Balloon Enteroscopy

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Introduction

The advent of double-balloon enteroscopy (DBE) a decade ago was a major breakthrough for the diagnosis and treatment of small bowel disorders [1–4]. Soon thereafter single-balloon enteroscopy (SBE) was introduced [5–8]. Both DBE and SBE have replaced push enteroscopy as the methods of choice to perform deep enteroscopy. Both techniques of SBE and DBE, similar to push enteroscopy, use the principle of the push-and-pull technique: The endoscope is first advanced (pushed) into the small bowel and this is followed by advancement of the overtube toward the tip of the endoscope. Then both the endoscope and overtube are pulled back together, pleating the small bowel over the scope. Hence the concept of "push and pull" [9]. However, when performing SBE and DBE, the major factor governing the maneuverability and depth of insertion of the enteroscope is the presence of a balloon on the distal end of the flexible overtube. Therefore, we proposed to call this technique "balloon-assisted" enteroscopy (BAE) [10]. This terminology also allows one to include the through-the-scope balloon into the spectrum of BAE [11].

In the meantime another overtube-based spiral enteroscopy device was developed [12]. The principle of spiral enteroscopy is based on the use of an overtube, which has a screwlike tubing covering it. This configuration allows for "screwing" the overtube and the endoscope into the jejunum [12, 13]. Because all modern deep enteroscopy methods rely on some sort of device, the term "device-assisted enteroscopy" was coined [14]. However, spiral enteroscopy did not gain the expected popularity and utility and is currently unavailable in most parts of the world. In addition, a new disposable device, the NaviAid™ AB (AB = advancing balloon), also called BGE

Electronic supplementary material: The online version of this chapter (doi: 10.1007/978-3-319-14415-3_7) contains supplementary material, which is available to authorized users. Videos can also be accessed at http://link.springer.com/chapter/10.1007/978-3-319-14415-3_7.

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R. Kozarek and J.A. Leighton (eds.), *Endoscopy in Small Bowel Disorders*,
DOI 10.1007/978-3-319-14415-3_7,

device (balloon-guided endoscopy), has been developed [15]. The NaviAid™ system can be used with standard endoscopes, consisting of a catheter with an inflatable balloon attached at the distal end. Once advanced through the working channel, the balloon can be inflated and used for anchoring, allowing the advancement of the endoscope. In this chapter we present the technical aspects of performing BAE, focusing on advances of the technique, equipment, and indications.

Definition of Balloon-Assisted Enteroscopy

BAE is the performance of either diagnostic or therapeutic interventions of the small bowel using a balloon-catheter or balloon-overtube. Currently there are three types of BAE: DBE, SBE, and balloon-catheter-guided enteroscopy (BGE). Both DBE and SBE use an overtube with a balloon attached at the distal part of the overtube. The main difference between SBE and DBE is the presence of a second balloon attached to the scope (Figs. 7.1 and 7.2). Deep enteroscopy performed with a through-the-scope balloon catheter is known as balloon-guiding endoscopy (BGE, NaviAid®) [15] (Fig. 7.2). For easiness and clear understanding of the methods used, we prefer to specifically state whether the BAE was performed using an overtube with a single balloon (SBE) or double balloon (DBE), or if an on-the-scope balloon technique (BGE) was employed.

Indications

The indications for BAE have increased significantly since its introduction in 2004. Currently, BAE techniques are not only used to perform deep enteroscopy, but the equipment can also be used for endoscopic retrograde cholangiopancreatography (ERCP), incomplete colonoscopies, or exploring the gastrointestinal tract of patients with surgically deranged anatomy [16–28]

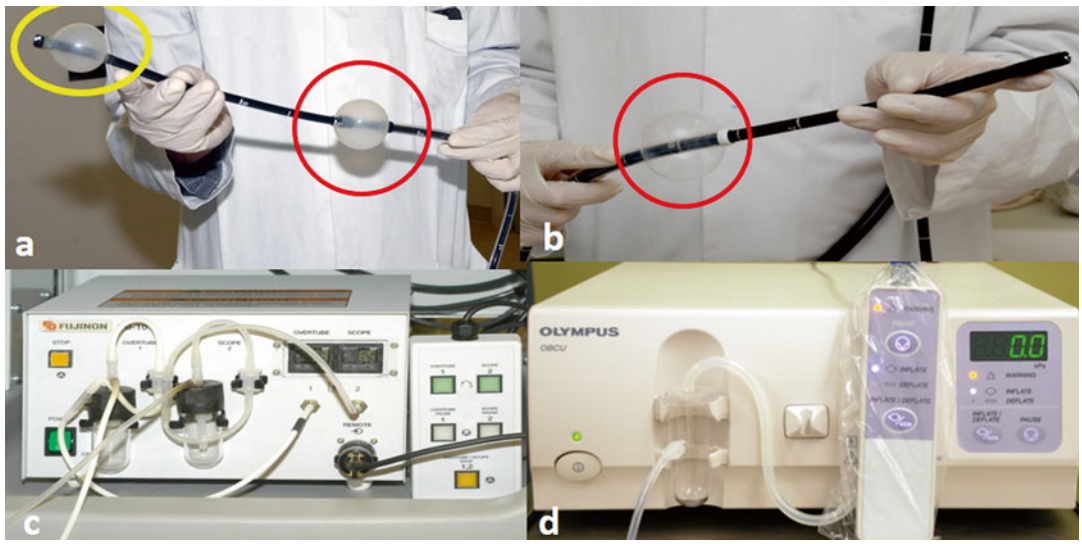

Fig. 7.1 Balloon-assisted enteroscopy. (**a**) Double-balloon enteroscope. (**b**) Single-balloon enteroscope. The major similitude is the overtube with the balloon (*red circle*). In double-balloon enteroscopy there is an additional balloon on top of the scope (*yellow oval*). Note balloon insufflators for Fujinon (**c**) and Olympus systems (**d**), respectively

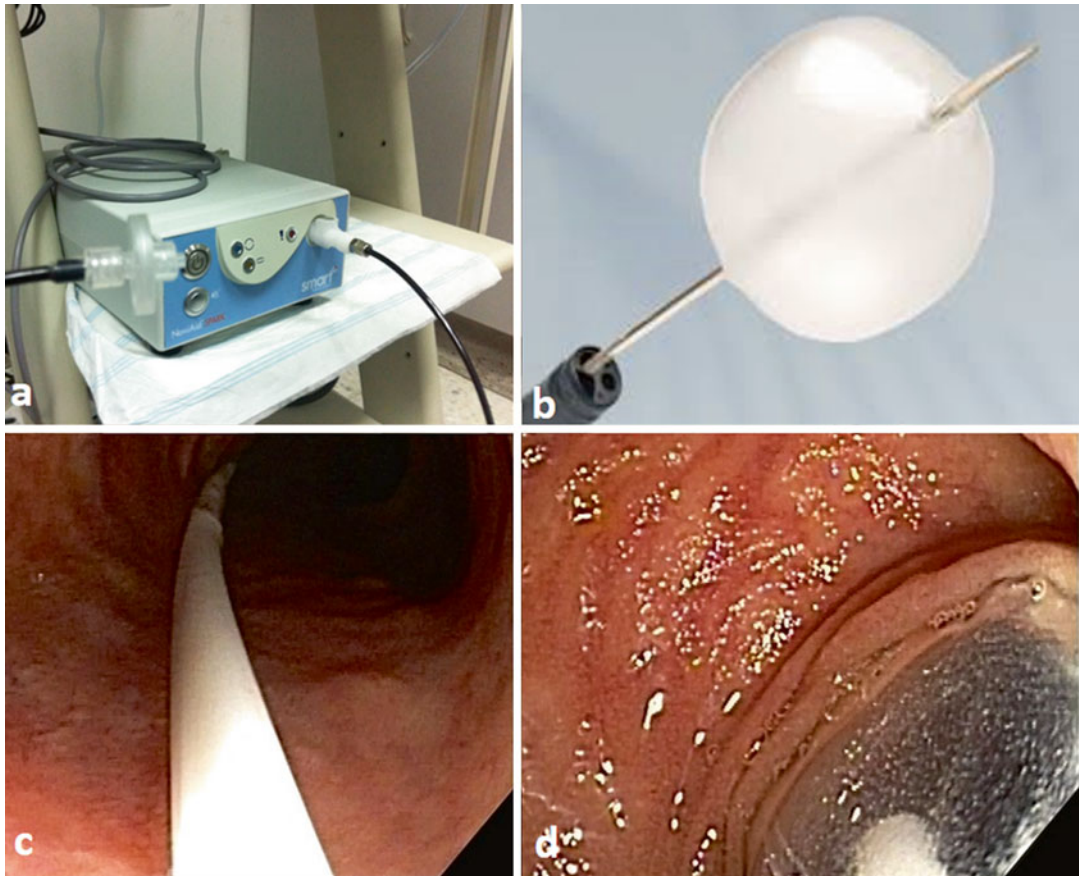

Fig. 7.2 Balloon-guided enteroscopy (BGE). The BGE device is attached to the scope. (**a**) Inflation device. (**b**) Advancing balloon. (**c**) Endoscopic view of advancing catheter. (**d**) Endoscopic view of advancing balloon

(Fig. 7.3). Table 7.1 lists indications for BAE. Furthermore, BAE has become an important tool to deliver various types of endoscopic therapies during deep enteroscopy, but also for many other gastrointestinal problems, such as insertion of self-expanding metal stents into the small bowel or into the stomach in patients with deranged anatomy [22–26] (Table 7.1, Figs. 7.4 and 7.5).

Equipment

We will separately describe the equipment and technique used for overtube-based BAE and through-the-scope balloon-guided enteroscopy.

Overtube-Assisted BAE

Currently there are two types of balloon enteroscopes: DBE (Fujifilm, Japan) and SBE (Olympus Optical Co, Ltd, Tokyo, Japan) [1–8, 13, 29, 30] (Fig. 7.1). The enteroscopes used to perform DBE come in various lengths and diameters (Table 7.2). This variety allows one to choose the scope for different conditions. The diagnostic or small-diameter enteroscope is potentially useful for narrowed luminal diameter, significant adhesions, and/or performing incomplete colonoscopy [13, 30]. However, the small working channel of this enteroscope limits the therapeutic capabilities, as there are few accessories that can be easily

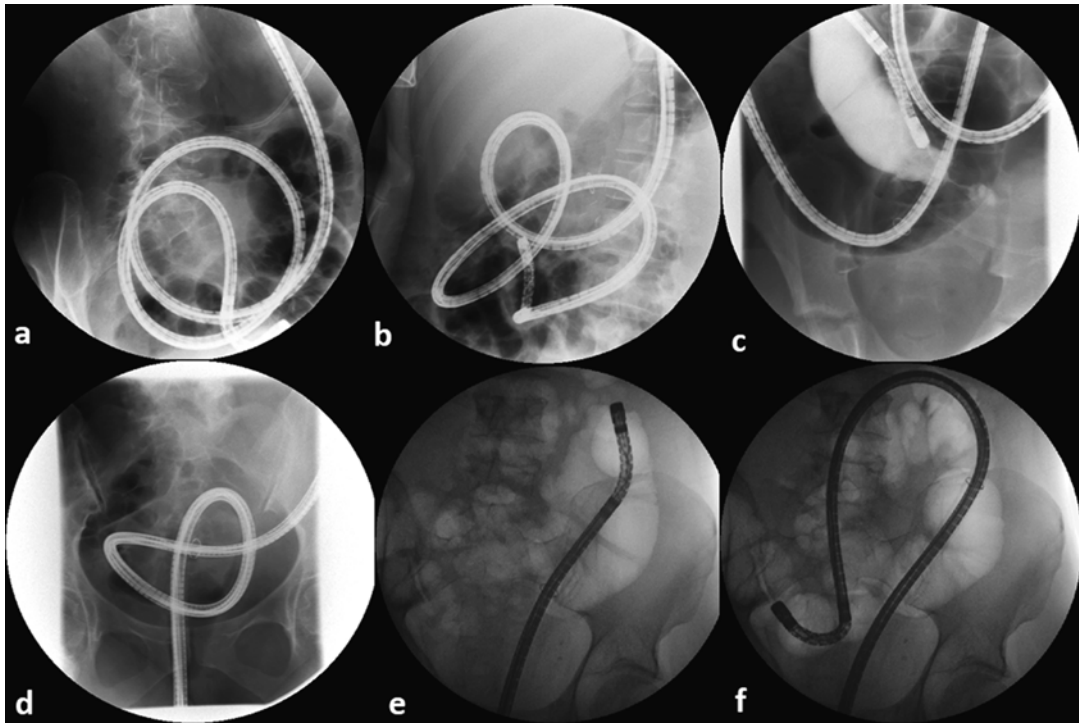

Fig. 7.3 Fluoroscopy during balloon-assisted enteroscopy (BAE). The images show (**a**) antegrade (oral) BAE, (**b**) looping of bowel due to adhesions during an oral BAE, (**c**) use of contrast to delineate a stricture in a patient with Crohn's disease, (**d**) "pretzel" configuration of the scope in a patient with previously failed colonoscopy, (**e**) retrograde (anal) BAE, and (**f**) passing of a long and floppy splenic flexure during anal BAE

Table 7.1 Indications and potential therapeutic interventions using the balloon-assisted enteroscopy

Small bowel bleeding Hemostasis • Argon plasma coagulation • Injection of diluted epinephrine (1:100,000) • Sclerotherapy (cyanoacrylate injection, Dermabond®, Histoacryl®) • Placement of clips (standard hemoclips or over-the-scope clips)
Crohn's disease Balloon dilation of strictures Retrieval of retained small bowel capsule
NSAID enteropathy Balloon dilation of strictures
Malabsorption syndromes
Celiac disease (surveillance)
Polyposis syndromes (surveillance)
Polypectomy
Endoscopic mucosal resection
Tumors (adenocarcinoma, gastrointestinal stromal tumors, search for primary neuroendocrine tumors)
Submucosal injection with India ink
Removal of foreign bodies (e.g., capsule endoscope, pins, dentures, needles, coins)
Colonoscopy Complete a previously failed colonoscopy Stent placement
Percutaneous endoscopic jejunostomy in normal and altered bowel anatomy (gastric bypass, Roux-en-Y)
Biliary interventions ERCP • Cholangiogram • Pancreatogram • Sphincterotomy • Precut sphincterotomy • Papillectomy • Balloon dilation • Stone removal • Stent placement/removal (plastic and metal stents) • Removal of dislocated metal stent

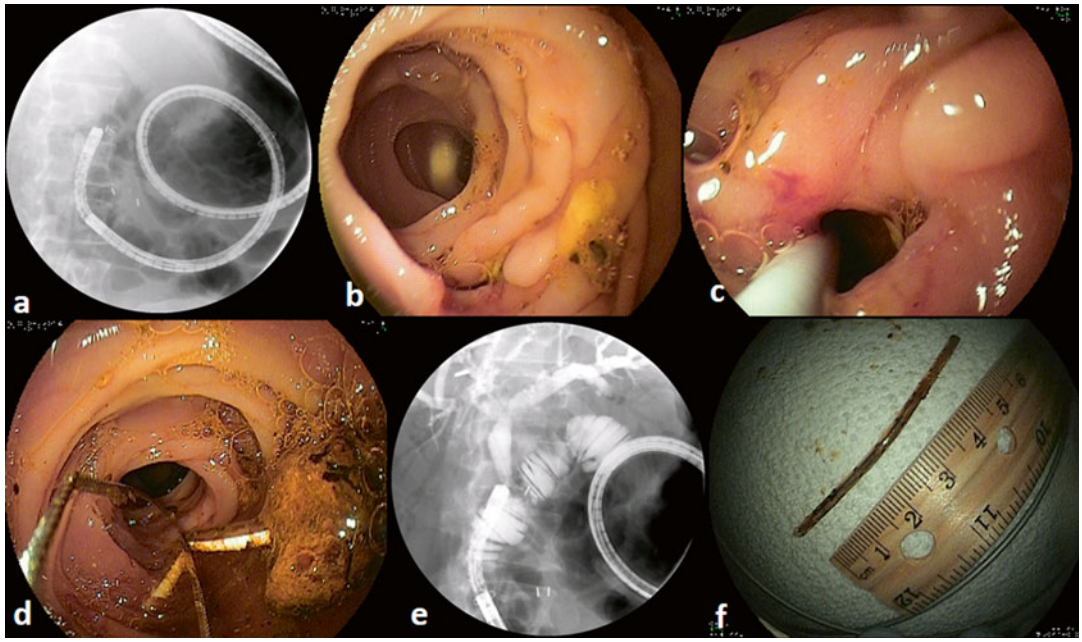

Fig. 7.4 BAE-ERCP in a patient with Whipple operation and hepaticojejunostomy with Roux-en-Y anastomosis. (**a**) Scope in biliodigestive limb. (**b**) The hepaticojejunostomy is often difficult to find. Here it is located at the 6 o'clock position. (**c**) Cannulation of the hepaticojejunostomy. (**d**) Removal of sludge and an inwardly migrated plastic stent with a basket. (**e**) Cholangiography. (**f**) Removed stent

advanced through this 2.2 mm channel. For this reason, most experts prefer the "therapeutic" enteroscope, which has a larger diameter and wider working channel (2.8 mm) [29, 30] (Table 7.2, Video 7.1). The single-balloon enteroscope (SIF Q260) has a 200 cm working length, a 9.2 mm outer diameter, and a 2.8 mm working channel [5–8]. This enteroscope from Olympus and the "diagnostic" and "therapeutic" enteroscopes from Fujifilm have the same length, in contrast to the short enteroscopes from Fujifilm (Table 7.2) [1–8, 13, 24]. The advantage of the shorter enteroscope is its utility for ERCP [27, 28, 30]. To simplify the definitions, we call the long enteroscopes "standard" length scopes and the shorter scopes "short enteroscopes." In addition, the reader should know that the DBE scopes could also be used to perform SBE [29]. In this instance, no balloon is attached to the endoscope itself.

Both standard DBE enteroscopes and their respective overtubes have the same length (enteroscope 200 cm, overtube 1,450 mm), but the external diameters of both the endoscope and the overtube are different. The diagnostic DBE (EN-450P5, Fujinon, Saitama, Japan) has an external diameter of 8.5 mm and the overtube has a diameter of 12.2 mm, whereas the therapeutic DBE (EN-450T5) has an external diameter of 9.4 mm and the overtube has a diameter of 13.2 mm [13, 24, 30]. The diameter of the working channel of the therapeutic DBE is 2.8 mm whereas the diagnostic one is 2.2 mm wide [13, 24, 29, 30]. Thus, careful attention should be paid when choosing accessories, as these must be long enough to exit the scope and also have an external diameter that permits their insertion and pushing through the respective working channels. In our endoscopy unit we keep a list of the

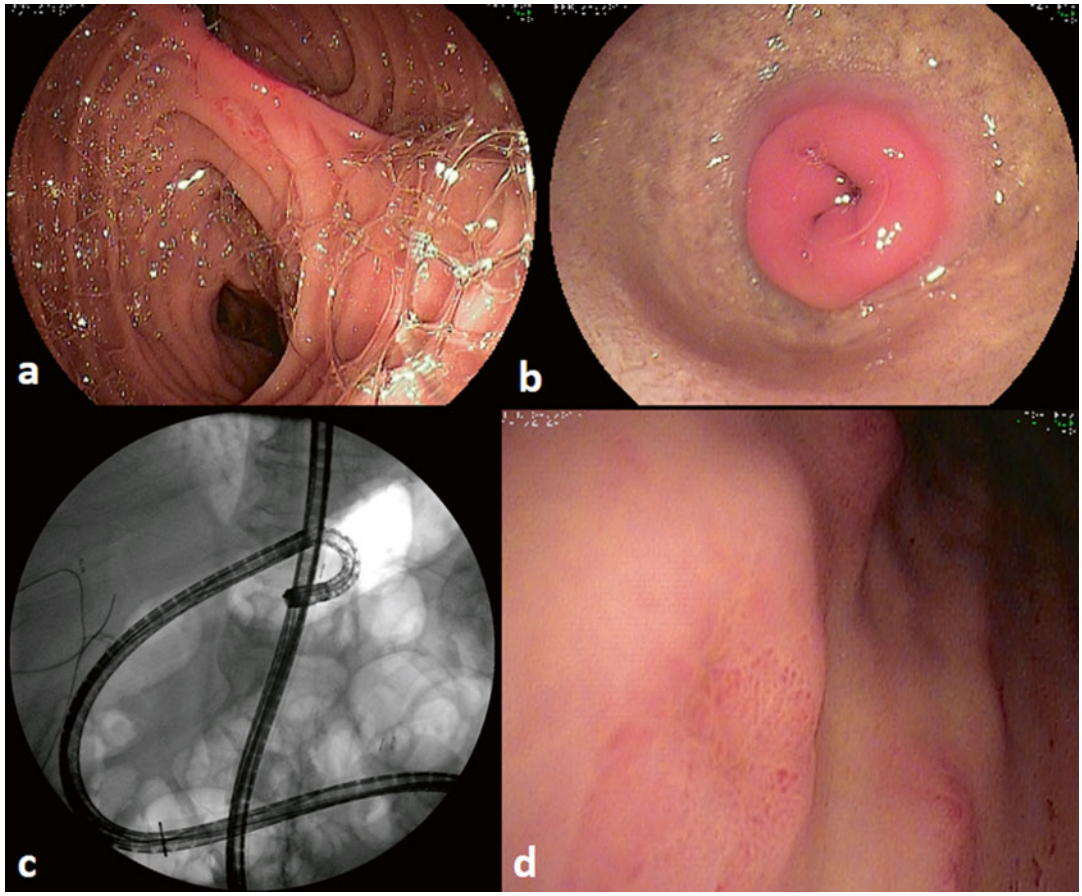

Fig. 7.5 BAE in a patient with Roux-en-Y gastric bypass. (**a**) Recognition of the afferent loop is facilitated by the presence of many small and large yellowish air bubbles, which result from the presence of bile. (**b**) Pylorus viewed from the "back." (**c**) Retroflexion of the enteroscope inside of the excluded stomach. The retroflexion was performed to visualize the antrum. (**d**) Multiple ulcers and erosions were seen

sizes, diameters, lengths, and working channel capabilities of all the endoscopes we use. These tables are posted on the wall of each room and serve as a quick reference. The lengths and sizes of the overtubes are also specified in Table 7.2.

Technique of Balloon-Assisted Enteroscopy

We prefer to use general anesthesia when performing oral (antegrade) BAE. When using general anesthesia we prefer to place the patient on their back (i.e., supine). This position will also allow for easy external manual compression when this is needed to improve advancement of the scope. When conscious sedation is utilized, left-lateral decubitus positions are mandatory, so that the patient's secretions can be managed properly and thus aspiration avoided [13]. We use moderate sedation for the majority of our patients undergoing anal (retrograde) BAE.

Both techniques of SBE and DBE, similar to overtube-assisted push enteroscopy, use the principle of the push-and-pull technique using the overtube: The endoscope is first inserted (pushed) into the small bowel, then the overtube is advanced toward the tip of the endoscope, and then both endoscope and overtube are pulled back; hence the name "push and pull" (Fig. 7.6) [13].

Table 7.2 Enteroscopy device specifications

Scopes	Scope working length (cm)	Scope diameter (mm)	Specifications		
			Channel diameter (mm)	Overtube length (cm)	Overtube outer diameter (mm)
SBE (Olympus, SIF-Q180)	200	9.2	2.8	140	13.2
DBE (Fujinon, EN-450PS/20)	200	8.5	2.2	145	12.2
DBE (Fujinon, EN-450T5)	200	9.4	2.8	145	13.2
DBE (Fujinon, EC-450BI5)	152	9.4	2.8	105	13.2
Pentax VSB-3,430 K	220	11.6	3.8		
SE Spirus medical, discovery SB	[a]	[a]	[a]	118	16

DBE double-balloon enteroscopy, *SB* small bowel, *SE* spiral enteroscopy, *SBE* single-balloon enteroscopy
[a]Either the Fujinon DBE enteroscope or the Olympus SBE enteroscope can be used to perform SE with a spiral enteroscopy overtube

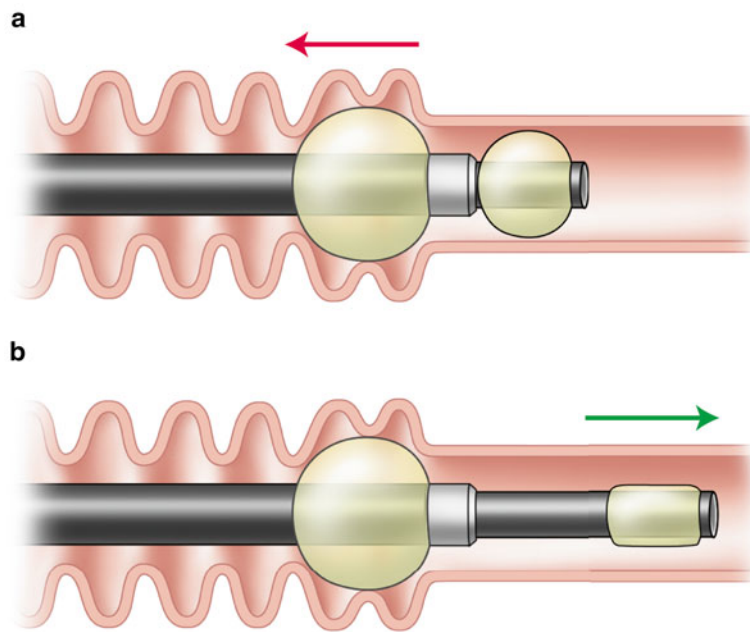

Fig. 7.6 Key elements of double-balloon enteroscopy. (**a**) Both the overtube and scope are pulled back (*red arrow*) to straighten the bowel and retract the proximal bowel on top of the overtube. (**b**) The balloon of the overtube is kept inflated (keeping the retracted bowel in place) and the balloon of the scope is deflated. The inflated balloon prevents the intestine to slide forward, keeping it "shortened" while the scope is being pushed or advanced forward (*green arrow* shows direction of scope)

This standard approach to BAE requires two people, the operator and an assistant. The assistant holding the overtube plays a crucial role, as a stable overtube will positively influence the depth of insertion and the maneuverability of the scope [13]. When using SBE and DBE, the major factor governing the depth of insertion of the enteroscope is the presence of the balloon on the distal end of the flexible overtube. The overtube stabilizes the intestine, preventing it from bending or looping [13, 30]. Although, the overtube stabilizes the intestine, preventing it from bending or looping, the key action of the inflated overtube balloon is to shorten the small bowel proximally (Fig. 7.6a). The inflated balloon prevents the intestine from sliding forward while the scope is being pushed or advanced forward (Fig. 7.6b) [13, 30]. This allows the endoscopist to firmly push on the enteroscope, effectively transmitting forces to the distal end of the endoscope and hence permitting the advancement of the enteroscope deeper into the small bowel without looping or stretching of the proximal intestine [1–8, 10, 13, 30]. The key steps and aspects of BAE are listed in Table 7.3 and shown in Fig. 7.6 and Video 7.2.

Table 7.3 Key technical steps used to perform double-balloon enteroscopy

Step 1	The scope and overtube are advanced into the intestine (large bowel or small bowel).
Step 2	The balloon of the overtube is inflated.
Step 3	The scope is advanced (pushed) forward into the small bowel.
Step 4	The balloon of the scope is inflated, anchoring the bowel.
Step 5	The balloon of the overtube is deflated.
Step 6	The overtube is advanced (slid) toward the tip of the scope.
Step 7	The balloon of the overtube is inflated. Now both the scope and overtube balloons are inflated.
Step 8	Both the overtube and scope are pulled back to straighten the bowel and retract and pleat the proximal bowel onto the overtube.
Step 9	The balloon of the overtube is kept inflated (keeping the retracted bowel in place) and the balloon of the scope is deflated.
At this level the procedure continues with step 3 (see above).	

Single-balloon enteroscopy follows exactly the same principles, with the exception of not inflating any balloon on the scope. In SBE, the scope tip needs to bend to anchor the intestine. Therefore step 4 is bending of the tip of the scope instead of inflating a balloon

The insertion method for both SBE and DBE is similar (Table 7.3, Fig. 7.6, Video 7.2). The main difference between the SBE and DBE technique is the approach of holding the small intestine in place while the overtube is advanced [13, 30]. When using the SBE technique, after the endoscope is inserted maximally, the tip of the endoscope is bent to form a hook shape, holding the small intestine in a stable position (Video 7.2), instead of the inflated balloon on the tip in DBE technique. When the sliding overtube is advanced to the tip of the scope, the overtube balloon is then inflated to hold and stabilize the intestine [13, 30]. After returning the tip of the endoscope to the neutral position to avoid mucosal injury, both the scope and the sliding tube are simultaneously withdrawn, thus pleating and shortening the intestine over the scope. By repeating these maneuvers, the endoscope can be inserted into the deep small bowel.

For performing ERCP in patients with a Roux-en-Y anastomosis or surgically altered upper gastrointestinal tract anatomy we recommend the use of the therapeutic DBE with a working channel of 2.8 mm or the short enteroscopes (Fig. 7.4) [30]. These therapeutic scopes have better maneuverability than the smaller diameter enteroscopes. In addition, the working channel is larger, allowing for an easier introduction of the diagnostic and therapeutic accessories. Although we have performed several cases of DB-ERCP utilizing only the balloon of the overtube ("single-balloon ERCP"), we still recommend attaching the balloons to both the scope and the overtube and we use the double-balloon push-and-pull technique to advance through the small bowel [30].

Balloon-Guided Enteroscopy

The BGE is made of disposable device consisting of a two-balloon element and an air supply unit to control the operation of the balloons (Fig. 7.2) [14]. The catheter length is 190 cm and the balloon diameter is 40 mm. The BGE device is compatible with scopes ranging from 10 to 13 mm in diameter. The BGE device is mounted on the scope, with a stabilizing balloon at the distal end of the scope and an advancing balloon, sheltered within the stabilizing balloon [14]. The advancing balloon is advanced or retracted manually ahead of the scope by a flexible advancing tube, which passes through a dedicated external channel, leaving the working channel of the scope free for accessory usage. BGE is performed in a similar fashion to DBE [14]. Once the scope has been positioned in the intestine (step 1), the stabilizing balloon is inflated and the anchoring balloon is advanced into the intestine (step 2), ahead of the scope. Once it has been advanced, it is inflated to

anchor the intestine (step 3). Then the stabilizing balloon at the scope tip is deflated and the scope is again inserted toward the inflated anchoring balloon (step 4). Then the stabilizing balloon is inflated as well (step 5) and with both balloons inflated, the scope is pulled back and the intestine is straightened (step 6). Then the advancing balloon is deflated and advanced, beginning with step 2.

Use of Fluoroscopy

We recommend the availability and/or use of fluoroscopy when performing the BAE (Figs. 7.3, 7.4, and 7.5, Video 7.3). Fluoroscopy may help estimate the depth of insertion, and scope positioning, and minimize the formation of figure-eight loops [13]. Whereas fluoroscopy is not always needed during a standard oral or retrograde BAE, it is mandatory to use it for planned therapeutic procedures, in patients with surgically altered anatomy and those with abdominal scarring and bowel adhesions (Figs. 7.4 and 7.5). Previous abdominal surgery may make BAE more difficult. Adhesions may limit the mobility of the intestine and make insertion of the BAE more cumbersome. The most important aspect to remember is to be patient and not to advance the scope and or overtube forcefully. In addition, careful attention should be paid to avoiding excessive air insufflation while advancing the endoscope as the bowel gets distended and further advancement is thus hampered. The use of carbon dioxide (CO_2) instead of air allows for deeper intubation and bowel visualization [31, 32]. In addition, patients experience less pain due to abdominal distention when using CO_2 [31]. Changing the patient's position or applying external abdominal pressure may help. Thus, it is evident that fluoroscopy can be very helpful in situations when advancement is limited, as it permits one to estimate the degree of looping present as well as to visualize the direction that the scope is taking.

Sedation and Anesthesia

BAE has been traditionally performed using conscious sedation [1–8]. However, these procedures are lengthy and physically demanding on both the patient and endoscopy team. The risk of aspiration and desaturation is high [32, 33]. Therefore, currently we perform the majority of BAE with the patient under general anesthesia [34]. Despite the procedures under general anesthesia needing additional time for preparation, we prefer this option to perform anterograde enteroscopies as well as therapeutic BAE and BAE-ERCP in patients with surgically altered upper GI tract anatomy [30, 32–34]. Conscious sedation may be used when retrograde BAE is performed.

Determination of the Primary Route of Insertion of BAE (Oral or Antegrade Versus Anal or Retrograde)

Oral or antegrade BAE allows for a median investigation of 250–300 cm of small bowel, whereas retrograde or anal enteroscopy permits depths of investigation of about 100–200 cm [1–8, 13]. When both routes are used successively a "total" small bowel enteroscopy can be achieved in 10–70 % of patients [1–8, 13]. In the ideal world, a total enteroscopy should be achieved using either route. But this is still not possible in the majority of cases. Thus, whenever a patient with a suspected small bowel disorder presents to us for small bowel investigation, the choice for either the oral ("antegrade") or the anal ("retrograde") route will depend on the suspected location of the lesion within the small bowel based on the clinical manifestations, as well as the results of laboratory, radiological, and capsule endoscopic examinations [1–10, 13]. When achieving total enteroscopy is desired, a second procedure in the opposite direction is scheduled.

Imaging and Advanced Imaging

Small bowel endoscopic imaging comprises techniques such as high-definition white light, standard white light with chromoendoscopy, virtual chromoendoscopy, magnification, as well as endomicroscopy for the evaluation of the gastrointestinal mucosa [29] (Table 7.4, Fig. 7.7). The concept of using more than one imaging method when performing endoscopy is currently called multimodal endoscopy [29]. For example, using a combination of standard white light and chromoendoscopy is an example of bimodal endoscopy.

Table 7.4 Standard and advanced endoscopic imaging during balloon-assisted enteroscopy

Standard white light endoscopy
High-definition white light endoscopy
Water immersion technique
Dye-based chromoendoscopy • Methylene blue • Indigo carmine
Dye-less chromoendoscopy ("virtual" chromoendoscopy) • Fujinon intelligent chromoendoscopy (FICE) • i-Scan • Narrow-band imaging (NBI)
Zoom and magnification endoscopy
Endocytoscopy
Confocal laser endomicroscopy

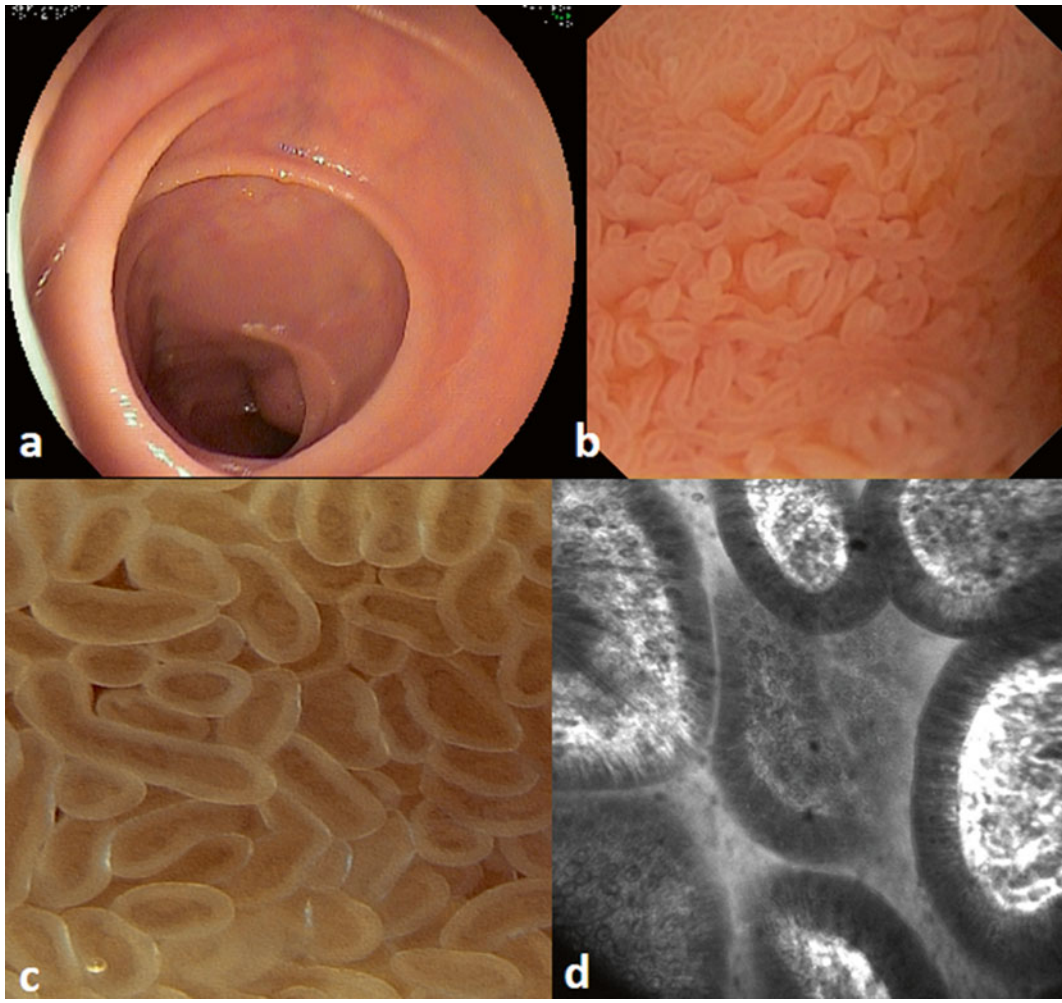

Fig.7.7 Advanced imaging during BAE. Normal small bowel mucosa. (**a**) High-definition white light. (**b**) Magnification endoscopy. (**c**) FICE and magnification endoscopy. (**d**) Confocal endomicroscopy

When using three methods the terminology changes to advanced trimodal imaging and so forth [29, 35, 36]. The most common methods used are high-definition white light, water immersion technique, and "dye-less" virtual chromoendoscopy [29, 35, 36]. The water immersion technique is very useful when mucosal atrophy is suspected. We utilize immersion technique every time when investigating patients for celiac disease and malabsorption syndromes [29]. Virtual chromoendoscopy is technically very simple, without the burden of the standard chromoendoscopy, and is also beneficial to demarcate lesions as well as identify disease activity and mucosal healing in inflammatory bowel disease [29, 35]. However, we prefer to use standard dye-based methods using indigo carmine or methylene blue when evaluating polyposis syndromes and during endoscopic resection [36].

Conclusion

This chapter reviews and demonstrates the indications, principles, and techniques of device-assisted enteroscopy. It is clear that device-assisted enteroscopy has become the primary method to perform deep enteroscopy and to perform diagnostic and therapeutic pancreatobiliary interventions in patients with surgically distorted small bowel anatomy such as Roux-en-Y anastomosis with hepaticojejunostomy. We expect further refinements of the endoscope such as increase in the working channel and innovations of the interventional accessories that will result in more possibilities to better treat patients who have small bowel disorders and those with complex postsurgical anatomy.

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Video Legends

Video 7.1 - Therapeutic DBE.

Video 7.2 - DBE technique step by step.

Video 7.3 - SBE with fluoroscopy.