Balloon-assisted enteroscopy: technology and troubleshooting

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HISTORICAL BACKGROUND

Endoscopic accessibility to the small intestine has been a challenge to the gastroenterologist for decades. The length of the small intestine, in addition to its free intraperitoneal location, vigorous contractility, and overlying loops, confounds standard endoscopic techniques.[1] The concept of attaching a balloon to the end of an enteroscope to propel an instrument into the proximal small intestine was proposed in 1955 by Dr. Margot Shiner of England, who attached a rubber balloon to the distal end of the headpiece of the duodenal biopsy tube.[2] Once peristalsis enabled the device to be propelled into the jejunum, biopsy specimens could be obtained; however, usage of the biopsy tube was cumbersome, so the technique was not widely adopted.

Sonde enteroscopy was introduced in 1986, but it was eventually abandoned because it was labor intensive for the gastroenterologist and uncomfortable for the patient.[3] The small thin Sonde scope was passed through the nose and then into the stomach. Another endoscope was then passed through the mouth, and the Sonde enteroscope was introduced into the small bowel by using the larger endoscope that had been passed through the mouth. A balloon was then inflated; with the help of peristalsis and the patient, who was advancing the enteroscope, the apparatus was eventually advanced to the distal jejunum or ileum over a 6- to 10-hour period. At the end of the advancement period, the gastroenterologist slowly removed the Sonde enteroscope and was able to visualize pathologic findings, but was unable to perform any therapeutic manuevers.

Push enteroscopy, with use of a pediatric colonoscope or a dedicated small bowel enteroscope ranging in length between 200 and 260 cm, remains the most commonly performed endoscopic procedure for the evaluation of the small intestine.[4,5] The endoscope is passed through the mouth with or without an overtube, and external compression is used in an attempt to pass the enteroscope 50 to 150 cm distal to the ligament of Treitz. Although the procedure is helpful for identification and treatment of proximal causes of small bowel bleeding or conditions, the examination is limited by looping of the enteroscope, causing patient discomfort and preventing further advancement of the enteroscope into the mid jejunum or ileum.

Intraoperative enteroscopy (IOE) was traditionally the gold standard for small-bowel imaging but has largely been replaced by the advent of balloon-assisted enteroscopy.[6] Although IOE traditionally had the highest diagnostic yield, disadvantages included a high complication rate, need for a surgeon as well as an endoscopist, and postprocedural hospital stay. IOE was initially performed in the 1950s with a sterile rigid sigmoidoscope passed through an operative colotomy or enterotomy.[7] By the 1970s, fiberoptic endoscopes were used for IOE.[8] In 1980, Bowden et al[9] performed IOE by passing a fiberoptic colonoscope first orally and then anally while the surgeon manually telescoped the bowel over the tip of the endoscope. The terminal ileum was intubated in over 90% of patients with this technique while minimizing the mortality and morbidity rates associated with enterotomy for earlier IOE procedures.

The concept of double-balloon enteroscopy (DBE), also known as ''push-and-pull'' enteroscopy, was initially conceptualized by Dr Hinori Yamamoto of Jichi Medical University in 1997.[10] Dr Yamamoto based the development of DBE on the concept that stretching of the small intestine prevents advancement (Fig. 1) and that the use of a balloon-attached flexible overtube and a second balloon attached to the endoscope tip would permit deep examination of the small bowel. With the development of a 200-cm enteroscope that had an outer diameter of 8.5 mm equipped with a 140-cm overtube with an outer diameter of 12 mm, total enteroscopy was completed with the endoscope tip advanced into the cecum in a reported case.[11]

To determine the necessary inflation pressure for latex balloons that would be associated with satisfactory grip of the small intestine, experiments were performed via laparotomy in dogs.[10] The results demonstrated that a soft latex balloon with an inflation pressure between 40 to 100 mm Hg produced grip pressures suitable for enteroscopy, and the minimum required pressure was determined to

0016-5107/$34.00
doi:10.1016/j.gie.2008.08.012

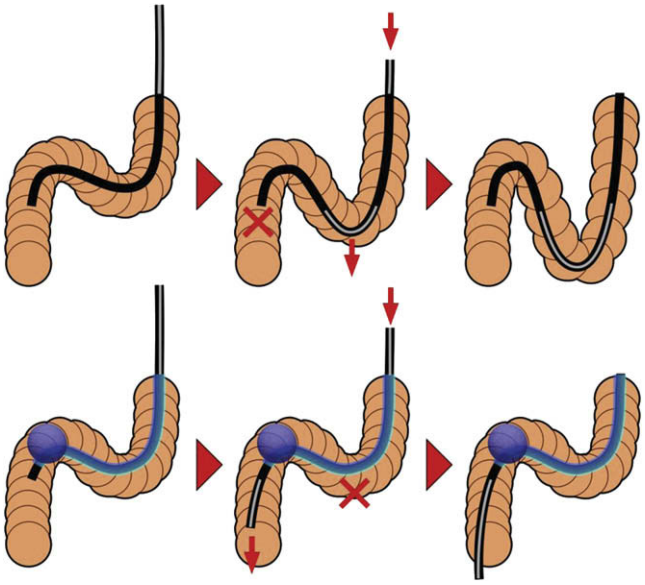

Figure 1. Rationale behind the development of balloon-assisted enteroscopy. *Top,* How introduction of a standard enteroscope leads to loop formation because of the stretchable nature of the small bowel. Introduction of a balloon grips the intestinal wall and prevents subsequent loop creation (source: Dr. Hironori Yamamoto, Yichi Medical School, Japan[10]).

be approximately 45 mm Hg. Dr Yamamoto also found that withdrawal of the latex balloon with an inflation pressure of 100 mm Hg produced no gross mucosal damage.

The single-balloon enteroscope (SBE) system (Olympus, Tokyo, Japan) was developed in 2006 and was introduced into the commercial market on May 19, 2007.[12] The rationale behind development of the Olympus Single Balloon Enteroscope System was to reduce the learning curve for balloon-assisted enteroscopy, avoid the difficulty of attaching the enteroscope balloon to the distal tip of the scope encountered in DBE, and eliminate the requirement of inflating and deflating 2 balloons in multiple steps with the current DBE insertion technique.

BALLOON-ASSISTED ENTEROSCOPY: THE ENTEROSCOPE

There are currently 3 Fujinon double-balloon enteroscopes available for use[10] (Fig. 2). The diagnostic enteroscope (EN450P5) has a 200-cm working length, an endoscope diameter of 8.5 mm, and an accessory channel of 2.2 mm. The EN450P5 can be used for pediatric patients or in cases where a more flexible insertion tube will facilitate passage through the small bowel or colon. Use of the stiffening wire will at times help to move the scope through difficult loops. However, the small channel makes passage of accessory tools for cautery or polypectomy challenging and time consuming. The therapeutic enteroscope (EN450T5) has a diameter of 9.4 mm and an accessory channel of 2.8 mm. Its larger outside diameter makes it

Figure 2. The Fujinon DBE system (source: Fujinon Corporation).

somewhat stiffer than the EN450P5, and it is used most often in the retrograde procedure and for the anterograde approach where added stiffness and a larger working channel are beneficial. The EN450BI5 enteroscope has a working length of 152 cm and will accept both colonoscopy and ERCP-length accessories. Indications for use are difficult or incomplete colonosopies where passage deep into the ileum is not an issue and in bariatric patients to transit the afferent limb. Each enteroscope has a built-in air route to inflate and deflate the balloon attached to the tip.

The Olympus single-balloon system (Fig. 3) consists of a high-resolution video endoscope, an Olympus SIF-Q180 (Olympus Optical, Tokyo, Japan) with a 200-cm working length, a 9.2-mm outer diameter, and a 2.8-mm working channel.[12] Comparison of the Fujinon and Olympus systems are shown in Table 1. There are no major differences between the 2 systems with regard to field of view, working length, or angulation range for the enteroscopes. As demonstrated, the major differences remain the composition of the overtube and balloons and the balloon on the tip of the enteroscope for the Fujinon DBE system.

Overtube, balloons, and balloon pump controller

The Fujinon DBE system supplies 3 types of overtubes: the TS-12140 with an outer diameter of 12.2 mm and length of 145 cm for use with the EN-450P5 and the TS-13140 and TS-13100 with an outer diameter of 13.2 mm and length of 145 cm for use with the EN-450T5 and the EN450BI5 enteroscopes.[10] Because of a concern about friction between the overtube and the endoscope, the initial overtubes were equipped with a lubricant inlet around one third the distance from the tip of the overtube so that olive oil could be applied during the examination. The current overtubes now have an internal and external hydrophilic coating by which water injection alone suffices to avoid friction between the overtube and the enteroscope