World Journal of Gastrointestinal Endoscopy

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DOI: 10.4253/wjge.v7.i1.59

World J Gastrointest Endosc 2015 January 16; 7(1): 59-65
ISSN 1948-5190 (online)

MINIREVIEWS

Current status of single-balloon enteroscopy: Insertability and clinical applications

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Received: August 26, 2014
Peer-review started: August 27, 2014
First decision: September 16, 2014
Revised: September 30, 2014
Accepted: November 7, 2014
Article in press: November 10, 2014
Published online: January 16, 2015

Abstract

The single-balloon enteroscopy (SBE) system was launched in 2007, proposed as a simpler method than double-balloon enteroscopy (DBE). Controversy surrounds whether the SBE system has the same insertability as DBE. However, many methods have been proposed to improve the depth of insertion with the SBE system, involving several techniques and endoscopic accessories. SBE is used for investigating not only small bowel diseases, but also diseases of the pancreatobiliary and colonic structures. SBE is a necessary advancement for many endoscopic procedures and applications in modern clinical practice. In our review, we summarized the current literature concerning the insertability of SBE and described the technical aspects of improving the rate of deep insertion in SBE procedures. In addition, the recent applications of SBE to diseases besides those of the small bowel are described.

Key words: Single-balloon enteroscopy; Double-balloon enteroscopy; Small-bowel endoscopy; Endoscopic retrograde cholangiopancreatography; Endoscopic submucosal dissection

Core tip: The insertability of the single-balloon enteroscopy (SBE) system can be improved by technical innovations and by using endoscopic accessories such as carbon dioxide insufflation equipment. SBE is used not only useful for small bowel diseases, but also for colonic lesions and pancreatobiliary diseases. The SBE system is a necessary advancement for many endoscopic procedures in modern clinical practice.

Kawamura T, Uno K, Tanaka K, Yasuda K. Current status of single-balloon enteroscopy: Insertability and clinical applications. *World J Gastrointest Endosc* 2015; 7(1): 59-65 Available from: URL: http://www.wjgnet.com/1948-5190/full/v7/i1/59.htm DOI: http://dx.doi.org/10.4253/wjge.v7.i1.59

INTRODUCTION

Double-balloon enteroscopy (DBE) was developed by Yamamoto *et al*[1]. Since then, endoscopic observation of the entire small intestine has been possible without surgical intervention. The single-balloon enteroscopy

(SBE) system was launched in 2007 by Olympus Medical Systems (Tokyo, Japan) as an alternative to DBE[2-5]. SBE is a simpler method because the second balloon at the tip of the enteroscope is not present. However, controversy surrounds whether the SBE system offers the same insertability and diagnostic yield as DBE.

The purpose of this review was to summarize the current literature concerning the insertability and diagnostic yield of SBE and to describe the technical aspects of improving the depth of insertion in SBE procedures. In addition, recent applications to diseases besides those of the small bowel are described. While spiral enteroscopy is another alternative method of DBE[6-8], this method is not widely used in Japan; therefore, we did not discuss spiral enteroscopy in the present article. Details of the instruments used, and the basic principles of the insertion technique of SBE, have already been reviewed by Manno *et al*[9] in 2012.

INSERTABILITY OF SBE

Insertability compared with DBE

Total enteroscopy can be achieved using SBE. Usually, total small bowel visualization is confirmed by inserting the enteroscope through both the oral and anal routes and marking the midway point with an Indian ink tattoo or endoscopic clipping (Figures 1 and 2). The initial experience reports of SBE in Japan have been characterized by total enteroscopy rates of 12.5% to 71.4% (Table 1)[2-5].

Three randomized, controlled trials thus far have compared the rates of total small bowel visualization by DBE and SBE[10-12]. May *et al*[10] reported that complete enteroscopy was achieved with the DBE technique in 66% (33/50) of cases and only 22% (11/50) with the SBE technique ($P < 0.0001$). However, this study had a number of significant limitations. One was that the SBE system used in this study was not the original system produced by Olympus, but a DBE system made by Fujifilm Corporation (Tokyo, Japan) without the tip balloon attached. In 2011, Takano *et al*[12] also reported worse results for the insertability of the SBE system developed by Olympus compared to those for the DBE system developed by Fujifilm. The total enteroscopy rate was 0% in the SBE group and 57.1% in the DBE group ($P = 0.002$). This result suggested that the insertability of SBE might be inferior to that of DBE. However, Domagk *et al*[11] reported that DBE and SBE have comparable performance in the evaluation of the small bowel. Their study revealed that complete visualization of the small bowel was achieved in 18% and 11% of procedures in the DBE and SBE groups, respectively. These randomized control studies yielded conflicting results concerning the insertability of SBE compared to that of DBE.

We have discussed the insertability of SBE using total enteroscopy rate as a comparative parameter, because none of the currently known methods of estimating insertion depth are ideal[13]. However, the clinical impact of total enteroscopy rate is controversial, because in majority of the patients the fact whether total enteroscopy is achieved is not necessary to diagnose small bowel diseases[14]. Lenz *et al*[8] indicated that the first-choice enteroscope should be selected according to availability, physicians' experience, and clinical implications.

In the next section, the many methods of improving the insertability of SBE will be discussed.

Methods of improving the depth of insertion

The most important difference between SBE and DBE is the manner in which the small intestine is held by the tip of the enteroscope during sliding tube insertion. If the holding force is not sufficient, the enteroscope will slip back. Ohtsuka *et al*[15] discussed the method of improving the holding force in the small intestine using the SBE technique. To prevent the scope from slipping back during sliding tube insertion, it is important to use both upward and left angulation, as this helps to increase the holding force applied by the tip of the enteroscope. Furthermore, they recommended the use of a distal attachment to assist the fixation of folds in the small intestine.

A recent study suggested the usefulness of carbon dioxide insufflation during the SBE procedure in improving intubation depth[16,17]. Li *et al*[17] reported that the total enteroscopy rate of the carbon dioxide insufflation group was significantly higher than that of the air insufflation group (34.9% *vs* 17.6%; $P = 0.006$). Lenz *et al*[16] reported that oral intubation depth was significantly higher in the carbon dioxide group than in the air group (258 ± 84 cm *vs* 192 ± 42 cm; $P < 0.05$) in patients with previous abdominal surgery.

By using the techniques described above alongside carbon dioxide insufflation, the depth of SBE insertion devices can be improved. Interestingly, Ohtsuka *et al*[15] reported several cases of total enteroscopy using only the anal approach.

Complications

SBE is a safe diagnostic endoscopic procedure. However, serious complications such as acute pancreatitis[18,19] and perforation[20] could occur, although the rates of these complications are very low. Aktas *et al*[21] reported that while post-SBE hyperamylasemia occurred in 16% (13/81) patients, no acute pancreatitis was observed in 105 consecutive patients undergoing peroral approach SBE. Lenz *et al*[22] reported that the rate of severe adverse events after SBE procedures was only 0.6% (2/298) and did not differ significantly from that after DBE procedures in their large case series.

CLINICAL APPLICATIONS OF SBE

SBE for small bowel diseases

Parikh *et al*[23] summarized the clinical applications of SBE for small bowel diseases in 615 patients reported

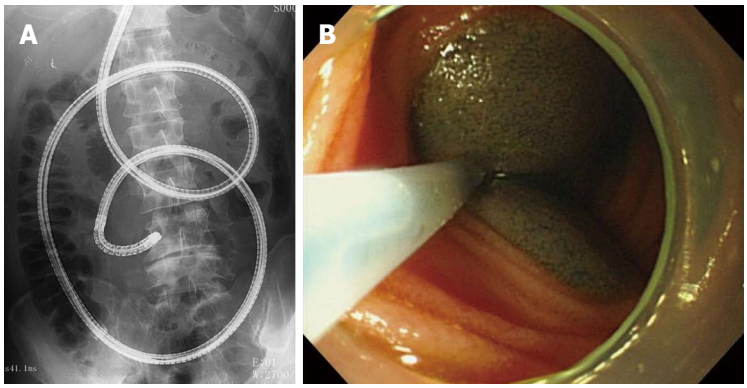

Figure 1 Case of total enteroscopy. A: Single-balloon enteroscope inserted orally; B: Indian ink was used as a tattoo in the deepest part of the intestine.

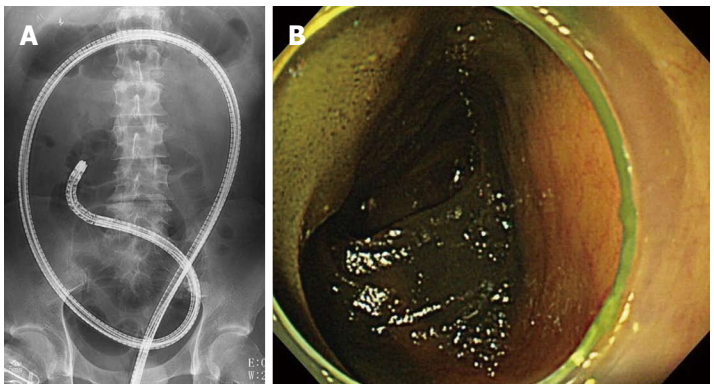

Figure 2 Case of total enteroscopy (continued). A: Single-balloon enteroscope inserted anally; B: Tattoo marked when enteroscope was inserted orally was confirmed.

Table 1 Rates of total enteroscopy using the single-balloon enteroscope

Ref.	Study design	No. of cases	Rate of total enteroscopy	Year
Tsujikawa *et al*[5]	Case series	78 exams in 41 pts	6/24 (25%)	2008
Kawamura *et al*[2]	Case series	37 exams in 27 pts	1/8 (12.5%)	2008
Ohtsuka *et al*[4]	Case series	48 exams in 30 pts	5/7 (71.4%)	2008
Kobayashi *et al*[3]	Case series	50 exams in 40 pts	3/5 (60%)	2008
Ramchandani *et al*[24]	Case series	131 exams in 106 pts	5/20 (25%)	2009
May *et al*[10]	RCT	50 pts	11/50 (22%)	2010
Domagk *et al*[11]	RCT	65 pts	7/65 (11%)	2011
Takano *et al*[12]	RCT	14 pts	0/14 (0%)	2011
Li *et al*[17]	RCT (CO_2 use)	106 pts	37/106 (34.9%)	2014
Li *et al*[17]	RCT (air use)	108 pts	19/108 (17.6%)	2014

RCT: Randomized controlled trial; pts: Patients.

thus far in their review article. The most common indication of SBE was obscure gastrointestinal bleeding (51%), followed by evaluation for Crohn disease (13%) and polyp/mass (8%). The most common lesions of the small bowel were angioectasias (22%), ulcers (15%), and polyp/mass (10%), and the most common interventions included hemostasis with argon plasma coagulation (22%), followed by polypectomy (3%) and dilation (3%).

Although there were conflicting results regarding the insertability of SBE compared with that of DBE, the diagnostic yield of small intestinal lesions using SBE was reported as equal to that of DBE. Diagnostic yields were 41%-65% in initial experience reports[2,5,24] and 37%-50% in randomized control studies[10-12], which were almost same as the rates of the DBE system.

Recently, SBE for disease in regions other than the small bowel has been reported. In the next session, the clinical applications of SBE for colonic and pancreatobiliary lesions are discussed.

SBE for colonic lesions

There are two main reasons for performing SBE for colonic lesions: One is when colonoscopy fails, and another is when endoscopic submucosal dissection (ESD) is required in difficult positions.

An elongated colon and adhesion would make it

Figure 3 Short-type prototype single-balloon enteroscope. This scope has a working length of 1520 mm and an inner channel of 3.2 mm, which are compatible with those of many endoscopic accessories. SBE: Single-balloon enteroscopy.

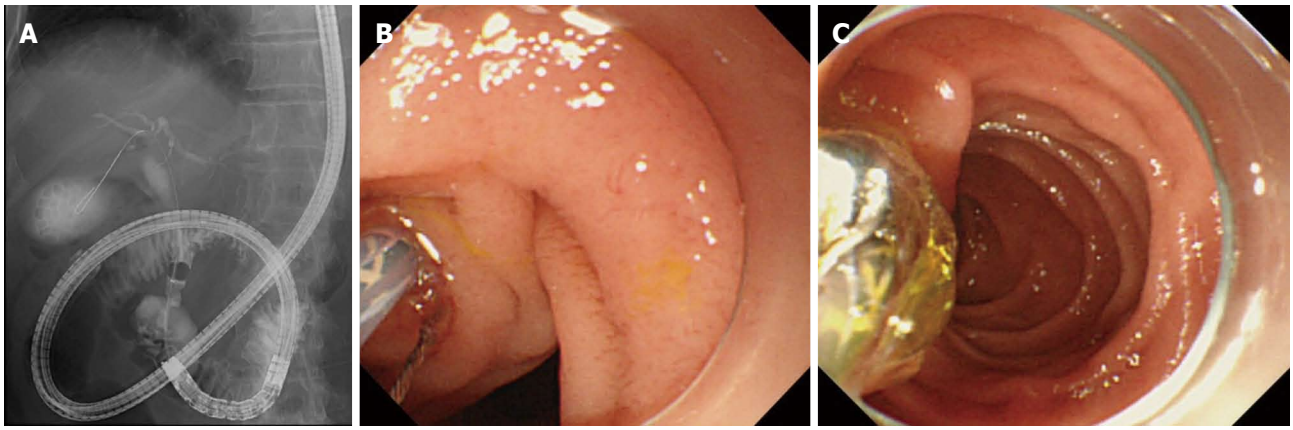

Figure 4 Case of common bile duct stones treated using a short-type prototype single-balloon enteroscope. Conventional endoscopic accessories such as retrieval balloon catheter (A), endoscopic sphincterotomy catheter (B), and endoscopic balloon dilation catheter (C), were used in this procedure.

difficult to achieve total colonoscopy. SBE is used to prevent stretching of the intestine. A case series suggested that the SBE system is successful in almost all patients in whom the cecum cannot be reached[25-27]. A randomized control trial revealed that the utility of SBE and DBE for colonoscopy seemed comparable in patients with incomplete previous colonoscopy using a conventional colonoscope[28].

ESD for colonic neoplasm is a technically challenging procedure, especially if the target neoplasm resides in a difficult to reach position. An overtube with a balloon is used to stabilize the endoscope during the ESD procedure. Ohya *et al*[29] reported the usefulness of a therapeutic gastroscope (GIF-Q260J; Olympus Medical systems, Tokyo) with an SBE overtube for colonic ESD. The SBE overtube was too long to use with the gastroscope, so a modified and shortened overtube of 70 cm from the distal end was used.

Endoscopic retrograde cholangiopancreatography for patients with surgically altered gastrointestinal anatomy

SBE is useful for both small bowel diseases and pancreatobiliary diseases in patients with altered gastrointestinal anatomy. Many studies have reported the usefulness of the SBE system for endoscopic retrograde cholangiopancreatography (ERCP) with altered gastrointestinal anatomy, especially in patients with Roux-en-Y anastomosis[30-43]. However, a limited number of ERCP accessories are compatible with the SBE system because of its narrow inner channel diameter and working length compared to those of a conventional duodenoscope. Recently, the usefulness of the short-type SBE prototype (SIF-Y0004; Olympus medical systems, Tokyo) has been reported[44-49]. The short-type SBE has a working length of 1520 mm and an inner channel diameter of 3.2 mm (Figure 3), which are both compatible with many conventional ERCP accessories (Figure 4). In the future, this short-type SBE system may become the first-choice endoscope for ERCP in patients with altered gastrointestinal anatomy.

Other applications of SBE

Recently, the efficacy and safety of SBE for children with Crohn disease and Peutz-Jeghers syndrome have been

reported[50-52]. SBE is expected to be as useful in children as in adult patients.

Endoscopic removal of foreign objects, diagnosis of parasite infestation, and SBE-assisted direct percutaneous endoscopic jejunostomy are reported as uncommon uses of SBE[53-56]. In cases in which the target regions lies in the small bowel, not far from the ligament of Treitz or the terminal ileum, the balloon at the tip of the enteroscope may not be needed. SBE might have advantages compared to DBE in such cases because of SBE involves a greater ease of preparation.

FUTURE PERSPECTIVES

In the future, detailed diagnosis will become more important and the optimal therapy after reaching the target region will be essential. For example, the usefulness of high-resolution enteroscopy, image-enhanced enteroscopy, magnified enteroscopy, and endoscopic ultrasonography[57-59] by using SBE will need to be discussed. Furthermore, several endoscopic accessories for ERCP and ESD performed using SBE will be required. Endoscopic procedures and applications using the SBE system are promising.

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P- Reviewer: Hu H, Sofi A, Sterpetti AV, Tepes B
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