10); one patient required a laparoscopic choledochoduodenostomy.

Olausson et al. reported on 3 cases of successful laparoscopic transcystic common bile duct exploration and concomitant cholecystectomy in patients with a RYGB anatomy [72].

Table 3
Endoscopic ultrasound directed transgastric ERCP

Author	Yr	Study design	Single -versus multi-center	N	Single-stage n (%)	Technical success	Clinical success	LAMS malposition/ dislodgement	Adverse events
Tyberg	2020	Prospective cohort study	Single	19	5 (26%)	100%	95%	N/A	Bleeding 10.5% Perforation 5.3% Pancreatitis 5.3%
Wang	2019	Prospective cohort study	Single	10	7 (70%)	100%	100%	2 (20%)	Bleeding 10%
Tyberg	2017	Prospective cohort study	Multi	16	4 (25%)	100%	91%	3 (19%)	Perforation 6.2% (treated endoscopically)
James	2019	Retrospective cohort study	Single	19*	4 (21%)	100%	100%	6 (32%)	No serious adverse events
Chiang	2018	Retrospective cohort study	Multi	66	43 (65%)	92%	N/A	6 (9%)	Bleeding 7.6% Perforation 1.5% Pancreatitis 1.5%

ERCP = endoscopic retrograde cholangiopancreatography; LAMS = lumen-apposing metal stent; N/A = not applicable.
* One of 20 patients was censored from analysis because the gastric remnant could not be identified by EUS.

Table 4
Comparative studies

Author	Yr	Study design	Single-versus multi-center	No.	Technical success	Clinical success	Adverse events
Dhindsa	2020	Systematic review and meta-analysis	Multi	124 (EDGE) 939 (LA-ERCP) 205 (DAE-ERCP)	95.5% (EDGE) 95.3% (LA-ERCP) 71.4 % (DAE-ERCP)	95.9% (EDGE) 92.9% (LA-ERCP) 58.7 % (DAE-ERCP)	21.9% (EDGE) Bleeding 6.6% Perforation 2.2% Pancreatitis 2.2% Stent migration 13.3% 17.4% (LA-ERCP) Bleeding 3.7% Perforation 2.2% Pancreatitis 6.8% 8.4% (DAE-ERCP) Bleeding 1.5% Perforation 1.8% Pancreatitis 6.3%
Kedia	2019	Retrospective cohort study	Multi	29 (EDGE) 43 (LA-ERCP)	96.5% (EDGE) 100% (LA-ERCP)	96.5% (EDGE) 97.7% (LA-ERCP)	24.1% (EDGE) Bleeding 3.4% Perforation 3.4% Stent dislodgement 10.3% 18.6% (LA-ERCP) Bleeding 2.3% Perforation 4.6% Abscess 4.6%
Bukhari	2018	Retrospective comparative cohort study	Multi	30 (EDGE) 30 (DAE-ERCP)	100% (EDGE) 70% (DAE-ERCP)	100% (EDGE) 60% (DAE-ERCP)	6.7% (EDGE) Bleeding 3.3% Persistent fistula 3.3% Stent migration 6.7% 10% (DAE-ERCP) Perforation 3.3% Pancreatitis 3.3% Cholangitis 3.3%
Ponte-Neto	2018	Systematic review and meta-analysis	Multi	466 (LA-ERCP) 166 (SB-ERCP) 71 (DB-ERCP)	97.0% (LA-ERCP) 88.1% (SB-ERCP) 84.3% (DB-ERCP)	95.7% (LA-ERCP) 62.2% (SB-ERCP) 82.2% (DB-ERCP)	18.0% (LA-ERCP) 9.9% (SB-ERCP) 2.0% (DB-ERCP)
Choi	2013	Retrospective cohort study	Single	42 (G-ERCP) 28 (DAE-ERCP)	100%* (LA-ERCP) 78% (DAE-ERCP)	100% (LA-ERCP) 56% (DAE-ERCP)	14.5% (LA-ERCP) G-tube site infection 11.9% G-tube dislodgement 4.8% G-tube tract leak 2.4% G-tube site bleeding 2.4% Persistent gastrocutaneous fistula 2.4% 3.1% (DAE-ERCP) Pancreatitis 3.1%
Schreiner	2012	Retrospective cohort study	Single	24 (LA-ERCP) 32 (DAE-ERCP)	100% (LA-ERCP) 72% (DAE-ERCP)	100% (LA-ERCP) 59% (DAE-ERCP)	8.3% (LA-ERCP) Pancreatitis 4.2% Enterocutaneous fistula 4.2% 3.1% (DAE-ERCP) Pancreatitis 3.1%

EDGE = endoscopic ultrasound-directed transgastric endoscopic retrograde cholangiopancreatography (ERCP); LA-ERCP = laparoscopic-assisted/transgastric ERCP; DAE-ERCP = device-assisted enteroscopy ERCP; SB-ERCP = single balloon ERCP; DB-ERCP = double balloon ERCP.

* In 2 patients, initial intubation of the G-tube was not successful, and tract required further dilation

In a multicenter prospective randomized trial comparing 2-stage versus single-stage management of nonbariatric surgery patients with proven or suspected choledocholithiasis, the success rate of laparoscopic transcystic duct exploration was 80% and the success rate of laparoscopic direct common duct exploration was 85% [73]. Technological advances such as single operator cholangioscopy and robotic common bile duct exploration may offer additional options in patients with altered anatomy due to bariatric surgery.

Trans-biliary approaches

Trans-biliary access of the sphincter of Oddi can be achieved through a percutaneous transhepatic or an

endoscopic ultrasound-guided approach. Placement of a percutaneous transhepatic catheter can provide expeditious access and decompression of an obstructed biliary system in patients with sepsis secondary to cholangitis. It can also be used to perform balloon dilation of the ampulla and extraction of stones using a stone retrieval basket, a balloon to push the stone through the ampulla, or a choledochoscope [74,75].

Weilert et al. reported on 6 patients with RYGB anatomy who underwent EUS-guided cholangiography [76]. Under EUS guidance a fine needle aspiration is used to puncture an intrahepatic bile duct, a guidewire is advanced across the ampulla and a 5.5-Fr ERCP cannula is used to dilate the transhepatic-transgastric access tract. Antegrade balloon sphincteroplasty and advancement of stones across the ampulla is performed using a balloon catheter. The procedure was successful in 4 (67%) patients. Sphincteroplasty failed in 2 patients due to the inability to advance the transhepatic dilation catheters, one of which developed a subcapsular liver hematoma that was treated conservatively. In both cases, wires were advanced through the ampulla, and rendezvous ERCP using double-balloon enteroscopy was successfully performed.

Tripathi et al. (2020) reported on 5 patients who underwent percutaneous transhepatic cholangioscopy with Spyglass: 2 with a RYGP anatomy, and 3 with a prior Roux-en-Y hepaticojejunostomy. Electrohydraulic lithotripsy was performed in 4 patients [77]. A variation of this technique includes placement of a self-expanding covered metal stent between the gastric pouch or the Roux limb and the left biliary system [66]. The tract is allowed to mature for 2 weeks and then using a Spyglass the common bile duct stones are fragmented by electrohydraulic lithotripsy. At the end of the procedure, the fistula is closed using an endoscopic over-the-scope clip.

Conclusions

Accessing the biliopancreatic GI tract in patients who have undergone RYGB can be technically challenging. Several approaches involving a combination of surgical, endoscopic, and percutaneous techniques exist to access the biliary system in patients with altered anatomy due to metabolic and bariatric surgery. This is an evolving field and technologic advancements introduce possibilities for new methods to access the surgically excluded GI tract.

LA-ERCP is a technique with which metabolic and bariatric surgeons are familiar, and for which there is significant literature to support its safety and efficacy. The success rate of cannulation of the ampulla in the largest series ranges from 95%–100%, while the success rate of endoscopic intervention ranges from 93%–98%. LA-ERCP can be performed at the time of the cholecystectomy and offers the advantage of examining the RYGB anatomy, identifying and repairing incidental internal hernias and mesenteric defects. It may however pose logistic challenges with schedule coordination of the surgical and advanced interventional endoscopy teams. If future attempts to examine and manipulate the biliary tree or the pancreatic duct are foreseen at the time of LA-ERCP, a gastrostomy tube can be inserted in the gastric remnant to provide future access through the mature tract of a gastrocutaneous fistula. The most common laparoscopy-related complications include surgical site infection, port site hematoma, incisional hernia, and bowel perforation.

DAE-ERCP avoids surgical intervention and offers both diagnostic and therapeutic capabilities. However, it has lower success rates, increased potential morbidity, and higher dependence on operator expertise. The success rates of identifying the ampulla and performing an ERCP in patients with RYGB anatomy are approximately 80% and 70%, respectively. The adverse event rate is 3.4% and most commonly includes bowel perforation, bleeding, and pancreatitis.

Gastrostomy-assisted ERCP through a mature tract is an approach that has the advantage of maintaining access for repeat procedures with risks similar to those of a gastric tube. Other options include surgical bile duct exploration, and trans-biliary access by interventional radiology. A trans-enteric approach can be used in patients with duodenal switch anatomy.

EDGE is an investigational technique that is gaining popularity among advanced interventional endoscopists. It allows the use of a standard duodenoscope for ERCP, after creating a fistula between the gastric pouch or the Roux limb and the gastric remnant, without the need for transabdominal surgical intervention. EDGE has been used for both urgent and nonurgent clinical indications. Small series report a clinical success rate up to 95%. Adverse events include bleeding (6.6%), perforation (2.2%), and stent migration (13.3%). Persistence of a gastrogastric (or gastrojejunal) fistula remains a concern. There are limited data to assess the presence of a chronic fistula and its potential effects on ulcer formation and weight gain. Short-term data support the use of some technique to close the fistula and subsequent confirmation of the closure. Further study is needed to determine the optimal timing and the best modality to minimize the risk of a chronic iatrogenic fistula. Advanced interventional endoscopists and bariatric surgeons should agree on performing the EDGE procedure prior to it being initiated and it should be done under an institutional review board (IRB) protocol.

For any approach to biliopancreatic access following anatomy-altering metabolic and bariatric surgery, close collaboration between surgeon and interventional endoscopist or radiologist is encouraged for adequate review and understanding of the patient's anatomy, and to formulate a clinical plan that is personalized to the needs of the

individual patient. The indication for ERCP, the urgency for intervention, the need for concomitant cholecystectomy, and the availability of local equipment and clinical expertise play a role in the selection of the proper technique and the development of a clinical plan.

Disclosures

The authors have disclosed no commercial associations that might be a conflict of interest in relation to this article.

References

[1] Bastouly M, Arasaki CH, Ferreira JB, Zanoto A, Borges FG, Del Grande JC. Early changes in postprandial gallbladder emptying in morbidly obese patients undergoing Roux-en-Y gastric bypass: correlation with the occurrence of biliary sludge and gallstones. Obes Surg 2009;19(1):22–8.

[2] Sugerman HJ, Brewer WH, Shiffman ML, et al. A multicenter, placebo-controlled, randomized, double-blind, prospective trial of prophylactic ursodiol for the prevention of gallstone formation following gastric-bypass-induced rapid weight loss. Am J Surg 1995;169(1):91–6; discussion 96–7.

[3] Wattchow DA, Hall JC, Whiting MJ, Bradley B, Iannos J, Watts JM. Prevalence and treatment of gallstones after gastric bypass surgery for morbid obesity. Br Med J (Clin Res Ed) 1983;286(6367):763.

[4] Friedman GD. Natural history of asymptomatic and symptomatic gallstones. Am J Surg 1993;165(4):399–404.

[5] Somasekar K, Chan DSY, Sreekumar NS, Anwer S. Choledocholithiasis after bariatric surgery—more than a stone's throw to reach? J Gastrointest Surg 2018;22(3):529–37.

[6] Mehta N, Strong AT, Stevens T, El-Hayek K, et al. Common bile duct dilation after bariatric surgery. Surg Endosc 2019;33(8):2531–8.

[7] Ponsky JL, Jones N, Rodriguez JH, Kroh MD, Strong AT. Massive biliary dilation after Roux-en-Y gastric bypass: is it ampullary achalasia? J Am Coll Surg 2017;224(6):1097–103.

[8] Gostout CJ, Bender CE. Cholangiopancreatography, sphincterotomy, and common duct stone removal via Roux-en-Y limb enteroscopy. Gastroenterology 1988;95(1):156–63.

[9] Yamamoto H, Sekine Y, Sato Y, et al. Total enteroscopy with a nonsurgical steerable double-balloon method. Gastrointest Endosc 2001;53(2):216–20.

[10] Wang TJ, Ryou M. Evolving techniques for endoscopic retrograde cholangiopancreatography in gastric bypass patients. Curr Opin Gastroenterol 2018;34(6):444–50.

[11] Saygili F, Saygili SM, Oztas E. Examining the whole bowel, double balloon enteroscopy: Indications, diagnostic yield and complications. World J Gastrointest Endosc 2015;7(3):247–52.

[12] Amer S, Horsley-Silva JL, Menias CO, Pannala R. Endoscopic retrograde cholangiopancreatography in patients with surgically altered gastrointestinal anatomy. Abdom Imaging 2015;40(8):2921–31.

[13] Kogure H, Watabe H, Yamada A, et al. Spiral enteroscopy for therapeutic ERCP in patients with surgically altered anatomy: actual technique and review of the literature. J Hepatobiliary Pancreat Sci 2011;18(3):375–9.

[14] Ross AS. Endoscopic retrograde cholangiopancreatography in the surgically modified gastrointestinal tract. Gastrointest Endosc Clin N Am 2009;19(3):497–507.

[15] Gomez V, Petersen BT. Endoscopic retrograde cholangiopancreatography in surgically altered anatomy. Gastrointest Endosc Clin N Am 2015;25(4):631–56.

[16] Emmett DS, Mallat DB. Double-balloon ERCP in patients who have undergone Roux-en-Y surgery: a case series. Gastrointest Endosc 2007;66(5):1038–41.

[17] De Koning M, Moreels TG. Comparison of double-balloon and single-balloon enteroscope for therapeutic endoscopic retrograde cholangiography after Roux-en-Y small bowel surgery. BMC Gastroenterol 2016;16(1):98.

[18] Shimatani M, Hatanaka H, Kogure H, et al. Diagnostic and therapeutic endoscopic retrograde cholangiography using a short-type double-balloon endoscope in patients with altered gastrointestinal anatomy: a multicenter prospective study in Japan. Am J Gastroenterol 2016;111(12):1750–8.

[19] Inamdar S, Slattery E, Sejpal DV, et al. Systematic review and meta-analysis of single-balloon enteroscopy-assisted ERCP in patients with surgically altered GI anatomy. Gastrointest Endosc 2015;82(1):9–19.

[20] Shah RJ, Smolkin M, Yen R, et al. A multicenter, U.S. experience of single-balloon, double-balloon, and rotational overtube-assisted enteroscopy ERCP in patients with surgically altered pancreaticobiliary anatomy (with video). Gastrointest Endosc 2013;77(4):593–600.

[21] Lennon AM, Kapoor S, Khashab M, et al. Spiral assisted ERCP is equivalent to single balloon assisted ERCP in patients with Roux-en-Y anatomy. Dig Dis Sci 2012;57(5):1391–8.

[22] Ali MF, Modayil R, Gurram KC, Brathwaite CEM, Friedel D, Stavropoulos SN. Spiral enteroscopy-assisted ERCP in bariatric-length Roux-en-Y anatomy: a large single-center series and review of the literature (with video). Gastrointest Endosc 2018;87(5):1241–7.

[23] Skinner M, Popa D, Neumann H, Wilcox CM, Mönkemüller K. ERCP with the overtube-assisted enteroscopy technique: a systematic review. Endoscopy 2014;46(7):560–72.

[24] Skinner M, Peter S, Wilcox CM, Monkemuller K. Diagnostic and therapeutic utility of double-balloon enteroscopy for obscure GI bleeding in patients with surgically altered upper GI anatomy. Gastrointest Endosc 2014;80(1):181–6.

[25] da Ponte-Neto AM, Bernardo WM, de A Coutinho LM, et al. Comparison between enteroscopy-based and laparoscopy-assisted ercp for accessing the biliary tree in patients with Roux-en-Y gastric bypass: systematic review and meta-analysis. Obes Surg 2018;28(12):4064–76.

[26] Peters M, Papasavas PK, Caushaj PF, Kania RJ, Gagné DJ. Laparoscopic transgastric endoscopic retrograde cholangiopancreatography for benign common bile duct stricture after Roux-en-Y gastric bypass. Surg Endosc 2002;16(7):1106.

[27] Saleem A, Levy MJ, Petersen BT, Que FG, Baron TH. Laparoscopic assisted ERCP in Roux-en-Y gastric bypass (RYGB) surgery patients. J Gastrointest Surg 2012;16(1):203–8.

[28] Bowman E, Greenberg J, Garren M, et al. Laparoscopic-assisted ERCP and EUS in patients with prior Roux-en-Y gastric bypass surgery: a dual-center case series experience. Surg Endosc 2016;30(10):4647–52.

[29] Falcão M, Campos JM, Galvao Neto M, et al. Transgastric endoscopic retrograde cholangiopancreatography for the management of biliary tract disease after Roux-en-Y gastric bypass treatment for obesity. Obes Surg 2012;22(6):872–6.

[30] Snauwaert C, Laukens P, Dillemans B, et al. Laparoscopy-assisted transgastric endoscopic retrograde cholangiopancreatography in bariatric Roux-en-Y gastric bypass patients. Endosc Int Open 2015;3(5):E458–63.

[31] Ceppa FA, Gagne DJ, Papasavas PK, Caushaj PF. Laparoscopic transgastric endoscopy after Roux-en-Y gastric bypass. Surg Obes Relat Dis 2007;3(1):21–4.

[32] Richardson JF, Lee JG, Smith BR, Nguyen B, Pham KP, Nguyen NT. Laparoscopic transgastric endoscopy after Roux-en-Y gastric bypass: case series and review of the literature. Am Surg 2012;78(10):1182–6.

[33] Frederiksen NA, Tveskov L, Helgstrand F, Naver L, Floyd A. Treatment of common bile duct stones in gastric bypass patients with laparoscopic transgastric endoscopic retrograde cholangiopancreatography. Obes Surg 2017;27(6):1409–13.

[34] Mohammad B, Richard MN, Pandit A, Zuccala K, Brandwein S. Outcomes of laparoscopic-assisted ERCP in gastric bypass patients at a community hospital center. Surg Endosc 2020;34(12):5259–64.

[35] Bertin PM, Singh K, Arregui ME. Laparoscopic transgastric endoscopic retrograde cholangiopancreatography (ERCP) after gastric bypass: case series and a description of technique. Surg Endosc 2011;25(8):2592–6.

[36] Gutierrez JM, Lederer H, Krook JC, Kinney TP, Freeman ML, Jensen EH. Surgical gastrostomy for pancreatobiliary and duodenal access following Roux en Y gastric bypass. J Gastrointest Surg 2009;13(12):2170–5.

[37] Habenicht Yancey K, McCormack LK, McNatt SS, Powell MS, Fernandez AZ, Westcott CJ. Laparoscopic-assisted transgastric ERCP: a single-institution experience. J Obes 2018;2018:8275965.

[38] Lim CH, Jahansouz C, Freeman ML, Leslie DB, Ikramuddin S, Amateau SK. Outcomes of endoscopic retrograde cholangiopancreatography (ERCP) and Sphincterotomy for suspected sphincter of Oddi dysfunction (SOD) post Roux-En-Y gastric bypass. Obes Surg 2017;27(10):2656–62.

[39] Banerjee N, Parepally M, Byrne TK, Pullatt RC, Coté GA, Elmunzer BJ. Systematic review of transgastric ERCP in Roux-en-Y gastric bypass patients. Surg Obes Relat Dis 2017;13(7):1236–42.

[40] Grimes KL, Maciel VH, Mata W, Arevalo G, Singh K, Arregui ME. Complications of laparoscopic transgastric ERCP in patients with Roux-en-Y gastric bypass. Surg Endosc 2015;29(7):1753–9.

[41] Aiolfi A, Asti E, Rausa E, Bernardi D, Bonitta G, Bonavina L. Transgastric ERCP after Roux-en-Y gastric bypass: systematic review and meta-analysis. Obes Surg 2018;28(9):2836–43.

[42] Abbas AM, Strong AT, Diehl DL, et al. Multicenter evaluation of the clinical utility of laparoscopy-assisted ERCP in patients with Roux-en-Y gastric bypass. Gastrointest Endosc 2018;87(4):1031–9.

[43] Martinez J, Guerrero L, Byers P, et al. Endoscopic retrograde cholangiopancreatography and gastroduodenoscopy after Roux-en-Y gastric bypass. Surg Endosc 2006;20(10):1548–50.

[44] Shaikh SH, Stenz JJ, McVinnie DW, et al. Percutaneous gastric remnant gastrostomy following Roux-en-Y gastric bypass surgery: a single tertiary center's 13-year experience. Abdom Radiol (NY) 2018;43(6):1464–71.

[45] Max J, Cooney W, Scheiman J, Dimagno M, Elmunzer B. Through-the-skin ERCP and endoscopic ultrasound-guided cystogastrostomy in a patient with a Roux-en-Y gastric bypass. Endoscopy 2014;46(Suppl 1 UCTN):E22–3.

[46] Law R, Wong Kee Song LM, Petersen BT, Baron TH. Single-session ERCP in patients with previous Roux-en-Y gastric bypass using percutaneous-assisted transprosthetic endoscopic therapy: a case series. Endoscopy 2013;45(8):671–5.

[47] Saxena P, Azola A, Kumbhari V, Kalloo AN, Khashab MA. Percutaneous through-the-stent assisted ERCP in patients with Roux-en-Y gastric bypass. Gastrointest Endosc 2014;80(1):163.

[48] Schwartz PB, Easler JJ, Lancaster WP, et al. Sphincter of Oddi dysfunction after gastric bypass: surgical or endoscopic therapy? J Surg Res 2019;238:41–7.

[49] Kedia P, Kumta NA, Widmer J, et al. Endoscopic ultrasound-directed transgastric ERCP (EDGE) for Roux-en-Y anatomy: a novel technique. Endoscopy 2015;47(2):159–63.

[50] Attam R, Leslie D, Arain MA, Freeman ML, Ikramuddin S. EUS-guided sutured gastropexy for transgastric ERCP (ESTER) in patients with Roux-en-Y gastric bypass: a novel, single-session, minimally invasive approach. Endoscopy 2015;47(7):646–9.

[51] Kedia P, Sharaiha RZ, Kumta NA, Kahaleh M. Internal EUS-directed transgastric ERCP (EDGE): game over. Gastroenterology 2014;147(3):566–8.

[52] Majmudar K, Wagh MS. EUS-guided jejuno-jejunostomy with lumen-apposing metal stent for complete jejunal obstruction after gastric bypass. Gastrointest Endosc 2016;84(5):853–4.

[53] Schulman AR, Thompson CC. Endoscopic reconstruction of Roux-en-Y gastric bypass with placement of gastrojejunal and remnant-jejunal lumen-apposing metal stents. Gastrointest Endosc 2018;87(3):890–1.

[54] Wang TJ, Thompson CC, Ryou M. Gastric access temporary for endoscopy (GATE): a proposed algorithm for EUS-directed transgastric ERCP in gastric bypass patients. Surg Endosc 2019;33(6):2024–33.

[55] Tyberg A, Nieto J, Salgado S, et al. Endoscopic ultrasound (EUS)-directed transgastric endoscopic retrograde cholangiopancreatography or EUS: mid-term analysis of an emerging procedure. Clin Endosc 2017;50(2):185–90.

[56] Tyberg A, Kedia P, Tawadros A, et al. EUS-directed transgastric endoscopic retrograde cholangiopancreatography (EDGE): the first learning curve. J Clin Gastroenterol 2020;54(6):569–72.

[57] James TW, Baron TH. Endoscopic ultrasound-directed transgastric ERCP (EDGE): a single-center us experience with follow-up data on fistula closure. Obes Surg 2019;29(2):451–6.

[58] Chiang AL, Gaidhane M, Loren DE, et al. Impact of EUS-directed transgastric ERCP (EDGE procedure) access route on technical success and adverse events: a multi-center experience. Gastrointest Endosc 2018;87(6):AB70–1.

[59] Dhindsa BS, Dhaliwal A, Mohan BP, et al. EDGE in Roux-en-Y gastric bypass: how does it compare to laparoscopy-assisted and balloon enteroscopy ERCP: a systematic review and meta-analysis. Endosc Int Open 2020;8(2):E163–71.

[60] Kedia P, Tarnasky PR, Nieto J, Steele SL, Siddiqui A, Xu MM, et al. EUS-directed transgastric ERCP (EDGE) versus laparoscopy-assisted ERCP (LA-ERCP) for Roux-en-Y gastric bypass (RYGB) anatomy: a multicenter early comparative experience of clinical outcomes. J Clin Gastroenterol 2019;53(4):304–8.

[61] Bukhari M, Kowalski T, Nieto J, et al. An international, multicenter, comparative trial of EUS-guided gastrogastrostomy-assisted ERCP versus enteroscopy-assisted ERCP in patients with Roux-en-Y gastric bypass anatomy. Gastrointest Endosc 2018;88(3):486–94.

[62] Amateau SK, Lim CH, McDonald NM, Arain M, Ikramuddin S, Leslie DB. EUS-guided endoscopic gastrointestinal anastomosis with lumen-apposing metal stent: feasibility, safety, and efficacy. Obes Surg 2018;28(5):1445–51.

[63] Capella JF, Capella RF. Gastro-gastric fistulas and marginal ulcers in gastric bypass procedures for weight reduction. Obes Surg 1999;9(1):22–7. discussion 28.

[64] Crismale JF, Riff BP, Schwartz M, DiMaio CJ. Closure of an iatrogenic gastrogastric fistula created during EUS-directed transgastric ERCP. VideoGIE 2016;1(3):61–2.

[65] Jirapinyo P, Thompson AC, Kroner PT, Chan WW, Thompson CC. Metabolic effect of foregut exclusion demonstrated by the impact of gastrogastric fistula on recurrence of diabetes. J Am Coll Surg 2018;226(3). 259–66.e1.

[66] Kröll D, Müller AC, Nett PC, et al. Tailored access to the hepatobiliary system in post-bariatric patients: a tertiary care bariatric center experience. Surg Endosc 2020;34(12):2469–76.

[67] Moreels TG. ERCP in the patient with surgically altered anatomy. Curr Gastroenterol Rep 2013;15(9):343.

[68] Mergener K, Kozarek RA, Traverso LW. Intraoperative transjejunal ERCP. Gastrointestinal Endoscopy 2003;58(3):461–3.

[69] Chahine E, Kassir R, Chouillard E. How to manage bile duct injury in patients with duodenal switch. Surg Obes Relat Dis 2018;14(3):428–30.

[70] Dalmonte G, Valente M, Bosi S, Gnocchi A, Marchesi F. Transjejunal laparoscopic-assisted ERCP: a technique to deal with choledocholithiasis after Roux-en-Y reconstruction. Obes Surg 2019;29(6):2005–6.

[71] Fuente I, Beskow A, Wright F, et al. Laparoscopic transcystic common bile duct exploration as treatment for choledocholithiasis after Roux-en-Y gastric bypass. Surg Endosc. Epub 2021 Jan 4.

[72] Olausson M, Westen M, Boilesen AEB, Shabanzadeh DM. Laparoscopic common bile duct exploration for common bile duct stones complicated with cholangitis in patients with Roux-en-Y gastric bypass-clinical experience from three cases. Obes Surg 2020;30(12):5142–4.

[73] Cuschieri A, Lezoche E, Morino M, et al. E.A.E.S. multicenter prospective randomized trial comparing two-stage vs single-stage management of patients with gallstone disease and ductal calculi. Surg Endosc 1999;13(10):952–7.

[74] Ahmed AR, Husain S, Saad N, Patel NC, Waldman DL, O'Malley W. Accessing the common bile duct after Roux-en-Y gastric bypass. Surg Obes Relat Dis 2007;3(6):640–3.

[75] Milella M, Alfa-Wali M, Leuratti L, McCall J, Bonanomi G. Percutaneous transhepatic cholangiography for choledocholithiasis after laparoscopic gastric bypass surgery. Int J Surg Case Rep 2014;5(5):249–52.

[76] Weilert F, Binmoeller KF, Marson F, Bhat Y, Shah JN. Endoscopic ultrasound-guided anterograde treatment of biliary stones following gastric bypass. Endoscopy 2011;43(12):1105–8.

[77] Tripathi N, Mardini H, Koirala N, Raissi D, Emhmed Ali SM, Frandah WM. Assessing the utility, findings, and outcomes of percutaneous transhepatic cholangioscopy with Spyglass™Direct visualization system: a case series. Transl Gastroenterol Hepatol 2020;5(5):12.