



## Stents for colorectal obstruction: Past, present, and future

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### Abstract

Since the development of uncovered self-expanding metal stents (SEMS) in the 1990s, endoscopic stents have evolved dramatically. Application of new materials

and new designs has expanded the indications for enteral SEMS. At present, enteral stents are considered the first-line modality for palliative care, and numerous types of enteral stents are under development for extended clinical usage, beyond a merely palliative purpose. Herein, we will discuss the current status and the future development of lower enteral stents.

**Key words:** Colon; Obstruction; Stent; Self-expanding metal stents

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**Core tip:** Endoscopic stents are considered the first-line modality for palliative care, and numerous types of enteral stents are under development for extended clinical usage beyond a palliative purpose. Herein, we will discuss the current status of and the future for lower enteral stents.

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### INTRODUCTION

Since the development and experimental use of uncovered self-expanding metal stents (SEMS) in the 1990s, endoscopic stents have evolved dramatically. Enteral stents have been developed mainly for the palliation of inoperable gastrointestinal malignancy. In cases with malignant colorectal obstruction, which requires urgent intervention, the traditional solution was surgical diversion and stoma formation. However, the morbidity and mortality rates of this surgical modality were high, and thus a new therapeutic modality for malignant GI obstruction was sought<sup>[1]</sup>.

Today, an enteral stent is considered the first-line

modality for palliative care, and numerous types of enteral stents are under development for extended clinical usage beyond a merely palliative purpose. Herein, we will discuss the current status of and the future for lower enteral stents.

## MATERIALS

Although plastic stents are still used for biliary and pancreatic stenting, most of the stents used in the gastrointestinal tract are SEMs. SEMs are composed of a radiopaque, woven, metal mesh with a cylindrical shape that exerts self-expansion forces. Unexpanded SEMs are small enough to fit into the channel of the endoscope. Following delivery to the desired location, they expand through a deployment device and are placed against the luminal surface of interest. Although the basic delivery system and deployment mechanism are identical, several types of stents are available to overcome the limitations of the SEMs, each with its own characteristics.

### **Stainless steel stent**

SEMs are usually manufactured from stainless steel or other alloys. Z-stent® (Cook Medical, Bloomington, IN, United States) is a representative example of a stainless steel SEM. The Z-stent was the first SEM and is still available in both covered and uncovered forms. However, stainless steel SEMs are relatively stiff and adversely affect the quality of magnetic resonance images.

### **Elgiloy stent**

Elgiloy is an alloy of cobalt, chromium and nickel. The Wallstent (Boston Scientific, Natick, MA, United States) is a stent of this type. In contrast to stainless steel stents, this type of stent has no hazard or risk associated with magnetic resonance imaging (MRI). Moreover, Elgiloy itself can be reduced to very thin wires with good elasticity and flexibility.

### **Nitinol stent**

Nitinol, also known as nickel-titanium, is an alloy of nickel and titanium. Good examples of this type of stent are the Ultraflex (Boston Scientific, Natick, MA, United States) and Alimaxx E stents (Alveolus, Charlotte, NC, United States). Most of these types of stents have poorer fluoroscopic visibility compared with Elgiloy stents. To compensate for this weakness, they are usually used in conjunction with radiopaque markers composed of other materials, such as gold and silver. However, because nitinol has a characteristic shape memory and super-elasticity, nitinol stents are more flexible than stainless steel or Elgiloy stents. Because of these characteristics, nitinol stents are used widely.

### **Covered vs uncovered SEMs**

Enteral stents can be divided into two types: uncovered and covered. Uncovered stents have bare wires, while covered stents have a silicone membrane over the bare wires. The covered form can be subdivided into fully and partially covered stents. Although covered stents reduce the risk of tumor ingrowth and can be used to seal fistulas, fully covered stents have less anchoring power and an increased risk of migration compared with uncovered stents. To overcome this problem, partially covered stents with flared uncovered segments at both ends have been developed. However, these three stent types—fully covered, partially covered, and uncovered—show no significant differences in overall technical success rates, clinical success rates, complication rates or patency duration<sup>[2-4]</sup>. However, tumor ingrowth occurs more frequently with uncovered SEMs, and migration occurs more frequently with covered SEMs<sup>[5]</sup>. The efficacies and complication rates of each stent type (as determined by a previous meta-analysis) are summarized in Table 1.

### **Stent selection**

Because many types of stents with unique features, in terms of their material, design, diameter, length, radial force, flexibility, foreshortening ratio, and delivery system, are available, selection of the appropriate stent for a specific patient is important clinically. However, there is no evidence to indicate which stent type is superior, and whether the unique features of enteral stents affect clinical outcomes is unknown<sup>[10-15]</sup>. Although further large-scale studies are needed to obtain objective evidence, currently, operators must select the type of enteral stent on a clinical basis. Moreover, operators should be aware of the unique features of each type of enteral stent (Table 2).

## INDICATION

### **Stenting in malignancy**

The majority of experience with stenting in lower gastrointestinal malignancy is for left-sided colonic lesions. This is probably because obstruction complicated by proximal colon cancer is not as severe as that by left-sided colon cancer due to the relatively small amount of retained fecal material. Indeed, many proximal colon cancers are managed primarily by one-stage surgery without bowel preparation or stoma formation. Although some studies have shown that SEMs could be a good therapeutic option for proximal colonic lesions<sup>[16-19]</sup>, others have reported conflicting results<sup>[20-24]</sup>. A recent study reported high technical and clinical success rates with new through-the-scope stents (not over-the-wire stents)<sup>[25]</sup>. However, because of conflicting data from previous studies, the current consensus regarding the treatment of choice for right-

**Table 1 Comparison of efficacy and complication of stent by type (covered stent vs uncovered stent)**

Study	No. of patients	Stent	Indication	Mean age	Covering material	Patency duration between stent types	Complication
Kang <i>et al</i> <sup>[6]</sup>	26	Not reported	Palliation/ BTS	58.0	Fully/Partially (polyurethane)	No difference	More migration in fully covered stent group
Choi <i>et al</i> <sup>[7]</sup>	74	Choo stent <sup>TM</sup>	Palliation	60.0	Fully/Partially (polyurethane)	No difference	More migration in covered stent group
Lee <i>et al</i> <sup>[2]</sup>	80	Niti-S <sup>TM</sup>	Palliation/ BTS	63.3	Partially (polyurethane)	No difference	More migration in covered stent group
Park <i>et al</i> <sup>[3]</sup>	151	WallFlex <sup>TM</sup> Comvi <sup>TM</sup>	Palliation/ BTS	61.4	Partially (polytetrafluoroethylene)	No difference	More tumor ingrowth in uncovered stent group/more migration in covered stent group
Moon <i>et al</i> <sup>[4]</sup>	68	Niti-S <sup>TM</sup> D-type Comvi <sup>TM</sup>	Palliation/ BTS	65.8	Partially (polytetrafluoroethylene)	No difference	More migration in covered stent group
Park <i>et al</i> <sup>[8]</sup>	103	Wallstent <sup>TM</sup> Niti-S <sup>TM</sup> Bonastent <sup>TM</sup>	Palliation	67.3	Partially (polytetrafluoroethylene or silicon)	No difference	No difference between stent types/variable migration rates between manufacturers
Choi <i>et al</i> <sup>[9]</sup>	152	Hanarostent <sup>TM</sup> Niti-S <sup>TM</sup> Hanarostent <sup>TM</sup> Choo stent <sup>TM</sup> Bonastent <sup>TM</sup>	Palliation/ BTS	70.0	Not reported	No difference	More migration and perforation in covered stent group

BTS: Bridge to surgery; No: Number; PS: Prospective study; RS: Retrospective study.

**Table 2 Commercially available colorectal stents**

Name	Material	Diameter (mm)	Flare	Flare diameter (mm)	Length (mm)	Covered/uncovered	Feature	Manufacturer
Colonic Z-stent <sup>TM</sup>	Stainless steel	25	A	35	40, 60, 80, 100, 120	Uncovered	No foreshortening	Cook
Evolution <sup>TM</sup>	Nitinol	25	A	30	60, 80, 100	Uncovered	Controlled-release delivery system	Cook
		20	A	22	80, 100, 125, 150	Partially covered		
		18, 20	A	23, 25	80, 100, 120	Fully covered		
Wallstent <sup>TM</sup>	Stainless steel	20, 22	NA	NA	60, 90, 120	Uncovered	Reconstrainable	Boston Scientific
Wallstent <sup>TM</sup> Enteral	Elgiloy	20, 22	NA	NA	60, 90	Uncovered	Reconstrainable	Boston Scientific
Wallflex <sup>TM</sup> Colonic	Nitinol	22, 25	A	27, 30	60, 90, 120	Uncovered	Reconstrainable	Boston Scientific
Ultraflex <sup>TM</sup> colonic	Nitinol	25	A	30	57, 87, 117	Uncovered	Non-Reconstrainable	Boston Scientific
Hanarostent <sup>TM</sup> colorectal	Nitinol	22	A	28	60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170	Covered	Reconstrainable	MI tech
		24	A	30	60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170	Uncovered		
Bonastent <sup>TM</sup>	Nitinol	22, 24, 26	NA	NA	60, 80, 100, 120, 140, 160	Covered Uncovered	Non-foreshortening	EndoChoice
Niti-S <sup>TM</sup> D-Enteral colonic stent	Nitinol	18, 20, 22, 24	NA	NA	60, 80, 100, 120, 140, 150	Uncovered	Reconstrainable	Taewoong medical
Comvi <sup>TM</sup> Colonic stent	Nitinol	18, 20, 22	NA	NA	60, 80, 100, 120	Triple layered	Reconstrainable	Taewoong medical
Niti-S <sup>TM</sup> S-enteral colonic stent	Nitinol	18, 20	A	24	60, 80, 100, 120, 140, 150	Covered	Reconstrainable	Taewoong medical

A: Available; NA: Not available.

side obstructing colon cancer is surgical resection. If SEMS placement for right-sided colon obstructions is considered because of other co-morbidities, the patient should be carefully selected on a clinical basis.

**Palliative purpose**

While other modalities can relieve colorectal obstruction (e.g., palliative surgery and radiation therapy), SEMS can provide a good alternative therapeutic

option for colorectal obstruction. The role of palliative stenting in patients who are operative candidates is unclear; however, several studies have shown that SEMs placement in patients with unresectable malignant colorectal obstruction was effective in the short term<sup>[26]</sup>. In a retrospective study comparing SEMs and palliative surgery, there was no difference in early success rates, and there were fewer complications in the SEMs group<sup>[27]</sup>. In one case-control study that compared SEMs placement with a surgical method in patients with left-sided unresectable colon cancer, survival was not significantly different between the two groups, but hospital durations were shorter in the SEMs group<sup>[28]</sup>. Other studies that compared SEMs with surgical methods in patients with surgically incurable colorectal cancer also reported that the survival rate was not significantly different, and that morbidity and mortality were better in the SEMs group<sup>[29,30]</sup>.

However, because the risk of tumor perforation in patients who received chemotherapy is well known—especially the risk of perforation caused by bevacizumab-based chemotherapy—palliative SEMs placement in patients undergoing chemotherapy remains a matter of debate<sup>[21,31,32]</sup>. One study reported a significant survival difference between palliative surgery and SEMs placement in patients with incurable colorectal cancer<sup>[33]</sup>. In that study, the SEMs placement group showed superior outcomes in terms of early morbidity and hospital stay, while the palliative surgery group showed a survival advantage in patients undergoing chemotherapy, but not in those who were not candidates for chemotherapy. According to these studies, SEMs placement represents a good therapeutic option in patients who do not receive chemotherapy for a palliative purpose; an alternative modality should therefore be considered for patients undergoing chemotherapy.

Since the introduction of SEMs in the 1990s, and despite many case reports and case control studies, the short-term and long-term outcomes of SEMs placement for palliation remain a matter of debate. Several recent studies have reported the long-term outcomes of SEMs placement. In a study that compared the long-term outcomes of SEMs placement with those of palliative surgery in patients with incurable obstructive colorectal cancer, early success rates were not different, and the SEMs group showed fewer early complications. Although the patency duration of the first stent was shorter, that of the second SEMs was comparable in the SEMs group compared with the surgery group<sup>[27]</sup>. However, in a study that involved 168 patients who underwent SEMs placement for palliation or as a bridge to surgery, 41 patients (24.4%) in the palliative group experienced complications, including perforation, occlusion, migration, and ulcer, and the mean stent patency was 145 d<sup>[21]</sup>. In another study investigating the complications and long-term clinical outcomes of

SEMs placement, long-term clinical failure occurred in 21 (51%) patients due to late complications of SEMs, such as migration, occlusion, perforation and tenesmus<sup>[34]</sup>.

Consequently, in patients with incurable malignant colorectal obstruction, SEMs placement for palliation can improve quality of life with a relatively low risk of early complications. However, because long-term outcomes of SEMs placement remain a matter of debate, an alternative modality can be considered in patients eligible for chemotherapy or with a long life expectancy. If SEMs placement is considered in patients with long life expectancy, a plan to address the possible long-term complications of SEMs placement (e.g., second SEMs placement for occlusion) should be formulated.

### **Bridge to surgery**

Although definitive treatment for colorectal cancer is achieved by traditional surgical methods, which are usually planned after staging evaluation, up to 10%-30% of patients with colon cancer initially present with acute colonic obstruction<sup>[35]</sup>. In those cases, traditionally, emergency surgery proceeded without any staging work up, despite the fact that the patients had other comorbidities. Emergency decompressive surgery on an unprepared basis carries significant risks of morbidity (32%-64%) and mortality (15%-34%)<sup>[36,37]</sup>. In these cases, colorectal SEMs can be a good option for the treatment of acute malignant colonic obstruction as a bridge to surgery, allowing time for a preoperative evaluation and for the patient's medical condition to improve.

In some reports, when SEMs was applied as a bridge to surgery, success rates for single-stage elective surgery were 60%-85%<sup>[10,11,21,38]</sup>. A systematic review comparing elective surgery after SEMs intervention as a bridge therapy with emergency surgery showed that elective surgery after SEMs insertion had a higher primary anastomosis rate. Hospital stay was shorter in the elective surgery group after SEMs insertion, and colostomy rates were higher in the emergency surgery group<sup>[39]</sup>. In a meta-analysis that also compared SEMs bridge therapy with open surgery, shorter hospital stay durations, lower rates of stoma formation, and fewer medical complications were noted in the SEMs bridge therapy group<sup>[40]</sup>. In a meta-analysis of randomized, controlled trials, SEMs bridge therapy showed higher primary anastomosis and lower stoma rates. However, permanent stoma rates, hospital mortality and complication rates were not significantly different between the two treatment modalities<sup>[41,42]</sup>.

Although some studies have shown that SEMs insertion as a bridge therapy may be a better choice than traditional emergency surgical decompression, others have reported conflicting data<sup>[43-46]</sup>. One study analyzed 181 patients to identify risk factors for

surgical failure after SEMS insertion as a bridge to surgery in left-sided colonic obstruction, and the use of multiple SEMS was identified as a risk factor for surgical failure<sup>[47]</sup>. In another study of the long-term outcomes of SEMS as a bridge to elective curative surgery vs emergency resection, the local recurrence rate was higher in the SEMS group<sup>[46]</sup>. Colonic SEMS insertion as a bridge to elective surgery might be a useful treatment option. However, conflicting data are also available, and the definitive indication remains a matter of debate, especially in patients who require multiple SEMS for decompression. Thus, candidates for SEMS insertion as a bridge to elective surgery should be selected carefully and planned on a clinical basis.

### **Cancer recurrence after surgery at the anastomosis site**

The incidence of recurrence at the colonic anastomotic site after curative resection of colorectal cancer is low<sup>[48]</sup>. In patients with colorectal anastomosis site obstruction due to cancer recurrence, treatment options are still under debate because of the low incidence of anastomosis site recurrence. However, strictures at the anastomosis site usually occur in the presence of cancer recurrence at the anastomosis site; few of these patients experience obstructive symptoms<sup>[49]</sup>. Several modalities are available for patients with anastomotic obstruction. Surgical revision, balloon dilation, and laxatives could be appropriate treatments, depending on the severity of the symptoms<sup>[50,51]</sup>.

In a recent case series, SEMS was reported to be a good treatment option for benign strictures, including those at the anastomotic site<sup>[52-55]</sup>. In one retrospective study that included five patients who underwent endoscopic stenting for obstructions caused by cancer recurrence at the anastomotic site, 100% technical and clinical success rates and a 60% overall success rate were reported<sup>[56]</sup>.

Although further large-scale studies are required, because of the low incidence of anastomosis site recurrence of malignancy, the current evidence suggests that SEMS is a good therapeutic option for patients with obstructed colonic anastomosis sites due to cancer recurrence.

### **Stenting in benign lesions**

The role of enteral stents for benign colonic lesions is unclear; the majority of studies are case reports or case series<sup>[57-60]</sup>. In a case series of 10 patients, SEMS were inserted for diverticulitis with complicated pelvic abscess (two cases), colonic fistula (four cases), and post-surgical anastomotic stricture (four cases). The complicated abscess was resolved, but fistulae developed in both cases. Of the cases with colonic fistulae, two resolved after SEMS placement, and SEMS relieved the symptoms of obstruction in all of the post-surgical anastomotic stricture cases<sup>[57]</sup>.

In another case series that included 23 patients

with benign obstructive disease treated with SEMS placement, the clinical success rate was 95%, but the major complication rate was 38%; the complications included migration, re-obstruction, and perforation. These results demonstrated that SEMS could effectively decompress benign colonic obstructions but is associated with a high rate of complications<sup>[58]</sup>.

A case series including 21 patients who had surgical anastomosis, anastomotic strictures due to Crohn's disease, diverticular disease, and stricture due to radiation therapy reported that the clinical success rate was 76% and the complication rate 43%; the majority of the complications were due to diverticular strictures<sup>[59]</sup>.

SEMS for benign lesions remains a matter of debate. However, based on the current data, SEMS can be a good option for the management of benign colorectal obstructive lesions as a bridge to surgery to avoid emergency surgery or as a treatment in patients at risk for surgery.

### **Extrinsic compression**

Enteral stenting can also be used in some patients with obstruction due to extracolonic tumors<sup>[61]</sup>. The majority of colonic obstructions result from intrinsic factors, including colorectal cancer or stenosis. However, malignancies of extracolonic origin can also disrupt colorectal patency.

Several studies have analyzed the success rates of SEMS placement for colorectal obstruction due to extrinsic malignancies. The overall success rates of SEMS placement in extrinsic compression vary among reports, with technical success rates of 42%-100% and clinical success rates of 25%-87.5%<sup>[62-67]</sup>. One study reported that technical failure in colonic SEMS placement was related to female sex and colonic obstruction due to extrinsic compression. Additionally, SEMS placed in patients with extracolonic malignancies showed lower patency compared with those with intrinsic malignancies<sup>[68]</sup>. In one retrospective study, the efficacy of SEMS for colorectal obstruction by non-colonic malignancy with peritoneal carcinomatosis was evaluated in 20 patients. The technical success rate was 90%, and the mean event-free survival was 119 d<sup>[65]</sup>.

Based on these results, the clinical outcome of SEMS placement for colorectal obstruction with an extracolonic cause might be less favorable than that of SEMS placement in colorectal cancer patients. Therefore, SEMS placement may be a useful option in selected patients.

## **COMPLICATIONS**

Although SEMS placement is a relatively low-risk procedure with a mortality rate of less than 1%<sup>[69,70]</sup>, SEMS placement for colorectal obstruction can be associated with various complications, such as perforation, migration, tumor ingrowth, stool impaction, bleeding, and pain. According to a study of SEMS

**Table 3 Comparison of clinical guidelines**

	BTS	Proximal colonic lesions	Palliative	Extra colonic obstruction	Benign lesions	Covered vs uncovered
ESGE	Δ	Δ	○	Δ	X	=
ASGE	○	Δ	○	Δ	Δ	<
KSGE	Δ	Δ	○	Δ	Δ	=

ESGE: European Society of Gastrointestinal Endoscopy; ASGE: American Society of Gastrointestinal Endoscopy; KSGE: Korean Society of Gastrointestinal Endoscopy; BTS: Bridge to surgery; SEMs: self-expanding metal stents; ○: Recommended; Δ: Consider stent based on clinical situation; X: Not recommended; >: Covered type is preferred; <: Uncovered type is preferred; =: Same effectiveness.

safety, the overall complication rate associated with the procedure can reach 25%<sup>[71]</sup>.

### Decompression failure

In some patients, stent placement does not immediately resolve colonic obstruction despite successful deployment. Failure to achieve decompression could be a result of incomplete stenting of the entire length of the stricture, additional sites of intestinal obstruction (*e.g.*, synchronous lesions), early stent migration, incomplete expansion of the stent, or fecal impaction<sup>[72]</sup>. In these cases, a radiographic contrast study (*e.g.*, a water soluble enema examination) before SEMs placement might be useful<sup>[73]</sup>. However, in patients with decompression failure despite SEMs placement, secondary SEMs placement can achieve decompression. In a study of the clinical outcomes of patients who underwent stent re-insertion vs palliative surgery as a second intervention, although the median lumen patency in the stent re-insertion group was shorter than that in the surgery group, the stent re-insertion group had a lower mortality rate<sup>[74]</sup>.

### Perforation

Perforation is the most serious complication of colorectal stenting. Although in one systematic review perforation rates ranged from 0 to 83%, the overall risk of perforation was about 5%, which is a relatively low risk<sup>[39]</sup>. However, the mortality rate of patients with perforations was 16%<sup>[69]</sup>.

Perforation can be divided into two categories: immediate and delayed. Technical problems related to wire or catheter misplacement are frequently responsible for immediate perforation, while stent quality is an important factor affecting delayed perforation<sup>[75,76]</sup>. Patients in whom a SEMs was placed at the recto-sigmoid junction with sharp angulation are at high risk of delayed perforation. In patients with a dilated and thin-walled cecum, because the amount of air inflation can be a factor in perforation, restriction of air inflation during the endoscopic procedure can help avoid cecal perforation<sup>[77]</sup>.

Upon confirmation of stent-related perforation, emergency management is needed. An emergency surgery is required in up to two-thirds of patients with stent-related perforation; only patients with minor

perforation or micro-perforation can be treated with bowel rest and antibiotics<sup>[78]</sup>.

High perforation rates have been reported in patients receiving bevacizumab. Colorectal stenting should be avoided as much as possible in patients undergoing bevacizumab-based chemotherapy<sup>[21,32,79]</sup>.

### Tumor ingrowth or overgrowth

Late stent obstruction or occlusion can be caused by tumor ingrowth or outgrowth. Because colorectal cancers are proliferative and progressively invade local tissues, stent occlusion may occur over time if the cancer is not removed surgically.

Treatment options for stent occlusion include a surgical approach and repeat stenting within a stent. In one study of the long-term outcomes of palliative therapy using endoscopic stenting and surgery, tumor ingrowth-related stent occlusion occurred in 15% of patients. However, in that study, all patients with tumor ingrowth-related stent occlusion were managed successfully with additional SEMs, and the median patency duration after a second stent was comparable to that of the surgery group<sup>[27]</sup>.

Covered stents are associated with less tumor ingrowth and could be considered a prophylactic treatment for tumor ingrowth. However, in some studies, covered stents have a higher risk of stent migration and show no significant difference in overall stent patency duration<sup>[3,4]</sup>. Because of these results of studies, there are slightly inconsistent recommendations between clinical guidelines (Table 3).

### Stent migration

The incidence of migration is affected by many factors, one of the most important and well-known being SEMs type. Migration rates of covered stents exceed those of uncovered stents (8%-50% and 3%-36%, respectively)<sup>[2,4,21,78,80,81]</sup>.

One of the factors that might affect stent migration risk is the relationship between the characteristics of SEMs and those of the obstructing lesion. Migrations might occur if stents are too narrow in diameter or too short in length in relation to the obstructing lesion<sup>[82]</sup>, or if the tumor shrinks after oncologic therapy. However, stent migration can be managed by second stent placement even if colonic obstruction remains<sup>[76]</sup>.

**Minor complications**

Minor complications, such as bleeding, fecal incontinence, and pain, following SEMs placement are encountered frequently in the clinic. Post-SEMS placement bleeding is usually minor and likely due to superficial mucosal injury or the friable tumor itself. Most of the bleeding resolves spontaneously or can be managed conservatively<sup>[19]</sup>. Fecal incontinence can occur if the stent is placed within 2 cm proximal to the anal verge<sup>[77]</sup>. To avoid fecal incontinence, rectal stents should be deployed at least 2 cm proximal to the upper end of the anal canal. Pain or tenesmus is another frequent minor complication. SEMs insertion within 5 cm of the anal verge is considered a contraindication because of the possibility of pain. In one retrospective study that investigated the safety of SEMs placement in patients with rectal obstruction within 5 cm of the anal verge, the pain disappeared spontaneously in 3 of the 10 patients who underwent SEMs placement within 5 cm of the anal verge; the remaining patients required analgesics<sup>[83]</sup>. Retrievable stents can be a good treatment option for patients who have rectal obstruction within 5 cm of the anal verge.

**FUTURE FOR STENTS****Biodegradable stents in benign lesions**

Due to recent important advances in materials science, new materials for biodegradable stents are being developed and investigated. Several clinical studies have evaluated the usefulness of biodegradable stents in refractory benign esophageal strictures, including stenosis due to corrosive agents or post-operative stenosis<sup>[84-88]</sup>. However, the usefulness of biodegradable stents in benign upper gastrointestinal lesions is still vague. In one pilot, randomized controlled trial of biodegradable stents for benign esophageal strictures, compared with the balloon-only group, the stenting group exhibited greater dysphagia, need for co-medication and adverse events<sup>[84]</sup>. Moreover, information about the usefulness of biodegradable stents in the lower gastrointestinal tract is limited. Only case reports and a small case series about biodegradable colorectal stent application for benign lesions of the lower gastrointestinal tract have been published<sup>[53,89-92]</sup>. In one case report, a biodegradable stent was applied for a colonic stricture in Crohn's disease, and no recurrence of obstructive symptoms occurred during the 16-mo follow up<sup>[93]</sup>. In another case series that included three patients with Crohn's disease, representing the initial experience in the Czech Republic, balloon dilatation of the stenosis followed by biodegradable stent placement showed favorable results, with no stent migration or major complications<sup>[94]</sup>. However, current biodegradable stents, which are made of poly-dioxanone, can lose their radial force overtime as the material degrades. For further clinical use of biodegradable stents in lower gastrointestinal lesions, long-term data and adequate

randomized control studies are needed.

**Drug-eluting stents**

Drug-eluting stents are actively used in the cardiovascular field; however, they might also be useful in the gastrointestinal tract for reducing stent ingrowth or overgrowth. To date, several animal studies and a few clinical studies of the use of drug-eluting or drug-coated stents in gastrointestinal tract have been performed. Most of the reports evaluated the usefulness of drug-eluting stents in biliary stenosis, and many of these were animal studies<sup>[95-100]</sup>. The usefulness of drug-eluting stents in the lower gastrointestinal tract is vague; limited data are available. In one animal study that validated the usefulness of 5-fluorouracil-loaded polydioxanone stent for the treatment of colorectal cancer, in-stent re-stenosis was reduced by use of a drug-loaded stent<sup>[101]</sup>. The uncovered SEMs used currently is at risk for stent ingrowth or overgrowth. Although covered SEMs are estimated to have a low risk of ingrowth, covered SEMs are at high risk of migration. As new stent designs and materials are developed, drug-eluting stents could be the next generation of stents for use in the lower gastrointestinal tract. However, further well-designed clinical investigations are needed. With continued development and innovation in endoscopic techniques and devices, use of gastrointestinal stenting with drug-eluting stents will result in expansion beyond the current indications and improve clinical outcomes.

**CONCLUSION**

Currently, colorectal stenting using SEMs can be performed for the management of colorectal malignant obstructions as a palliative therapy or bridge to surgery. SEMs also can be used for benign lesions such as fistulae, benign colorectal strictures, and extrinsic compression.

Although endoscopic colorectal stenting is relatively safe and has a low incidence of complications, the endoscopist should be familiar with the features, material, design, and characteristics of the stents to reduce the risk of complications.

Self-expanding metal stents are increasing in use and their indications extending. Because new materials such as biodegradable and drug-eluting stents are being developed, new indications and novel techniques will likely soon become available<sup>[100,102,103]</sup>. As a novel technology, an evidence-based approach will be needed to establish the role of these new stents in clinical practice.

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