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Review Article

Recent advances of endoscopic retrograde cholangiopancreatography in surgically altered anatomy

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ABSTRACT

Endoscopic retrograde cholangiopancreatography (ERCP) in patients with surgically altered anatomy (SAA) of the upper gastrointestinal tract is a more technically challenging and arduous procedure accompanied by a low success rate of reaching the target orifice and a relatively high rate of complications, compared to those with normal anatomy. Since the introduction of device-assisted enteroscopies such as balloon enteroscopy (BE) and manual spiral enteroscopy (SE) for small bowel disorders, they have also been used for ERCP in patients with SAA. The recent development of short-type BE makes ERCP in patients with SAA technically easier with high success rates and short procedural duration, and then short-type BE is considered the gold standard endoscopic procedure in these patients. Laparoscopy-assisted ERCP is another therapeutic option, especially for patients with a long excluded afferent limb of SAA. The choice of procedure for high success rates should be individualized according to patient characteristics and available physician competence. Moreover, novel motorized SE is a promising alternative procedure for the successful performance of ERCP.

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Keywords: Balloon enteroscopy; Double-balloon enteroscopy; Endoscopic retrograde cholangiopancreatography; Single-balloon enteroscopy

Introduction

Since its introduction in 1968, endoscopic retrograde cholangiopancreatography (ERCP) using side-viewing duodenoscope has been still widely used for the diagnostic and therapeutic procedures in biliopancreatic disorders in patients with normal gastrointestinal anatomy, although ERCP has recently evolved mainly into a therapeutic intervention due to the recent introduction of non-invasive and safer diagnostic procedures, such as endoscopic ultrasonography and magnetic resonance cholangiopancreatography. In patients with surgically altered anatomy (SAA) such as Billroth I or Billroth II anatomy with short limb, success rates of the performance of ERCP are similar to those with normal anatomy. However, ERCP is usually very challenging and time-consuming in patients with SAA, such as Roux-en-Y surgical reconstruction with hepaticojejunostomy, choledochojejunostomy, pancreaticoduodenectomy, or gastric bypass surgery, because the complexity of the long and tortuous anatomy or postoperative adhesion makes it difficult to access endoscopically.^{1,2} Although push enteroscope or conventional colonoscope has historically been used to access a long small bowel limb in those with SAA, it

is still technically challenging to perform ERCP with limited intubation depth by intragastric or small bowel looping.³

After introducing device-assisted enteroscopy, significant advances have recently been achieved for ERCP in patients with SAA. Double-balloon enteroscopy (DBE) using a 200-cm long standard-type double-balloon enteroscope was first introduced for small bowel disorders in 2001.⁴ In 2003, Fujifilm Endoscopy Company commercially introduced the standard-type double-balloon enteroscope with a 2.8-mm working channel and a 200-cm working length, with standard-type single-balloon enteroscope following in 2007.⁵ BE-assisted ERCP using double-balloon enteroscope was first successfully performed in a patient with Roux-en-Y choledochojejunostomy reconstruction in 2005.⁶ However, it was still a troublesome procedure because only limited ERCP accessories are available for these 200-cm long enteroscopes.⁷ Since short-type balloon enteroscopy (BE) was introduced into clinical practice for ERCP performance, it has been considered the first-line policy for diagnosis and therapeutic intervention of biliopancreatic disorders in patients with problematic SAA (Table 1). Moreover, ERCP with motorized spiral enteroscopy (SE) will be another upcoming new technology for the successful performance

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of ERCP.⁸ This review discusses recent advances of ERCP using device-assisted enteroscopes in patients with SAA, except for the role of endoscopic ultrasonography-guided interventions.

Balloon Enteroscopy

The advent of BE allows deep and even complete intubation of the small bowel for diagnosis and endoscopic intervention in patients with small bowel disorders. Moreover, its indications have been extended to ERCP in those with SAA, where it was impossible to complete the procedure using conventional forward-viewing or side-viewing endoscopes. The balloon enteroscope is advanced by holding and shortening the small bowel long-limbs with the inflated balloon(s). When it makes a loop during insertion, the small bowel is fixed using the inflated balloon(s) and shortened by withdrawing the BE. There are four types of balloon enteroscopes; standard-type double-balloon enteroscope, short-type double-balloon enteroscope, standard-type single-balloon enteroscope, and short-type single-balloon enteroscope. A single-balloon enteroscope has a balloon attached to the tip end of the over-tube, while a double-balloon enteroscope has two balloons attached to each tip end of the endoscope and the over-tube. Table 2 shows the specifications of balloon enteroscopes currently

available for ERCP in those with SAA. A novel standard-type single balloon enteroscope (SIF-H190; Olympus Optical Co., Tokyo, Japan) was launched in Japan and Europe early in 2021. It has a wider working channel with a diameter of 3.2 mm to improve endo-therapeutic instrumental maneuverability than that of the existing enteroscope with a diameter of 2.8 mm (SIF Q260; Olympus Optical Co.), while maintaining an outer diameter of enteroscope equivalent to the existing one. After its introduction, all four types of balloon enteroscopes finally had the same wide working channel with a diameter of 3.2 mm. It has the same newly developed technologies as short-type single-balloon enteroscope (SIF-H290S; Olympus Optical Co.), such as a passive bending and high force transmission to facilitate smoother passage and sharp and clear high-definition imaging for better observation. Short-type double-balloon enteroscope (EI-580BT; Fujifilm Endoscopy, Tokyo, Japan) has another newly developed technology of an adaptive bending part and advanced force transmission, similar to the passive bending and high force transmission of single-balloon enteroscopes. The endoscopic accessories from the working channel port appear in a 5:30 o'clock direction on the endoscopic image for DBE, while it shows in an 8 o'clock direction for single-balloon enteroscopy (SBE).

A short-type balloon enteroscope with 152 cm in length

Table 1 Problematic Surgically Altered Anatomy and Choosing Initial Endoscope for Endoscopic Retrograde Cholangiopancreatography

Operation name	Gastric state	Intact papilla	Initial endoscope
Afferent/efferent gastrojejunostomy			
Billroth II gastrojejunostomy, short-limb/long-limb	Subtotal G	+	Side- or forward-viewing endoscope/BE
Classic/Pylorus-preserving Whipple operation	Subtotal G/Intact	-	BE
Short-limb Roux-en-Y (< 50 cm)			
Gastrectomy with Roux-en-Y	Subtotal G/Total G	+	BE
Classic/Pylorus-preserving Whipple with Roux-en-Y	Subtotal G/Intact	-	BE
Biliary diversion with Roux-en-Y	Intact	-	BE
Long-limb Roux-en-Y (Bariatric surgery, > 100 cm)			
Roux-en-Y gastric bypass	Gastric pouch	+	BE
Biliopancreatic diversion/Duodenal switch	Gastric pouch	+	BE

Subtotal G, subtotal gastrectomy; Total G, total gastrectomy; BE, balloon enteroscope.

Table 2 Specifications of Balloon Enteroscopes Currently Available

Scope type	Fujifilm		Olympus		
	Standard type	Short type	Standard type		Short type
	EN-580T	EI-580BT	SIF-Q260	SIF-H190	SIF-H290S
Release date (yr)	2013	2016	2007	2021	2016
Direction of view	Forward	Forward	Forward	Forward	Forward
Field of view (degree)	140	140	140	140	140
Distal outer diameter (mm)	9.4	9.4	9.2	9.2	9.2
Total length (mm)	2,300	1,820	2,345	2,280	1,840
Working length (mm)	2,000	1,550	2,000	2,000	1,520
Working channel (mm)	3.2	3.2	2.8	3.2	3.2
Adaptive bending part	No	Yes	No	No	No
Advanced force transmission	No	Yes	No	No	No
Passive bending part	No	No	No	Yes	Yes
High force transmission	No	No	No	Yes	Yes

Table 3 Outcomes of Short-Type Double-Balloon Enteroscopy-Assisted ERCP in Patients with Surgically Altered Anatomy

Author (year)	No. of patients (procedures)	Altered anatomy (n)	Enteroscopy success, % (n)	Selective cannulation success, % (n)	Therapeutic success, % (n)
Shimatani et al (2009) ¹⁰	68 (103)	Overall (103)	97.1 (100/103)	98.0 (98/100)	100 (98/98)
		B-II (17)	100 (22/22)	100 (22/22)	100 (22/22)
		R-Y TG (36)	94.5 (52/55)	96.2 (50/52)	100 (50/50)
		PD (15)	100 (26/26)	100 (26/26)	100 (26/26)
Tsujino et al (2010) ¹⁵	6 (12)	Overall (12)	100 (12/12)	100 (12/12)	100 (12/12)
		HJ (7)			
		R-Y (3)			
		PD (2)			
Cho et al (2011) ⁹	20 (29)	Overall (20)	86.2 (25/29)	96.0 (24/25)	100 (24/24)
		B-II (6)			
		R-Y (13)			
		PD (1)			
Osoegawa et al (2012) ¹⁶	28 (47)	Overall (47)	95.7 (45/47)	88.9 (40/45)	100 (40/40)
		B-II (19)	94.7 (18/19)	88.9 (16/18)	100 (16/16)
		R-Y (25)	96.0 (24/25)	87.5 (21/24)	100 (21/21)
		PD (3)	100 (3/3)	100 (3/3)	100 (3/3)
Siddiqui et al (2013) ¹⁷	79 (79)	Overall (79)	89.9 (71/79)	90.1 (64/71)	100 (64/64)
		B-II (3)	100 (3/3)	100 (3/3)	
		R-Y (53)	86.8 (46/53)	91.3 (42/46)	
		HJ (3)	100 (3/3)	100 (3/3)	
		PD (20)	95.0 (19/20)	84.2 (16/19)	
Choi et al (2013) ¹⁸	28 (32)	RYGB (32)	78.1 (25/32)	80.0 (20/25)	90.0 (18/20)
Katanuma and Isayama (2014) ¹²	N/A (281)	Overall (281)	94.0 (264/281)	N/A	N/A
		B-II (23)	100 (23/23)		
		R-Y (68)	97.1 (66/68)		
		PD (92)	95.7 (88/92)		
		HJ (72)	87.5 (63/72)		
		LT (18)	88.9 (16/18)		
		Interposition (8)	100 (8/8)		
Tsutsumi et al (2015) ²⁷	72 (72)	Overall (72)	98.6 (71/72)	100 (71/71)	100 (71/71)
		PD (41)			
		PPPD (20)			
		SSPPD (10)			
Sakakihara et al (2015) ²²	44 (44)	Overall (44)	86.4 (38/44)	94.7 (36/38)	100 (36/36)
		R-Y (17)			
		PD (27)			
Shimatani et al (2016) ²⁴	311(311)	Overall (311)	97.7 (304/311)	96.4 (293/304)	97.9 (277/283)
		B-II (26)	96.2 (25/26)	100 (25/25)	100 (24/24)
		R-Y (203)	97.0 (197/203)	97.0 (191/197)	96.8 (179/185)
		PD (44)	100 (44/44)	97.7 (43/44)	100 (42/42)
		PPPD (31)	100 (31/31)	90.3 (28/31)	100 (26/26)
		Others (7)	100 (7/7)	85.7 (6/7)	100 (6/6)
Tomoda et al (2016) ²⁵	20 (20)	HJ (20)	85.0 (17/20)	82.4 (14/17)	78.6 (11/14)
Tsou et al (2016) ²⁶	47 (73)	R-Y (47)	76.6 (36/47)	94.9 (37/39)*	100 (37/37)*
Shimatani et al (2017) ¹³	100 (112)	Overall (112)	99.1 (111/112)	98.2 (109/111)	100 (109/109)
		B-II (11)	100 (11/11)	100 (11/11)	100 (11/11)
		R-Y (67)	98.5 (66/67)	98.5 (65/66)	100 (65/65)
		PD (17)	100 (17/17)	100 (17/17)	100 (17/17)
		PPPD (14)	100 (14/14)	92.9 (13/14)	100 (13/13)
		Others (3)	100 (3/3)	100 (3/3)	100 (3/3)
Matsumoto et al (2018) ²⁰	11 (11)	Overall	100 (11/11)	N/A	63.6 (7/11)
		R-Y (7)	100 (7/7)		42.9 (3/7)
		PPPD (4)	100 (4/4)		100 (4/4)
Mizukawa et al (2018) ²¹	46 (46)	PD (46)	100 (46/46)	100 (46/46)	100 (46/46)
Yamada et al (2019) ¹⁴	N/A (163)	Overall (163)	100 (163/163)	95.7 (156/163)	96.2 (150/156)
		B-II (16)			
		R-Y (107))			
		HJ (9)			
		PD (29)			

Table 3 Continued

Author (year)	No. of patients (procedures)	Altered anatomy (n)	Enteroscopy success, % (n)	Selective cannulation Success, % (n)	Therapeutic success, % (n)
Uchida et al (2020) ²⁸	319 (805)	Overall (805)	94.3 (759/805)	N/A	90.7 (730/805)
		B-II (43)	97.7 (42/43)		93.0 (40/43)
		R-Y (390)	91.0 (355/390)		87.2 (340/390)
		PPPD (60)	96.7 (58/60)		95.0 (57/60)
		SSPPD (312)	97.4 (304/312)		93.9 (293/312)
Sato et al (2020) ²³	102 (102)	Overall (102)	N/A	N/A	89.2 (91/102)
		B-II (22)			
		R-Y (80)			

ERCP, endoscopic retrograde cholangiopancreatography; B-II, Billroth II; R-Y, Roux-en-Y; TG, total gastrectomy; PD, pancreaticoduodenectomy; HJ, hepaticojejunostomy; RYGB, Roux-en-Y gastric bypass; LT, liver transplantation; PPPD, pyloric preserving pancreaticoduodenectomy; SSPPD, subtotal stomach-reserving pancreaticoduodenectomy; N/A, not available.

*Success rate combined short-type double-balloon enteroscopy and standard-type double-balloon enteroscopy.

overcomes some of the problems associated with manipulating a long instrument of standard-type with 200 cm in length and allows most ERCP accessories with standard length to be used and facilitated treatment procedures.⁹ The ability of the short-type BE to reach the papilla of Vater or bilioenteric anastomosis was comparable with and even slightly superior with that of the standard-type BE.¹⁰ Comparing DBE and SBE for ERCP in patients with Roux-en-Y reconstruction, both techniques were equally competent with high success rates and acceptable complication rates.¹¹ When the target site cannot be reached during short-type BE in patients with long-limb Roux-en-Y reconstruction because of its short length, standard-type BE should be considered as the next step before performing more invasive percutaneous or surgical alternatives.¹² The most severe and problematic complication of BE-assisted ERCP was a perforation, which can occur in five different types, including intestinal perforation by scope tip, scope body, or tight tension during scope manipulation, peri-papillary perforation by device insertion, and bile duct perforation during balloon dilation.¹²

Short-type double balloon-assisted ERCP

A double-balloon endoscope has two balloons; one is attached to the tip end of the endoscope, and the other is attached to the tip end of the over-tube. Since a short-type double-balloon endoscope (EC-450BI5; Fujifilm Endoscopy) was first introduced in 2005, with a 2.8-mm working channel and a 152-cm working length, short-type double-balloon endoscope (EI-580BT; Fujifilm Endoscopy) with a 155-cm working length and a 3.2-mm working channel has newly developed technology of an adaptive bending part and advanced force transmission tract.¹³ The adaptive bending system is designed to control intestinal tract angulations with a flexible soft part at the end of the endoscope. It allows the endoscope to bend along the angulation of the intestinal tract and helps the endoscope return to its straight shape after passing through angulation. The advanced force transmission is designed to transmit the pushing, pulling, and rotating movements from the handle to the distal end of the endoscope, thus providing enhanced maneuverability of the double-balloon endoscope.

The patient group performing short-type DBE had a shorter insertion time required to reach the target site than the patient group performing standard-type DBE (10 min vs 14 min; $P < 0.01$). The success rate of pancreaticobiliary interventions in the short-type DBE group was as high as that in the standard-type DBE group (92% vs 89%; $P = 0.35$). A short-type DBE allows faster insertion to the target site for pancreaticobiliary intervention in

patients with SAA.¹⁴ Table 3 shows the outcomes of short-type DBE-assisted ERCP in patients with SAA.^{9,10,12-28} The success rates of reaching the target site, biliary cannulation, and therapeutic procedure in short-type DBE-assisted ERCP were 94.8%, 95.6%, and 94.5%, respectively, from these pooled data. On the other hand, the latest systematic review and meta-analysis reported that the success rates of reaching the target site, biliary cannulation, and therapeutic procedure in both short-type and standard-type DBE-assisted ERCP were 90%, 94%, and 93%, respectively.²⁹ Complications occurred in 6.8% during short-type DBE-assisted ERCP (Table 4). Perforation or emphysema occurred in 28 out of 2016 cases (1.4%). Pancreatitis occurred 1.7%. Other minor complications included cholangitis, bleeding, mucosal laceration, bile leakage, biliary damage, aspiration pneumonia, and ischemic liver graft.

Short-type single balloon-assisted ERCP

A single-balloon endoscope has one balloon attached to the tip of the over-tube without a balloon attached to the tip end of the endoscope. A short-type double-balloon endoscope (SIF-H20S; Olympus Optical Co.) was launched in 2016 with a 152-cm working length and a 3.2-mm working channel, enabling nearly all devices used to perform conventional ERCP. It has sharp and clear high-definition imaging for better observation and also has newly developed passive bending and high force transmission technology to facilitate smoother passage, similar to a colonoscope. The use of a SBE with passive bending and high force transmission functions may increase the success rate of reaching the blind end. Yamauchi et al³⁰ reported that short-type SBE was useful for ERCP in patients with Roux-en-Y anastomosis and may reduce the time required to reach the blind end.

Table 5 shows the outcomes of short-type SBE-assisted ERCP in patients with SAA.^{19,30-36} The success rates of reaching the target site, biliary cannulation, and therapeutic procedure in short-type SBE-assisted ERCP were 91.8%, 89.9%, and 91.1%, respectively, from these pooled data. Causes of procedural failure included malignant biliary obstruction, first ERCP attempt, and Roux-en-Y reconstruction,³² and multivariate analyses indicated that pancreatic indication, first ERCP attempt, and no transparent hood were potential risk factors for procedural failure.³³ Complications occurred in 6.8% during short-type SBE-assisted ERCP (Table 6). Perforation or emphysema occurred in 9 out of 636 cases (1.4%). Pancreatitis occurred 2.8%. Other minor complications included cholangitis, Cholecystitis, bleeding of the papilla, mucosal laceration, and hematoma.

Table 4 Complications of Short-Type Double-Balloon Enteroscopy-Assisted ERCP in Patients with Surgically Altered Anatomy

Author (year)	Complications, % (n)	Perforation or emphysema (n)	Pancreatitis (n)	Others (n)
Shimatani et al (2009) ¹⁰	4.9 (5/103)	Intestinal perforation (1) Retroperitoneal perforation (1) Post-EST perforation (1) Retroperitoneal emphysema (1) Subcutaneous emphysema with pneumothorax (1)	0	0
Tsujino et al (2010) ¹⁵	16.6 (2/12)	Retroperitoneal air (1)	0	Cholangitis (1)
Cho et al (2011) ⁹	0 (0/29)	0	0	0
Osoegawa et al (2012) ¹⁶	3.6 (1/28)	Intestinal perforation (1)	0	0
Siddiqui et al (2013) ¹⁷	8.9 (7/79)	0	Mild (3)	Abdominal pain (3) Post-procedural bleeding (1)
Choi et al (2013) ¹⁸	3.1 (1/32)	0	Moderate (1)	0
Katanuma and Isayama (2014) ¹²	N/A	N/A	N/A	N/A
Tsutsumi et al (2015) ²⁷	2.8 (2/72)	0	0	Cholangitis (2)
Sakakihara et al (2015) ²²	15.9 (7/44)	0	0	Cholangitis (7)
Shimatani et al (2016) ²⁴	10.6 (33/311)	Obvious perforation (1) Microperforation (6)	11	Mucosal laceration (1) Biliary damage (4) Cholangitis (8) Aspiration pneumonia (2)
Tomoda et al (2016) ²⁵	10.0 (2/20)	0	0	Ischemic liver graft (1)
Tsou et al (2016) ²⁶	4.3 (2/47)	Intestinal perforation (1)	0	Cholangitis (1)
Shimatani et al (2017) ¹³	2.7 (3/112)	0	0	Mucosal laceration (3)
Matsumoto et al (2018) ²⁰	0 (0/11)	0	0	0
Mizukawa et al (2018) ²¹	6.5 (3/46)	0	0	Cholangitis (3)
Yamada et al (2019) ¹⁴	4.3 (7/163)	Retroperitoneal emphysema (1)	6	0
Uchida et al (2020) ²⁸	5.4 (44/805)	Intestinal perforation (6)	14	Cholangitis (20) Others (4)
Sato et al (2020) ²³	17.6 (18/102)	Intra-abdominal and/or retroperitoneal air (6)	0	Cholangitis (10) Bile leakage (1) Bleeding (1)

ERCP, endoscopic retrograde cholangiopancreatography; EST, endoscopic sphincterotomy; N/A, not available.

Spiral Enteroscopy-Assisted ERCP

SE is a technique that was first introduced in 2006 by Akerman et al³⁷ for deep small bowel intubation. SE has recently been used for deep enteroscopy in patients with many normal and altered anatomy, including ERCP procedures. Diagnostic and therapeutic yields were similar with SBE-assisted ERCP and SE-assisted ERCP in patients with Roux-en-Y anatomy with no significant difference in procedure time or complication rates.³⁸ In a multicenter retrospective study on device-assisted enteroscopy, ERCP success rates were similar among SBE, DBE, and SE with an overall ERCP success rate of 63% in patients with both Roux-en-Y gastric bypass and other long-limb surgical bypasses.³⁹ A recent large single-center study reported that SE-assisted ERCP in 35 patients with bariatric-long-limb Roux-en-Y reconstruction is safe and effective with overall success rate of 86%.⁴⁰

Motorized SE is another upcoming new technology, namely 'self-propelling' enteroscopy, available from 2015.⁴¹ A novel reusable PSF-1 PowerSpiral enteroscope (Olympus Medical Systems, Tokyo, Japan) has an integrated electric motor for rotating a disposable short spiral overtube mounted on a rotation coupler located in the distal quarter of the insertion tube.⁴² It has a working length of 168 cm, an outer diameter of 11.3 mm, and a working channel diameter of 3.2 mm. Disposable atraumatic spiral

overtube has a total length of 240 mm, an outer diameter of 18.1 mm, an outer diameter of soft spiral fins of 31.1 mm. Recent two prospective clinical studies in patients with suspected small bowel disorders showed that complete enteroscopy is feasible with motorized SE, either from antegrade alone or bidirectionally, with high success rates and short procedural duration.⁴³ These results justify further evaluation for clinical application and safety of motorized SE in a large-scale prospective multicenter study.

Other Device-Assisted ERCP

In patients with biliopancreatic diversion, the long efferent and afferent limbs prevent any change of performing traditional ERCP. Moreover, it is usually impossible to perform traditional ERCP very similar to the biliopancreatic diversion surgery in duodenal switch procedure.⁴⁴ Since the introduction of BE, it becomes the gold standard for performing ERCP in altered anatomy, especially with a very long limb as in Roux-en-Y gastric bypass and Roux-en-Y reconstruction. When BE-assisted ERCP failed in these patients, many alternative endoscopic and surgical techniques can be adopted as the next step for successful biliopancreatic diagnosis and intervention, such as endoscopic ultrasonography-guided ERCP, endoscopic gastropexy or gastrostomy ERCP, and laparoscopy-assisted ERCP.⁴⁵ Laparoscopy-assisted ERCP is performed by

Table 5 Outcomes of Short-Type Single-Balloon Enteroscopy-Assisted ERCP in Patients with Surgically Altered Anatomy

Author (year)	No. of patients (procedures)	Altered anatomy (n)	Enteroscopy success, % (n)	Selective cannulation success, % (n)	Therapeutic success, % (n)
Yamauchi et al (2013) ³⁶	22 (31)	Overall (31)	90.5 (28/31)	89.3 (25/28)	95.7 (22/23)
		B-II (8)	87.5 (7/8)	85.7 (6/7)	100 (5/5)
		R-Y gastrectomy (21)	90.5 (19/21)	89.5 (17/19)	93.8 (15/16)
		R-Y HJ (2)	100 (2/2)	100 (2/2)	100 (2/2)
Obana et al (2013) ³⁴	8 (12)	R-Y gastrectomy (8)	87.5 (7/8)	71.4 (5/7)	71.4 (5/7)
Iwai et al (2014) ³¹	N/A (62)	Overall (62)	91.9 (57/62)	87.7 (50/57)	94.1 (48/51)
		B-II (10)	90.0 (9/10)	88.9 (8/9)	100 (8/8)
		R-Y (52)	92.3 (48/52)	87.5 (42/48)	93.0 (40/43)
Shimatani et al (2014) ³⁵	26 (26)	Overall (26)	92.3 (24/26)	91.7 (22/24)	100 (22/22)
		B-II (3)	100 (3/3)	100 (3/3)	100 (3/3)
		R-Y gastrectomy (4)	100 (4/4)	75.0 (3/4)	100 (3/3)
		R-Y HJ (8)	75.0 (6/8)	100 (6/6)	100 (6/6)
		PD (4)	100 (4/4)	100 (4/4)	100 (4/4)
		PPPD (5)	100 (5/5)	100 (5/5)	100 (5/5)
		Other (2)	100 (2/2)	50.0 (1/2)	100 (1/1)
Kawamura et al (2015) ¹⁹	18 (27)	Overall (27)	88.9 (24/27)	83.3 (20/24)	95.0 (19/20)
		B-II (2)	100 (2/2)	50.0 (1/2)	100 (1/1)
		R-Y gastrectomy (15)	86.7 (13/15)	76.9 (10/13)	90.0 (9/10)
		R-Y CJ (10)	90.0 (9/10)	100 (9/9)	100 (9/9)
Yamauchi et al (2015) ³⁰	62 (84)	Overall (84)	90.5 (76/84)	89.5 (68/76)	95.6 (65/68)
		R-Y gastrectomy (63) R-Y HJ (21)			
Yane et al (2017) ³³	117 (203)	Overall (203)	92.6 (188/203)	N/A	81.8 (166/203)
		B-II (20)	100 (20/20)		95.0 (19/20)
		R-Y gastrectomy (45)	95.6 (43/45)		88.9 (40/45)
		R-Y HJ (59)	81.4 (48/59)		79.7 (47/59)
		PD (79)	97.5 (77/79)		75.9 (60/79)
Tanisaka et al (2019) ³²	121 (191)	Overall (191)	94.8 (181/191)	92.3 (167/181)	98.2 (164/167)
		B-II (31)	100 (31/31)	100 (31/31)	100 (31/31)
		R-Y gastrectomy (87)	93.1 (81/87)	85.2 (69/81)	95.7 (66/69)
		R-Y HJ (34)	88.2 (30/34)	96.7 (29/30)	100 (29/29)
		PD (39)	100 (39/39)	97.4 (38/39)	100 (38/38)

ERCP, endoscopic retrograde cholangiopancreatography; B-II, Billroth II; R-Y, Reux-en-Y; HJ, hepaticojejunostomy; PD, pancreaticoduodenectomy; PPPD, pyloric preserving pancreaticoduodenectomy; CJ, choledochojejunostomy; N/A, not available.

Table 6 Complications of Short-Type Single-Balloon Enteroscopy-Assisted Endoscopic Retrograde Cholangiopancreatography in Patients with Surgically Altered Anatomy

Author (year)	Complications, % (n)	Perforation or emphysema (n)	Pancreatitis (n)	Others (n)
Yamauchi et al (2013) ³⁶	12.9 (4/31)*	Intestinal perforation (1)	2	Bleeding of papilla (1)
Obana et al (2013) ³⁴	0 (0/12)	0	0	0
Iwai et al (2014) ³¹	9.7 (6/62)	Intestinal perforation (2)	3	Bleeding of papilla (1)
Shimatani et al (2014) ³⁵	3.8 (1/26)	0	0	Hematoma (1)
Kawamura et al (2015) ¹⁹	0 (0/27)	0	0	0
Yamauchi et al (2015) ³⁰	4.8 (4/84)*	Intestinal perforation (2)	Mild (2)	0
Yane et al (2017) ³³	5.9 (12/203)	Intestinal perforation (2)	3	Cholangitis (4)
		Guidewire perforation (1)		Cholecystitis (1)
				Mucosal laceration (1)
Tanisaka et al (2019) ³²	8.4 (16/191)	Intestinal perforation (1)	8	Cholangitis (6)

*Hyperamylasemia was excluded from major complications.

laparoscopically creating a gastrostomy through which a standard duodenoscope can be advanced into the excluded stomach and duodenum.⁴⁶ Studies about Laparoscopy-assisted ERCP reported that this method had high success rates with a higher overall complication rate than standard ERCP due to the laparoscopic approach.^{46,47} In patients with Reux-en-Y gastric bypass, laparos-

copy-assisted ERCP and BE-assisted ERCP had high success rates of 87.2% and 72.5%, respectively, if performing in experienced hands.⁴⁸ Therefore, the choice of procedure should be individualized according to the patient's characteristics and the expertise of endoscopists.

Conclusions

Diagnostic and therapeutic options for ERCP in patients with SAA have traditionally been limited and frustrating for endoscopists. Recently, device-assisted enteroscopy, including BE-, SE-, and laparoscopy-assisted ERCP, have improved the diagnostic and therapeutic yield compared with earlier methods. However, each of the currently available methods has limitations. Motorized SE could be another upcoming new ERCP technology in patients with SAA. The success of ERCP in terms of reaching the target site, biliary cannulation, and procedural success in patients with SAA is mainly related to the length and mobility of the bowel needing to be traversed and the expertise of endoscopists. Despite these significant advances in device-assisted ERCP, there still exists considerable room for improvement, and the development of new, rapid, safe, and practical techniques is needed for ERCP in patients with SAA.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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