CHAPTER 99

# Enteroscopy

**G. Anton Decker,[1] Jonathan A. Leighton,[1] and Frank J. Lukens[2]**

[1]Division of Gastroenterology, Mayo Clinic, Scottsdale, AZ, USA

[2]Department of Gastroenterology and Hepatology, Mayo Clinic, Jacksonville, FL, USA



## Summary

New methods of enteroscopy enable potential visualization of the entire small bowel and allow for biopsies and therapeutic intervention in areas previously out of reach of push enteroscopy or ileocolonoscopy. The technique for advancement, utilizing double-balloon enteroscopy (DBE), makes use of a push-and-pull method, with inflation and deflation of two balloons and telescoping of the intestine on to an overtube. DBE can be carried out in an antegrade and/or a retrograde fashion. Visualization of the entire small bowel is reported in up to 86% of cases, usually through a combination of antegrade and retrograde approaches.

## Equipment and Review of Technology

Modern enteroscopy includes several technologies: DBE (Fujinon Inc., Saitama, Japan), single-balloon enteroscopy (SBE) (Olympus, Japan), and rotational enteroscopy using a spiral overtube (Spirus Medical, Stoughton, MA). The equipment and techniques differ, but the principles are the same: plicating or foreshortening the small bowel so that the depth of insertion exceeds the endoscope length. Because DBE has been available for longer and has produced more published data, this chapter will focus exclusively on DBE; however, the principles are common to all methods.

The DBE system consists of three components: a high-resolution videoendoscope with an inflatable balloon at the tip, an overtube with an inflatable balloon at the tip, and a balloon pump controller. Both a diagnostic and a therapeutic endoscope and overtube are available. The main difference between the two is the larger diameter of the therapeutic scope and overtube. The specifications of the endoscopes are given in Table 99.1, and those of the overtubes in Table 99.2. The balloon pump controller has a remote switch, as well as foot pedals to inflate and deflate the balloons. Its maximum flow rate is 170 mL/10 seconds, and it inflates the balloons to a pressure of 5.6 ± 2 kPa.

## How to Perform Double-Balloon Enteroscopy

### Endoscopy Technique

The technique of DBE was first described by Yamamoto *et al.* in 2001 [1]. A technician loads the balloon on to the overtube, which is then back-loaded on to the endoscope. The second balloon is loaded on to the tip of the endoscope. Both balloons are connected to the balloon pump controller via flexible plastic tubing. The procedure can be done in an antegrade or a retrograde fashion and is dependent on an assistant holding the overtube. Single-operator DBE has been reported but is not widely practiced. Fluoroscopy can be used to monitor advancement and minimize loop formation, but is not essential.

### Insufflation

It is well known that $CO_2$ insufflation during colonoscopy is useful in reducing intestinal gas retention and pain. $CO_2$ insufflation during SBE and DBE reduces abdominal pain and residual gas retention. A safety assessment based on blood gas analysis shows no risk of systemic $CO_2$ retention. Accordingly, $CO_2$ insufflation during SBE or DBE seems to be a more useful alternative than routine air insufflation [2,3].

### Antegrade DBE

With both balloons deflated, the endoscope and the overtube are advanced to the duodenum. Inflation of the balloons in the area of the ampulla should be avoided because the trauma or duodenal hypertension may cause pancreatitis. The balloon on the overtube is inflated and holds the overtube in a stationary position while the endoscope is advanced to its maximal extent (Figure 99.1a). The balloon at the end of the endoscope is then inflated while the balloon on the overtube is deflated (Figure 99.1b). The overtube is advanced to the distal end of the endoscope when the overtube balloon is inflated. At this point, the balloons approximate each other (Figure 99.1c). The endoscopist then gently withdraws the overtube and the endoscope together, allowing the intestine to be pleated over the overtube (Figure 99.1d). This is the most important step in the process, and is what prevents looping of the endoscope. The balloon at the tip of the endoscope is then deflated, and the endoscope advanced, and then the sequence is repeated until the desired depth of insertion is reached or the scope cannot be advanced any further. It is advisable to inject an India ink tattoo at the most distal extent reached, to allow its identification should a retrograde procedure be necessary.

Withdrawing the scope follows a similar sequence, but in reverse. The overtube is withdrawn and anchored by inflating the balloon. The endoscope balloon is then deflated and the endoscope withdrawn until the tip reaches the tip of the overtube. After inflating

*Practical Gastroenterology and Hepatology Board Review Toolkit*, Second Edition. Edited by Nicholas J. Talley, Kenneth R. DeVault, Michael B. Wallace, Bashar A. Aqel and Keith D. Lindor.

Table 99.1 Endoscope specifications.

| | EN-450P5/20 | EN-450T5 |
|---|---|---|
| **Distal diameter (mm)** | 8.5 | 9.4 |
| **Field of view (degrees)** | 120 | 140 |
| **Working length (cm)** | 200 | 200 |
| **Total length (cm)** | 230 | 230 |
| **Forceps channel diameter (mm)** | 2.2 | 2.8 |

the balloon on the endoscope, the overtube balloon is deflated and the sequence is repeated.

### Retrograde DBE

The principles are exactly the same as for the antegrade procedure, once the small bowel is intubated. It is critical that all loops are reduced in the colon if subsequent advancement in the small bowel is to be successful. It can be challenging to get both endoscope and overtube across the ileocecal valve, but abdominal pressure, patient rotation, and subtle adjustments in endoscope and overtube position are helpful.

### Sedation and Anesthesia

DBE can be a lengthy procedure, and patients find the distension of the small bowel uncomfortable. Moderate sedation can be used, as in esophagogastroduodenoscopy (EGD) and colonoscopy [4]. Particularly with antegrade procedures, monitored anesthesia care (MAC) or general anesthesia with intubation and ventilation may be required. Glucagon may also be utilized to slow the peristalsis of the small intestine.

### Bowel Preparation

Antegrade DBE does not require any specific bowel preparation, but patients are asked to fast for 8 hours prior to the procedure. Retrograde DBE requires a standard bowel-cleansing regimen, as is used for colonoscopy.

## Diagnostic and Therapeutic Methods

Virtually all diagnostic and therapeutic modalities that can be performed with a standard EGD or colonoscope can also be performed during DBE. The limited outcomes data on DBE are addressed in this section.

### Indications

The most common indication is obscure gastrointestinal (GI) bleed (69%). Other, less common ones include abnormal radiology exams, polyposis syndromes, Crohn's disease, and abdominal pain.

Patients with surgically altered bowel anatomy are frequently referred for balloon-assisted enteroscopy in order to help evaluate small-bowel pathology. Surgically altered bowel anatomy often excludes part of the GI tract from conventional endoscopic access. Balloon-assisted enteroscopy plus endoscopic retrograde cholangiopancreatography (ERCP) can be performed when indicated.

Table 99.2 Overtube specifications.

| | TS-12140 | TS-13140 |
|---|---|---|
| **Outer diameter (mm)** | 12.2 | 13.2 |
| **Inner diameter (mm)** | 10.0 | 10.8 |
| **Distal end diameter (mm)** | 8.7 | 9.8 |
| **Outer diameter with balloon (mm)** | 40 | 40 |
| **Working length (cm)** | 135 | 135 |
| **Total length (cm)** | 145 | 145 |

### Depth of Insertion

The pliable nature of the small bowel makes it difficult to judge endoscopic advancement. The only true gauge of insertion depth is when total enteroscopy is achieved: by reaching the ileocecal valve during an antegrade procedure or by reaching the tattoo during a DBE performed from the opposite direction to a first one. When this does not happen, the advancement with each push–pull cycle needs to be estimated and totaled at the end of the procedure. The average depth of insertion by the antegrade approach ranges from 220 [5] to 360 cm [4]. The average depth of insertion into the small bowel from a retrograde approach ranges from 120 [3] to 180 cm [6].

### Total Enteroscopy

Total enteroscopy from an antegrade approach is technically possible, but variably achieved [7]. The true rate of total enteroscopy is difficult to discern, as most endoscopists do not set out to achieve it: once the lesion(s) have been found, scope advancement is usually halted. Yamamoto *et al.* [7] did report total enteroscopy by combining antegrade and retrograde approaches in 84% of patients when this was the specific goal. Zhong *et al.* [8] have also reported high total enteroscopy rates of 56%. The United States, Australia, and Europe have all reported lower rates of total enteroscopy, ranging from 0% in a small series from Australia [9] to 45% in Germany [10]. In a large study from the Mayo Clinic, total enteroscopy rates were related to the endoscopist's experience, with 8% being achieved in the first 50 cases but >63% after 150 cases [11].

## Diagnostic Yield

The diagnostic yield is broadly defined as the rate at which the cause for a patient's symptoms is discovered or a lesion is identified on pre-DBE small-bowel imaging. There are geographic differences in the diagnostic yield reported in larger series, ranging from 42% in a US multicenter study [6] to 65.3% in a Chinese study [8] and 80% in a European one [10].

The diagnostic yield in cases of obscure GI bleed ranges from 51 [6] to 81% [8]. The most common cause of GI bleed in Western countries is arteriovenous malformations [6, 12], whereas Eastern countries report more ulcerations [7, 13]. The higher rate of ulceration in Eastern countries may be caused by the fact capsule endoscopy is not widely available or approved for clinical use there.

With the ability to take biopsies, DBE is potentially useful in the diagnosis of Crohn's disease and in monitoring mucosal healing [14]. Because there is no single gold-standard diagnostic test for Crohn's disease of the small bowel, DBE is complimentary to other imaging modalities, such as capsule endoscopy, computed tomographic (CT) enterography, and magnetic resonance enterography (MRE). Retrograde DBE also allows inflammatory changes to be reached that might be beyond the capability of ileocolonoscopy [15].

In a large study from the Mayo Clinic, the overall diagnostic yield of DBE was 61% in patients with surgically altered bowel anatomy, with a success rate in achieving a complete examination of 92% [16].

A large multicenter study evaluated and compared ERCP success using SBE, DBE, and rotational overtube enterosocpy in patients

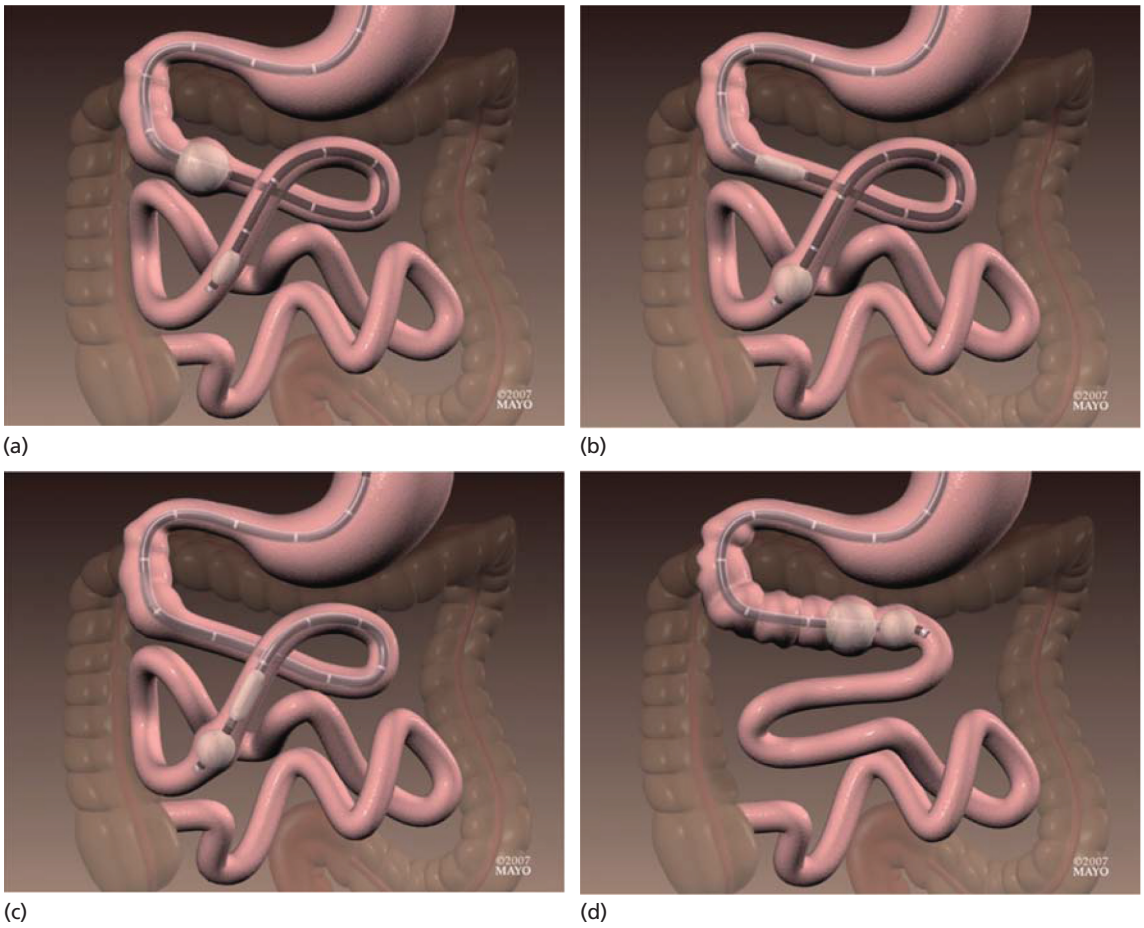


**Figure 99.1** Double balloon enteroscopy. (a) The overtube is fixed by the inflated balloon and the enteroscope with the deflated balloon is advanced. (b) The balloon on the enteroscope is inflated and the balloon on the overtube is deflated. (c) The enteroscope is fixed by the inflated balloon and the overtube is advanced to the level of the enteroscope balloon. (d) The balloons on the enteroscope and the overtube are inflated and both tubes pulled back, thereby plicating the small bowel over the overtube. Source: Used with permission of the Mayo Foundation for Medical Education and Research.

with surgically altered pancreaticobiliary anatomy. ERCP was successful in nearly two-thirds of long-limb surgical bypass patients, and in 88% when the papilla or pancreaticobiliary-enteric anastomosis was reached. Enteroscopy success in long-limb surgical bypass was similar among SBE, DBE, and rotational overtube enteroscopy [17].

## Comparison to Other Imaging Modalities of the Small Bowel

The depth on insertion and the yield of antegrade DBE are significantly greater than with push enteroscopy [18]. A meta-analysis of 11 studies by Pasha *et al.* [19] also found that DBE had a comparable diagnostic yield to capsule endoscopy; however, when only full-length articles of prospective studies were analyzed, capsule endoscopy had a 19% higher diagnostic yield compared to DBE. This is not surprising, as capsule endoscopy is able to visualize the entire small bowel in the majority of cases, whereas DBE is not. Because of this, and also because of the non-invasive nature of capsule endoscopy, the authors recommend capsule endoscopy to precede DBE. Capsule endoscopy also helps direct the route of DBE. Gay *et al.* [20] showed that if the lesion is seen after 75% of the capsule transit time, then an anal-route DBE has a positive predictive value (PPV) of 94.7% and a negative predictive value (NPV) of 96.7%. There is a lack of data comparing DBE to radiologic studies, particularly CT enterography, MRE, and barium small-bowel follow-through, but these tests are best thought of as complementary to rather than exclusive of DBE.

DBE is new technology, so data on its ability to affect long-term clinical outcome are lacking. Zhong *et al.* [8] reported outcomes 6 months after DBE. Among 247 patients with positive findings on DBE that led to specific endoscopic or medical treatment, relevant symptoms disappeared or were controlled in 76.9%. The results were best when DBE led to specific treatments, such as endoscopic therapy, surgery, or medical treatment, as opposed to symptomatic treatment.

A multicenter randomized study found similar diagnostic and therapeutic yields, procedure times, and insertion depths between SBE and DBE in patients with suspected or proven small-bowel disease [21].

## Therapeutic Role

DBE has an advantage over other small-bowel diagnostic tools in that it allows for biopsies and therapeutic interventions. In a large series, May *et al.* [10] reported that endoscopic therapy was used

in 41.5% of DBE cases, including argon plasma coagulation (APC), polypectomy, foreign body extraction, dilation, and injection therapy. Ell *et al.* [5] reported the use of endoscopic therapy in 62% of DBE procedures, mostly involving APC.

DBE allows for the endoscopic balloon dilation of small-bowel strictures in Crohn's disease, both native and anastomotic. Morini *et al.* [22] reported successful endoscopic dilation in 34 of 43 patients with ileal or ileocolonic anastomotic strictures, and surgery was avoided in about half of these patients over a mean follow-up period of 7 years. Repeated dilations are often required. Others have reported success with endoscopic dilations in Crohn's disease, but with rare reports of perforation [23, 24].

DBE can be used in patients with altered anatomy, for example to gain access to the excluded stomach or biliopancreatic limb after Roux-en-Y gastric bypass [25]. In these cases, DBE can also be used to facilitate ERCP or retrograde percutaneous endoscopic gastrostomy (PEG) placement [26].

## Complications

In a multicenter survey, Mensink *et al.* [27] reported 40 complications in 2362 DBE procedures (1.7%). The complication rate was higher in therapeutic DBE (4.3%) than in diagnostic DBE (0.8%). Typical complications include bleeding and perforation, but also self-limiting abdominal pain in up to 20% of patients [12]. May *et al.* [4] reported severe complications in 3.4% of therapeutic DBEs, including bleeding or perforation in 10.8% of patients undergoing polypectomy. In a multicenter US study, Gerson *et al.* [28] reported major complications in 0.9% of 2254 DBE examinations. Perforation was more likely to occur in patients with altered surgical anatomy, such as ileoanal anastomosis. Pancreatitis is a relatively unique complication, first reported by Honda *et al.* [29]. The rate of clinically significant pancreatitis has been reported to be in the range of 0.2–1.0% [12, 28]. Post-DBE asymptomatic hyperamylasemia appears to be common. In a study by Honda *et al.* [30], hyperamylasemia was found in 6 of 13 cases after DBE, though only one patient had clinical pancreatitis. The pathogenesis of acute pancreatitis from DBE has not been determined, but it might involve direct trauma to the pancreas or duodenal hypertension as a result of balloon insufflation. The current authors do not recommend routine measurement of pancreatic enzymes in patients with post-DBE abdominal pain. However, in the patient with severe or persistent abdominal pain, pancreatitis must be considered.

### Take Home Points

- Double-balloon enteroscopy (DBE) is one of several new technologies for performing enteroscopy.
- DBE allows for potential visualization of the entire small bowel, as well as for biopsies and therapeutic interventions.
- DBE can be performed in an antegrade (per os) or retrograde (per rectum) fashion.
- The DBE system consists of a high-resolution videoendoscope with an inflatable balloon at the tip, an overtube with an inflatable balloon at the tip, and a balloon pump controller.
- Push–pull cycles allow the small bowel to be pleated over the overtube.
- Total enteroscopy is rarely achieved by antegrade DBE alone, and usually requires combined antegrade and retrograde procedures.
- Complications are higher in patients with altered anatomy and after polypectomy.
- Pancreatitis occurs in 0.3–1.0% of patients, but asymptomatic hyperamylasemia is common.

## References


1 Yamamoto H, Sekine Y, Sato Y, *et al.* Total enteroscopy with a nonsurgical steerable double-balloon method. *Gastrointest Endosc* 2001; **53**: 216–20.

2 Hirai F, Beppu T, Nishimura, T, *et al.* Carbon dioxide insufflation compared with air insufflation in dou ble-balloon enteroscopy: a prospective, randomized, double-blind trial. *Gastrointest Endosc* 2011; **73**: 743–9.

3 Lenz P, Meister T, Manno M, *et al.* $CO_2$ insufflation during single-balloon enteroscopy: a multicenter randomized controlled trial. *Endoscopy* 2014; **46**: 53–8.

4 May A, Nachbar L, Pohl J, Ell C. Endoscopic interventions in the small bowel using double balloon enteroscopy: feasibility and limitations. *Am J Gastroenterol* 2007; **102**: 527–35.

5 Ell C, May A, Nachbar L, *et al.* Push-and-pull enteroscopy in the small bowel using the double-balloon technique: results of a prospective European multicenter study. *Endoscopy* 2005; **37**: 613–16.

6 Mehdizadeh S, Ross A, Gerson L, *et al.* What is the learning curve associated with double-balloon enteroscopy? Technical details and early experience in 6 US tertiary care centers. *Gastrointest Endosc* 2006; **64**: 740–50.

7 Yamamoto H, Kita H, Sunada K, *et al.* Clinical outcomes of double-balloon endoscopy for the diagnosis and treatment of small-intestinal diseases. *Clin Gastroenterol Hepatol* 2004; **2**: 1010–16.

8 Zhong J, Ma T, Zhang C, *et al.* A retrospective study of the application on double-balloon enteroscopy in 378 patients with suspected small-bowel diseases. *Endoscopy* 2007; **39**: 208–15.

9 Kaffes AJ, Koo JH, Meredith C. Double-balloon enteroscopy in the diagnosis and the management of small-bowel diseases: an initial experience in 40 patients. *Gastrointest Endosc* 2006; **63**: 81–6.

10 May A, Nachbar L, Ell C. Double-balloon enteroscopy (push-and-pull enteroscopy) of the small bowel: feasibility and diagnostic and therapeutic yield in patients with suspected small bowel disease. *Gastrointest Endosc* 2005; **62**: 62–70.

11 Gross S, Stark M. Initial experience with double-baloon enteroscopy at a US center. *Gastrointest Endosc* 2008; **67**: 890–7.

12 Heine GD, Hadithi M, Groenen MJ, *et al.* Double-balloon enteroscopy: indications, diagnostic yield, and complications in a series of 275 patients with suspected small-bowel disease. *Endoscopy* 2006; **38**: 42–8.

13 Ohmiya N, Yano T, Yamamoto H, *et al.* Diagnosis and treatment of obscure GI bleeding at double balloon endoscopy. *Gastrointest Endosc* 2007; **66**(3 Suppl.): S72–7.

14 Decker GA, Pasha SF, Leighton JA. Utility of double balloon enteroscopy for the diagnosis and management of Crohn's disease. *Tech Gastrointest Endosc* 2008; **10**: 83–6.

15 Oshitani N, Yukawa T, Yamagami H, *et al.* Evaluation of deep small bowel involvement by double-balloon enteroscopy in Crohn's disease. *Am J Gastroenterol* 2006; **101**: 1484–9.

16 Patel MK, Horseley JL, Gomez V, *et al.* Double balloon enteroscopy procedure in patients with surgically altered anatomy: analysis of a large prospectively collected database. *J Laproendosc Adv Surg Tech A* 2013; **23**: 409–13.

17 Shah RJ, Smolkin M, Yen R, *et al.* A multicenter, US experience of single-balloon, double-balloon, and rotational vertube-assisted enteroscopy ERCP in patients with surgically altered pancreaticobiliary anatomy. *Gastrointest Endosc* 2013; **77**: 593–600.

18 Matsumoto T, Moriyama T, Esaki M, *et al.* Performance of antegrade double-balloon enteroscopy: comparison with push enteroscopy. *Gastrointest Endosc* 2005; **62**: 392–8.

19 Pasha SF, Leighton JA, Das A, *et al.* Double-balloon enteroscopy and capsule endoscopy have comparable diagnostic yield in small-bowel disease: a meta-analysis. *Clin Gastroenterol Hepatol* 2008; **6**: 671–6.

20 Gay G, Delvaux M, Fassler I. Outcome of capsule endoscopy in determining indication and route for push-and-pull enteroscopy. *Endoscopy* 2006; **38**: 49–58.

21 Efthymiou M, Desmond PV, Brown G, *et al.* SINGLE-01: a randomized, controlled trial comparing the efficacy and depth of insertion of single- and double-balloon enteroscopy by using a novel method to determine insertion depth. *Gastrointest Endosc* 2012; **76**: 972–80.

22 Morini S, Hassan C, Lorenzetti R, *et al.* Long-term outcome of endoscopic pneumatic dilatation in Crohn's disease. *Dig Liver Dis* 2003; **35**: 893–7.

23 Ferlitsch A, Reinisch W, Püspök A, *et al.* Safety and efficacy of endoscopic balloon dilation for treatment of Crohn's disease strictures. *Endoscopy* 2006; **38**: 483–7.

24 Nomura E, Takagi S, Kikuchi T, *et al*. Efficacy and safety of endoscopic balloon dilation for Crohn's strictures. *Dis Colon Rectum* 2006; **49** (10 Suppl.): S59–67.
25 Kuga R, Safatle-Ribeiro AV, Faintuch J, *et al*. Endoscopic findings in the excluded stomach after Roux-en-Y gastric bypass surgery. *Arch Surg* 2007; **142**: 942–6.
26 Ross AS, Semrad C, Alverdy J, *et al*. Use of double-balloon enteroscopy to perform PEG in the excluded stomach after Roux-en-Y gastric bypass. *Gastrointest Endosc* 2006; **64**: 797–800.
27 Mensink PB, Haringsma J, Kucharzik T, *et al*. Complications of double balloon enteroscopy: a multicenter survey. *Endoscopy* 2007; **39**: 613–15.
28 Gerson LB, Tokar J, Chiorean M, *et al*. Complications associated with double balloon enteroscopy at nine US centers. *Clin Gastroenterol Hepatol* 2009; **7**: 1177–82.
29 Honda K, Mizutani T, Nakamura K, *et al*. Acute pancreatitis associated with peroral double-balloon enteroscopy: a case report. *World J Gastroenterol* 2006; **12**: 1802–4.
30 Honda K, Itaba S, Mizutani T, *et al*. An increase in the serum amylase level in patients after peroral double-balloon enteroscopy: an association with the development of pancreatitis. *Endoscopy* 2006; **38**: 1040–3.