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Review Article

Balloon enteroscope-assisted endoscopic retrograde cholangiopancreatography in patients with surgically altered anatomy

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A B S T R A C T

Endoscopic retrograde cholangiopancreatography (ERCP) is the gold standard for diagnosis and intervention in patients with biliopancreatic disorders. However, ERCP in patients with surgically altered anatomy (SAA) is considered more difficult than in patients with normal anatomy. Since the introduction of balloon enteroscopes for patients with small intestine disorders, single-balloon enteroscopes (SBEs) and double-balloon enteroscopes (DBEs) have also been used for biliopancreatic diseases in patients with SAA. Nevertheless, the use of conventional SBEs and DBEs is limited, as a balloon enteroscope has a working length of 200 cm and a narrow working channel with a diameter of 2.8 mm; therefore, few ERCP accessories are available for use. A short-type SBE with a working length of 152 cm and a working channel of 3.2 mm in diameter, and a short-type DBE with a working length of 155 cm and a working channel of 3.2 mm were introduced to solve these difficulties. Favorable outcomes of these devices have recently been reported. Moreover, studies have reported several tips to achieve procedural success and factors affecting procedure failure. Difficult cases necessitate alternative techniques, such as percutaneous transhepatic biliary drainage and endoscopic ultrasound-guided biliary drainage.

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

Introduction

Since its development in 1968, endoscopic retrograde cholangiopancreatography (ERCP) has been considered the gold standard for diagnosis and intervention in biliopancreatic diseases.¹ Studies published over 15 years ago reported that ERCP-related procedures were successful in around 95% of cases.^{1,2} However, ERCP-related procedures are quite difficult to perform using a conventional duodenoscope in patients with surgically altered anatomy (SAA) due to procedures such as Roux-en-Y gastrectomy, hepaticojejunostomy with Roux-en-Y, pancreaticoduodenectomy, or Billroth II gastrectomy. The presence of a long, tortuous afferent limb and adhesions makes it difficult to reach the target site (such as the papilla or hepaticojejunal anastomosis). Even after reaching the target site, selective cannulation and subsequent treatments, such as stone extraction or drainage, are more technically demanding in patients with SAA than in those with normal anatomy. Therefore, percutaneous transhepatic biliary drainage

(PTBD) or surgical drainage were preferred in such cases.^{3,4}

Since the introduction of the balloon enteroscope (BE) for small bowel disorders,⁵ balloon-assisted ERCP, such as single-balloon enteroscope (SBE)-assisted ERCP, or double-balloon enteroscope (DBE)-assisted ERCP, has been used in patients with SAA. Nevertheless, the use of conventional SBE and DBE has been limited since BEs have a long working length (200 cm) and a narrow working channel (2.8 mm in diameter); therefore, few ERCP accessories are available for use and scope exchange is generally needed.

A short-type SBE (short SBE) with a working length of 152 cm and a working channel of 3.2 mm in diameter and a short-type DBE (short DBE) with a working length of 155 cm and a working channel of 3.2 mm have been introduced to solve these difficulties. These scopes have made it possible to perform various procedures. Moreover, studies have reported factors that can help achieve procedural success and factors that increase the risk of procedure failure. In this review, we discuss recent advances in

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BE-assisted ERCP in patients with SAA.

Procedures Using Balloon Enteroscopes

A BE is advanced by holding and shortening the intestine with an inflated balloon while confirming the fluoroscopy findings. Two types of BEs are currently available: SBEs and DBEs. The difference between SBEs and DBEs is the number of balloons (Fig. 1). Table 1 lists the specifications of the SBEs and DBEs that are currently available. An SBE is equipped with one balloon, which is attached to the tip of the over-tube. In contrast, a DBE is equipped with two balloons. One is attached to the tip of the endoscope, while the other is attached to the tip of the over-tube. Moreover, the working channel port of an SBE appears in the 8-o'clock direction on the endoscopic screen. In contrast, it appears in the 5:30-o'clock direction for a DBE. Since both conventional SBEs and DBEs have a working length of 200 cm, only a few ERCP accessories are available for use. Therefore, scope exchange from BE to a conventional forward-viewing upper endoscope while leaving the over-tube after reaching the target site may be needed.⁶ Moreover, the working channel diameter of 2.8 mm in a conventional SBE also makes it difficult to use ERCP accessories and perform advanced techniques, such as the double-guidewire technique. According to the latest systematic review and meta-analysis, the total procedural success rate using conventional SBE was 72.7%.⁷ Recently, a short SBE and DBE, with a working length of 152 cm (short SBE) and 155 cm (short DBE), and with working channel diameters of 3.2 mm have become available, making it possible to use a wider range of accessories during BE-assisted ERCP. Furthermore, the short SBE

is equipped with passive bending and high-force transmission,⁸ while the short DBE permits adaptive bending and advanced force transmission.⁹ These features have contributed to overcoming the difficulties associated with scope insertion to the target site or performing the subsequent procedures. When using a short SBE, if the scope is at the intestinal tract wall when passing through a sharp flexure, the passive bending section allows the scope to bend along the curve of the intestinal wall, making it possible to move forward smoothly. High-force transmission makes it possible to perform torque operations efficiently and provides better scope control. Therefore, it is also useful for selective cannulation and subsequent procedures. When using a short DBE, adaptive bending and advanced force transmission play a role similar to passive bending and high-force transmission with a short SBE.

In general, ERCP-related procedures using BE are performed with the patient under conscious sedation (e.g., using intravenous midazolam and pethidine). During scope insertion, the patient is placed in the prone position, but in cases of difficult insertion, the patient's position is modified or abdominal pressure is applied. Following the insertion of a BE into the small intestine while forming a loop, the small intestine can be fixed with the balloon and shortened or straightened while observing fluoroscopy. The use of carbon dioxide has been recognized as a technical improvement for endoscope insertion. Some difficult cases, such as those with long afferent limbs as seen in Roux-en-Y reconstruction cases, necessitate changing from a short-type enteroscope to a long-type enteroscope because of the insufficient length of the short-type enteroscope.¹⁰ A transparent hood is useful both for scope insertion and for subsequent procedures such as biliary cannulation.¹¹ Since postoperative adhesions tend to occur in pa-

Fig. 1. Balloon enteroscope. (A) Single-balloon enteroscope. (B) Double-balloon enteroscope.

Table 1 Specifications of SBEs and DBEs

Variable	Company			
	Olympus		Fujifilm	
	SIF-Q260 (SBE)	SIF-H290S (SBE)	EN-580T (DBE)	EI-580BT (DBE)
Field of view (degrees)	140	140	140	140
Outer diameter (mm)	9.2	9.2	9.4	9.4
Working length (mm)	2,000	1,520	2,000	1,550
Working channel diameter (mm)	2.8	3.2	3.2	3.2
Passive bending	No	Yes	No	No
High-force transmission	No	Yes	No	No
Adaptive bending	No	No	No	Yes
Advanced force transmission	No	No	No	Yes

SBE, single-balloon enteroscopy; DBE, double-balloon enteroscopy.

Table 2 Outcomes of SBE-Assisted ERCP

Author	Year	Type of scope	Enteroscopy success	Cannulation success	Procedural success
Itoi et al ⁶	2010	Conventional	92.3 (12/13)	83.3 (10/12)	76.9 (10/13)
Wang et al ¹³	2010	Conventional	81.3 (13/16)	92.3 (12/13)	75.0 (12/16)
Azeem et al ¹⁴	2013	Conventional	91.4 (53/58)	83.0 (44/53)	75.9 (44/58)
Lenze et al ¹⁵	2014	Conventional	73.1 (19/26)	78.9 (15/19)	57.7 (15/26)
Trindade et al ¹¹	2015	Conventional	87.5 (49/56)	89.8 (44/49)	71.4 (40/56)
Kawamura et al ¹⁶	2015	Short	88.9 (24/27)	83.3 (20/24)	70.4 (19/27)
Yamauchi et al ¹⁷	2015	Short	90.5 (76/84)	89.5 (68/76)	77.4 (65/84)
Yane et al ¹⁸	2017	Short	92.6 (188/203)	N/A	81.8 (166/203)
Tanisaka et al ¹⁰	2019	Short	94.8 (181/191)	92.3 (167/181)	85.9 (164/191)

Values are presented as % (number).

SBE, single-balloon enteroscopy; ERCP, endoscopic retrograde cholangiopancreatography; N/A, not available.

tients with SAA, endoscopists can feel the adhesions during scope insertion or shortening. It must be considered that perforation can occur more frequently during scope insertion in patients with SAA compared to patients with normal anatomy. After reaching the target site, selective cannulation is performed by advancing the guidewire while injecting the contrast medium to confirm its direction. After selective cannulation and cholangiopancreatography, endoscopic diagnoses or interventions, such as stone extraction, balloon dilation of the hepaticojejunostomy or pancreaticojejunostomy anastomosis, stent placement, and biopsy or cytology for diagnosis, are performed.

Endoscopic sphincterotomy (EST) is a common procedure during ERCP in patients with normal anatomy. However, it can be challenging in patients with SAA (after Billroth II gastrectomy or Roux-en-Y gastrectomy). It is considered difficult because the correct direction of the incision is sometimes uncertain due to the inverted position in these patients; if the incision is made in the wrong direction, perforation can occur. A study from a tertiary referral endoscopy center evaluated 40 cases of endoscopic papillary large balloon (> 10 mm) dilation (EPLBD) without EST for stone extraction in patients who had undergone Billroth II gastrectomy. The stones were successfully removed in all cases. The acute complications from EPLBD included mild pancreatitis in two patients (5.0%).¹² This result shows the usefulness and safety of EPLBD without EST. If endoscopists find it difficult to perform EST in patients with a history of Billroth II gastrectomy or Roux-en-Y gastrectomy, EPLBD without EST may be recommended.

Single-Balloon Enteroscopy-Assisted ERCP

Table 2 shows the outcomes of conventional or short SBE-assisted ERCP procedures in patients with SAA.^{6,10,11,13–18} The success of enteroscopy is indicated by the successful insertion of the scope to the target site. The procedural success rates for conventional and short SBE-assisted ERCP, which indicate the rates of successful completion of all steps, were 57.7%–76.9% and 70.4%–85.9%, respectively. It seems that the outcomes were better with short SBEs than with conventional SBEs. A recent multicenter retrospective study of 1,318 patients reported that the enteroscopy, cannulation, and procedural success rates were 87.9%, 87.0%, and 74.9%, respectively. Adverse events occurred in 7.7% of patients.¹⁹ A systematic review and meta-analysis that was mentioned previously reported that the pooled enteroscopy, cannulation, and procedural success rates were 86.6%, 90%, and 75.8%, respectively. Adverse events occurred in 6.6% of the pro-

cedures.⁷ Various procedures, such as metallic stent placement, were performed using short SBEs (Fig. 2).^{20,21}

Several strategies are used to ensure the success of SBE-assisted ERCP. For scope insertion to the target site, as mentioned before, a change from a short SBE to a conventional SBE is useful in cases with long afferent limbs, such as in patients who have undergone Roux-en-Y reconstruction. Selective cannulation is considered to be more difficult in patients with SAA than in those with normal anatomy. Possible reasons are that the papilla appears inverted, the view of the papilla tends to be tangential, the SBE is forward-viewing, and an elevator system is not present. As previously mentioned, the use of a transparent hood is effective for biliary cannulation.¹¹ It has been reported that using the retroflex position helps to obtain a better view of the papilla in patients with Roux-en-Y gastrectomy.^{22,23} To achieve the retroflex position, the enteroscope is advanced while using the upper angle at the inferior duodenal angle. The scope provides a J-turn form (Fig. 3). Furthermore, various techniques, such as the double-guidewire method, insertion along the pancreatic duct stent,²⁴ and the use of a unique cannula equipped with a double lumen,²⁵ have been reported to be useful.

Several studies have analyzed factors affecting the procedural results of SBE-assisted ERCP. One study reported that pancreatic indications, the first ERCP attempt, and the absence of a transparent hood affected procedural failure.¹⁸ Another study claimed that malignant biliary obstruction, the first ERCP attempt, and Roux-en-Y reconstruction affected the procedural results.¹⁰ Similarly, a multicenter study reported that the factors that affected procedural failure were malignancy, pancreatic indication, and Roux-en-Y reconstruction.¹⁹

Double-Balloon Enteroscopy-Assisted ERCP

Table 3 shows the outcomes of conventional/short DBE-assisted ERCP procedures in patients with SAA.^{26–34} The procedural success rates of conventional and short DBE-assisted ERCP were 80.0%–88.0% and 69.8%–98.6%, respectively. A multicenter prospective study of 311 patients reported that the enteroscopy, cannulation, and procedural success rates were 97.7%, 96.4%, and 92.3%, respectively. Adverse events occurred in 10.6% of patients.³⁵ According to the latest systematic review and meta-analysis, the pooled enteroscopy, cannulation, and procedural success rates were 90%, 94%, and 93%, respectively. Adverse events occurred in 4% of the procedures.³⁶ Major adverse events included pancreatitis ($n = 34$), perforation ($n = 27$), and cholan-

Fig. 2. Endoscopic metallic stent placement using a short single-balloon enteroscope in patients after pancreaticoduodenectomy. (A) The orifice of the hepaticojejunal anastomosis. (B) Cholangiography shows malignant biliary obstruction. The right and left intrahepatic bile ducts are not connected due to a malignant biliary obstruction. (C, D) Uncovered self-expandable metallic stents are inserted in the partial stent-in-stent manner.

Fig. 3. Retroflex position. (A, C) The papilla is positioned tangentially, making it difficult to perform biliary cannulation. (B, D) The endoscope is advanced while using the up-angle at the inferior duodenal angle, and adjusted to the retroflex position. Consequently, a better view of the papilla can be obtained.

Table 3 Outcomes of DBE-Assisted ERCP

Author	Year	Type of scope	Enteroscopy success	Cannulation success	Procedural success
Aabakken et al ²⁶	2007	Conventional	94.4 (17/18)	88.2 (15/17)	83.3 (15/18)
Emmett and Mallat ²⁷	2007	Conventional	85.0 (17/20)	94.1 (16/17)	80.0 (16/20)
Pohl et al ²⁸	2009	Conventional	88.0 (22/25)	100 (22/22)	88.0 (22/25)
Shimatani et al ²⁹	2009	Short	97.1 (100/103)	98.0 (98/100)	95.1 (98/103)
Parlak et al ³⁰	2010	Conventional	92.9 (13/14)	100 (13/13)	85.7 (12/14)
Tsutsumi et al ³¹	2015	Short	98.6 (71/72)	100 (71/71)	98.6 (71/72)
Cheng et al ³²	2015	Short	94.8 (73/77)	94.5 (69/73)	87.0 (67/77)
Liu et al ³³	2017	Short	75.6 (65/86)	92.3 (60/65)	69.8 (60/86)
Uchida et al ³⁴	2020	Short	94.3 (759/805)	N/A	90.7 (730/805)

Values are presented as % (number).

DBE, double-balloon enteroscopy; ERCP, endoscopic retrograde cholangiopancreatography; N/A, not available.

gitis ($n = 17$). One patient who experienced intestinal perforation during endoscopic insertion required an urgent laparotomy. A single-center large cohort study reported that the risk factors for complications were Billroth II gastrectomy and the presence of naïve papilla.³⁷ According to this study, Billroth II gastrectomy was a risk factor because the distance between the gastro-jejunal anastomosis and the Treitz ligament in a short afferent loop is extremely short because the afferent loop is lifted and sutured above the superior margin of the resected stomach to prevent reflux of the meal contents into the afferent loop. Therefore, it has been suggested that the perforation risk is increased due to the strong pushing force when inserting a scope into the afferent loop. Of course, this can also occur with an SBE.

Several suggestions have been made for ensuring the successful completion of DBE-assisted ERCP. Similar to procedures using an SBE, the retroflex position is also useful for biliary cannulation using a DBE. Since the working channel port appears in the 5:30-o'clock position in the endoscopic view, positioning the papilla in the 6-o'clock direction is effective for performing EST safely.³⁸ This position provides total protrusion and a hooding fold, which are the landmarks for the correct direction of the bile duct while performing EST. Furthermore, it is possible to confirm whether common bile duct stones are present between the balloon and common bile duct during EPLBD.³⁹

Factors affecting the procedural results of DBE-assisted ERCP have also been reported. A study reported that DBE-assisted ERCP in patients with childhood surgery, biliary atresia, and a second operation post-transplant was likely to fail among those who had undergone Roux-en-Y reconstruction.³³ Another study showed that Roux-en-Y reconstruction and first-time DBE-assisted ERCP affected the technical failure and adverse event rates.³⁴ In that study, whether the procedure was performed by a trainee did not significantly affect the technical success or adverse event rates. Moreover, a study that analyzed the factors affecting complete stone extraction revealed that a larger common bile duct diameter had a negative effect on complete stone extraction, while using the retroflex position could be useful for achieving complete stone clearance.⁴⁰

Alternative Treatments

Although many reports on BE-assisted ERCP have shown good outcomes in patients with SAA, there are several difficulties in achieving successful completion; therefore, it is impossible to complete treatment in all cases using BE-assisted ERCP only,

and alternative treatments are needed in some patients. PTBD is an effective drainage technique that is performed under fluoroscopic guidance to gain biliary access. A needle is passed through the skin into a dilated biliary duct, after which the patient may undergo external drainage.⁴¹ Despite high success rates, it may be impractical in urgent cases because of the requirement for serial dilation and track maturation.⁴² Moreover, there may be problems associated with the external drainage tube. However, PTBD can be used to perform stone extraction effectively and safely. Consequently, it is a good choice as an alternative treatment in cases of difficult stone extraction using BE.

In recent years, interventional endoscopic ultrasound (EUS) has been attracting attention as an alternative treatment for patients who have experienced ERCP failure (e.g., failure of scope insertion or biliary cannulation). Interventional EUS may be a first-line treatment in some cases, such as patients with malignant tumors with cancer invasion of the small intestine or papilla.¹⁰ Several drainage methods exist for interventional EUS in patients with SAA:⁴³ (1) EUS-guided hepaticogastrostomy (EUS-HGS), (2) EUS-guided antegrade stenting (EUS-AS), and (3) EUS-guided rendezvous procedure (EUS-RV). The stomach is punctured in EUS-HGS. When the stomach has been resected, such as in Roux-en-Y gastrectomy cases, the puncture is performed from the jejunal limb. After cholangiography and guidewire insertion, the fistula is dilated using a dilation device followed by the placement of a biliary stent.⁴⁴ Fig. 4 shows successful EUS-HGS in a patient with SAA. In EUS-AS, after puncture of the bile duct, a guidewire is passed through the papilla, and a biliary stent is placed via an antegrade route.⁴⁵ EUS-RV is a suitable option for difficult cannulation cases. After puncture of the bile duct, the guidewire is directed beyond the papilla. As a result, the guidewire is positioned in the duodenum. Afterward, the scope is exchanged from the duodenoscope. The guidewire is grasped using a forceps device and pulled into the working channel. Finally, biliary cannulation through the papilla is successfully completed.⁴⁶

Table 4 shows the outcomes of EUS-guided biliary drainage (EUS-BD).⁴⁷⁻⁵⁵ According to the latest systematic review and meta-analysis, the pooled technical success rates and clinical success rates were 91.5% and 87%, respectively. Adverse events occurred in 17.9% of patients. The main adverse events were bile leakage (4.1%), stent migration (3.9%), and infections (3.8%).⁵⁶ Although interventional EUS had high success rates, adverse events were more frequent than with BE-assisted ERCP.

Several reports have compared BE-assisted ERCP and EUS-BD in patients with SAA. A multicenter retrospective study reported

Fig. 4. Endoscopic ultrasound-guided hepatico-gastrostomy in patients with surgically altered anatomy (SAA), which is responsible for failure of single-balloon enteroscope assisted endoscopic retrograde cholangiopancreatography. (A) It was impossible to reach the target site due to tumor invasion of the duodenum. (B) Endoscopic ultrasound-guided biliary drainage was performed with a B3 puncture to obtain a cholangiogram. (C, D) A biliary stent was successfully placed.

Table 4 Outcomes of EUS-BD

Author	Year	Technical success	Clinical success	Adverse events
Hara et al ⁴⁷	2011	94.4 (17/18)	100 (17/17)	16.7 (3/18)
Shah et al ⁴⁸	2012	70.5 (62/88)	70.5 (62/88)	6.8 (6/88)
Khashab et al ⁴⁹	2013	94.3 (33/35)	91.4 (32/35)	11.4 (4/35)
Kawakubo et al ⁵⁰	2014	95.3 (61/64)	N/A	18.8 (12/64)
Gupta et al ⁵¹	2014	88.5 (207/234)	N/A	34.6 (81/234)
Kunda et al ⁵²	2016	98.2 (56/57)	94.7 (54/57)	7.1 (4/56)
Kahaleh et al ⁵³	2016	91.4 (32/35)	88.6 (31/35)	25.7 (9/35)
Tsuchiya et al ⁵⁴	2018	100 (19/19)	94.7 (18/19)	36.8 (7/19)
Minaga et al ⁵⁵	2019	85.2 (46/54)	85.2 (46/54)	18.5 (10/54)

Values are presented as % (number).

EUS-BD, endoscopic ultrasound-guided biliary drainage; N/A, not available.

that the clinical success rates of BE-assisted ERCP and EUS-BD were 59.1% and 88%, respectively ($P = 0.03$). In the EUS-BD group, the procedure was completed in a shorter time than in the BE-assisted ERCP group (55 min vs. 95 min; $P < 0.0001$). However, adverse events occurred more often in the EUS-BD group (20% vs. 4%, $P = 0.01$).⁵⁷ An international multicenter study compared EUS-BD and BE-assisted ERCP in patients who had undergone Roux-en-Y gastric bypass, and showed that the technical success rate of EUS-BD was superior to that of BE-assisted ERCP (100% vs. 60%). Adverse events were comparable.⁵⁸ Although interventional EUS was associated with a higher success rate and shorter procedure time, the rate of adverse events tended to be high. Fatal

complications, such as aberrant stent displacement into the abdominal cavity, have also been reported.⁵⁹ Dedicated devices for EUS-BD are warranted for safety. Hence, the choice between BE-assisted ERCP and interventional EUS depends on the postoperative reconstruction, the patient's general condition, and the expertise of the endoscopist.

Conclusions

In this review, we discussed recent advances in BE-assisted ERCP in patients with SAA. Many studies have demonstrated the usefulness and safety of BE-assisted ERCP. Recommendations to

achieve procedural success and factors affecting the procedural results have been reported. In difficult cases, alternative techniques, such as PTBD and EUS-BD, are required.

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Conflicts of Interest

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

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