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Power Spiral Enteroscopy: A Quick and Powerful Dive Deep Inside the Small Bowel!

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Abstract

A comprehensive and detailed small bowel evaluation became possible since 2001 with the advent of a wireless capsule endoscope that was primarily used for diagnostic purposes. Simultaneously, the development of balloon-assisted enteroscope made detailed evaluation and therapy possible in the deeper small bowel. A novel motorized spiral enteroscope, introduced in 2015, is the most recent addition to the list of device-assisted enteroscopes. The rotational movements of the spiral overtube controlled by the integrated motor are transmitted into a linear force causing forward and backward propulsion of the scope in the bowel. There is emerging evidence about its safety and efficacy in the diagnosis and therapy of various small bowel diseases.

Keywords
- motorized spiral enteroscope
- power spiral enteroscopy
- spiral overtube
- rotational movements
- depth of maximum insertion
- total enteroscopy

Introduction

Historically, endoscopic evaluation of deep small bowel started in 1971 using ropeway and "sonde" enteroscopes. But did not achieve wide acceptance as they were cumbersome, time consuming, and technically challenging. Later for the next three decades, the push enteroscope using long endoscopes was used for the evaluation of the upper jejunum only leaving the deeper small bowel uninvestigated. An intraoperative enteroscope was also put into practice but it was invasive involving abdominal incision and enterotomy and, thus, remained a less acceptable choice. In 2000, a wireless capsule endoscope was introduced as a novel non-invasive method for the evaluation of small bowel mucosa,

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and since then, we have witnessed an enhanced capability in the diagnosis of small bowel diseases.[1]

In 2001, Yamamoto et al[2] introduced the double-balloon enteroscope which offers a detailed evaluation of deep small bowel. Within a decade, this was quickly followed by the introduction of a single-balloon enteroscope[3] and a spiral enteroscope[4] and later a novel through-the-scope balloon was also described for the same purpose.[5] These device-assisted enteroscopes (DAEs) not only allow detailed evaluation of the small bowel mucosa but also allow us to carry out various therapeutic procedures including tissue sampling, clip application, polypectomy, argon plasma coagulation, foreign body removal, stricture dilatation, biliary interventions in surgically altered anatomy, etc.[6] Additionally, total enteroscopy also became a reality with the introduction of these techniques into our practice.[7] Despite a significant advancement, the above-described techniques still remain complex, time-consuming, labor-intensive, cumbersome, and require refined endoscopic skills. Also, long-length accessories might be required to pass through these long enteroscopes to carry out various therapeutic interventions. These above challenges warrant further refinement of the enteroscope which could offer us a faster, safer, and deeper evaluation of small bowel on a more stable platform using a shorter length scope.

A novel motorized spiral enteroscope (MSE) was introduced in 2015 by Neuhaus et al,[8] and initial evidence indicates that MSE has tried to address these shortcomings of the currently available DAE. In this review, we present the details of the equipment and its specifications, procedure technique, indications and contraindications, current evidence on this technology, and future improvements.

Device, Equipment, and Specifications

MSE was introduced as a power spiral enteroscope (PSE) in November 2015. It is a 168-cm-long flexible reusable endoscope. The PSE carries a rotating coupler at around 40 cm from the tip of the scope and an integrated motor just below the wheels on the enteroscope (►**Fig. 1A, B**). It is fully compatible with the EVIS EXERA III and the latest EVIS X1 CV-1500 endoscopy systems (Olympus medical systems corporation, Tokyo) for usage. The device specifications of PSE in comparison with other available enteroscopes are detailed in ►**Table 1**. Additionally, the PSE unit comes along with other essential equipment such as (1) control unit, (2) foot pedal, (3) force gauze, (4) disposable 24-cm-long spiral overtube, (5) Bite block, (6) lubricating jelly specific for the enteroscope and spiral overtube, and (7) connecting cables (►**Fig. 2A–F**). To perform the procedure, additionally, we need a water flush pump, CO_2 pump, 18-mm and 20-mm bougie dilators, tattooing ink, and fluoroscopy in our endoscopy unit.

Setting Up the Equipment

The enteroscope needs to be liberally lubricated using the jelly provided by the manufacturer (EndoLan) from the tip of the enteroscope to the rotational segment. The disposable spiral overtube is 24-cm-long, 18-mm-wide overtube with pliable silicone spiral attached on the outer surface of it making it altogether around 31 mm wide. The inner surface of the spiral overtube has grooves. The spiral overtube is loaded onto the enteroscope with a connector pointing toward the rotational segment of the enteroscope, and it has to be adjusted gently such that the ridges on the rotational segment align with the grooves of the spiral overtube. Further advancement locks the overtube in place with a click. The lock collar on the overtube is further advanced onto the connector to lock the assembly completely that is confirmed by the nonvisualization of the yellow mark on the spiral overtube (►**Fig. 3**).

The next step would be a system check. System check is done after the control unit is turned on or the enteroscope has been replaced. As soon as the inspection mode is turned on, the backward light starts blinking first on the force gauge and the backward pedal has to be pressed to rotate the spiral overtube in a counter-clockwise direction. While maintaining the anticlockwise rotation, the overtube is bent gradually, and on the force gauge display, the changing forces can be appreciated. A manual squeezing pressure in the middle of the overtube would increase the forces indicated on the display and a continuous increase in squeeze pressure would activate the limit function, and the rotational movement is automatically halted by the built-in safety function. The same maneuver is repeated by pressing the forward pedal during clockwise rotation of the spiral overtube. Pressing the backward pedal and forward pedal would cause anticlockwise and clockwise movements of the spiral overtube, respectively. This would be transmitted as backward or forward propulsion of the enteroscope in the small bowel. Detailed information about the system assembly and setting up the equipment is available on the manufacturer website (www. https://www.olympusprofed.com/gi/powerspiral/).

Indications

Patients with (1) suspected small bowel bleeding, (2) positive stool occult blood with unrevealing upper endoscopic and colonoscopic study, (3) unexplained iron deficiency anemia, (4) chronic diarrhea, (5) malabsorption and protein-losing enteropathy, (6) foreign body obstruction, (7) radiologic imaging suggestive of mucosal thickening, luminal narrowing, tumor, ulcer, bleeding, (8) unexplained pain abdomen, etc., in the small bowel need enteroscopy for various diagnostic and therapeutic purposes, and PSE can be considered in such cases.

Contraindications

While choosing PSE, a number of patient-related factors, underlying other gastrointestinal diseases, and various miscellaneous factors are needed to be considered.

Patient-related factors like (1) severe comorbid illness causing medical instability, (2) contraindication to general anesthesia, (3) contraindication to endotracheal intubation,

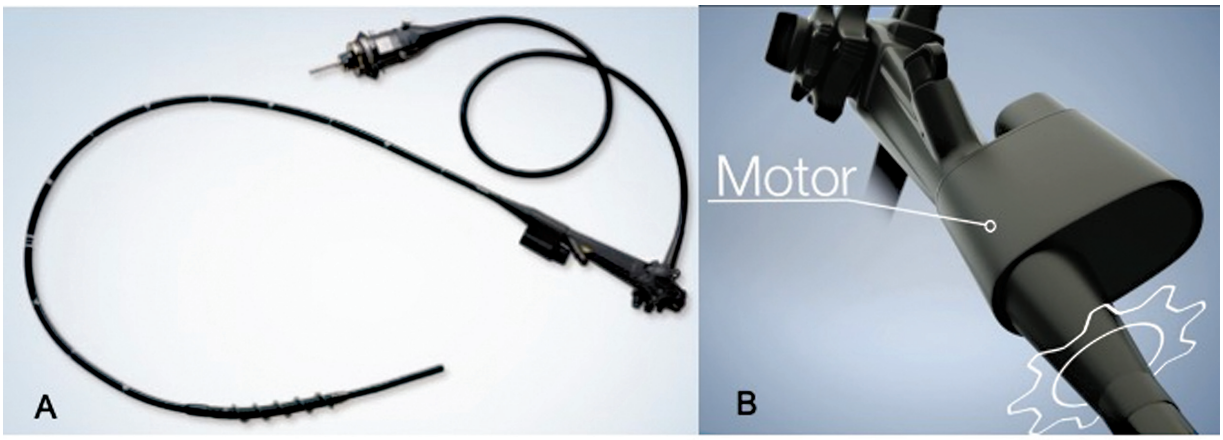

Fig. 1 (**A**) Power spiral enteroscopy with (**B**) integrated motor available below the wheels on the enteroscope.

and (4) uncontrolled coagulopathy; underlying other gastrointestinal diseases like (1) known intestinal perforation, (2) recent feeding jejunostomy tube placement (<2 weeks), (3) esophagogastric tumors/varices, (4) tumors/stenosis/metal stent prosthesis in the esophagogastric/colonic location, (5) eosinophilic esophagitis, (6) severe colitis, (7) surgically altered anatomy, and (8) radiation-induced mucosal changes; and other miscellaneous factors like (1) children especially infants and toddlers, (2) pregnancy, (3) failure to provide consent, and (4) inability to accept the mouth piece are needed to be considered and any contraindications should be explored at.

Patient Preparation

The procedure is done under general anesthesia with preferably nasotracheal intubation. The mouth piece is 35 mm wide and so adequate jaw opening and proper dental alignment have to be checked before considering for PSE. All indications and contraindications should be checked and a prior laboratory workup and anesthetic checkup should be completed before the procedure. A thorough history including the use of anticoagulants should be obtained. Overnight fasting is required for antegrade PSE, and an additional bowel lavage preparation is required for retrograde PSE. The procedure is done with the patient in the left lateral decubitus position or supine position. Gentle neck extension is needed in antegrade PSE to allow smooth negotiation of the enteroscope loaded with a spiral overtube. Findings of previously done investigations like upper endoscopy, colonoscopy, radiologic imaging, capsule endoscopy were noted. This would pick up any unnoticed contraindication, would guide the route of PSE, and also plan appropriate therapeutic intervention if needed.

Technique of Power Spiral Enteroscope

Prior esophageal bougie dilation over the guidewire up to 18 to 20 mm is encouraged for all antegrade PSE procedures to

Table 1 Device specifications of various enteroscopes

DAE system type	Single-balloon enteroscope	Double-balloon enteroscope	Balloon-guided enteroscope	Spiral enteroscope	PowerSpiral enteroscopy
Company	Olympus Tokyo, Japan	Fujifilm Corporation Tokyo, Japan	SmartMedical Systems Raanana, Israel	Spirus Medical Stoughton, Massachusetts, United States	Olympus Tokyo, Japan
Endoscope model	SIF-Q 180	EN-580T	No specific scope	No specific scope	PSF-1
Outer diameter distal end of endoscope	9.2 mm	9.4 mm			11.2 mm
Instrument channel inner diameter	2.8 mm	3.2 mm			3.2 mm
Outer diameter of Overtube	13.2 mm	13.2 mm		14.5 mm	18.1 and 31.1 mm (with spiral)
Total length	2,345 mm	2,300 mm			2,015 mm
Working length	2,000 mm	2,000 mm			1,680 mm
Virtual chromoendoscopy	Yes	Yes	Depend on endoscope used	Depend on endoscope used	Yes

Abbreviations: DAE, device-assisted enteroscope; PSE, power spiral enteroscope.

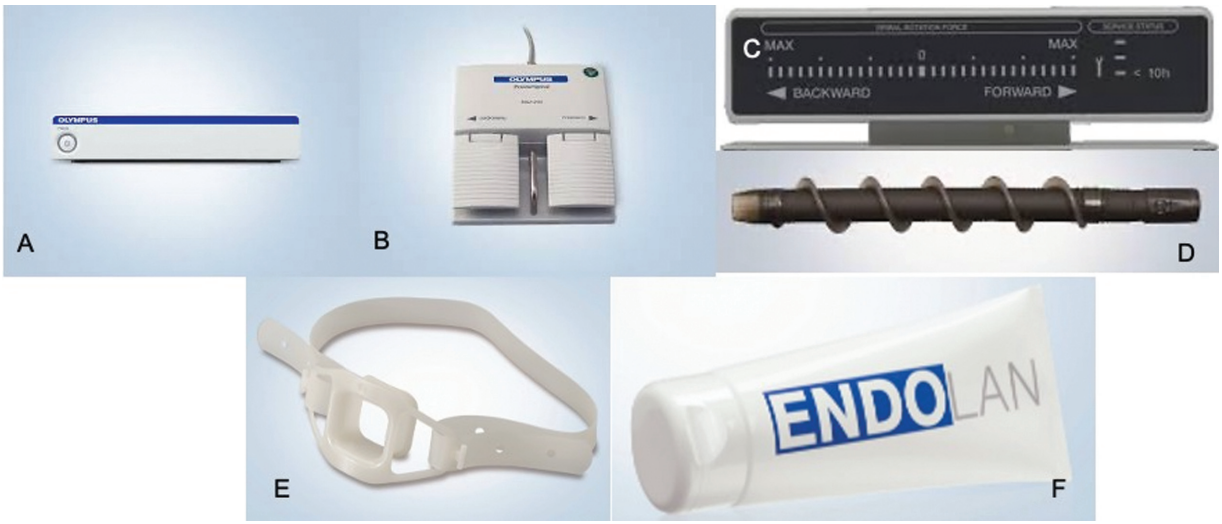

Fig. 2 (A) Control unit, (B) foot pedal, (C) force gauze, (D) disposable 24-cm-long spiral overtube, (E) mouth piece, and (F) lubricating jelly.

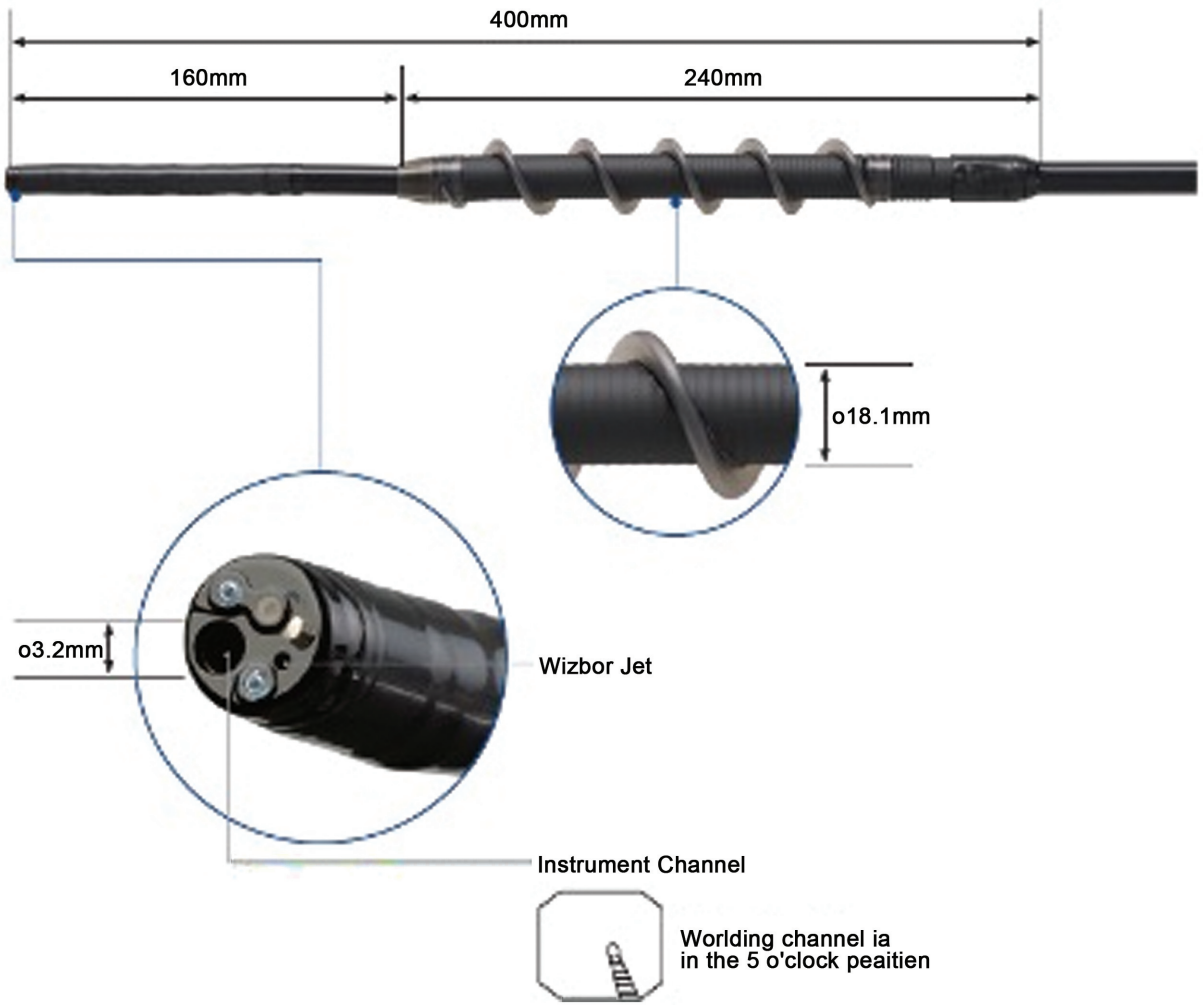

Fig. 3 Power spiral enteroscopy after loading with spiral overtube and device specifications and measurements.

facilitate the smooth passage of the enteroscope. The technique of PSE grossly remains the same for antegrade and retrograde routes of PSE.[9,10]

PSE is introduced via the mouth into the oral cavity and gently negotiated into the upper esophagus. A forward foot pedal is activated as soon as the distal portion of the spiral

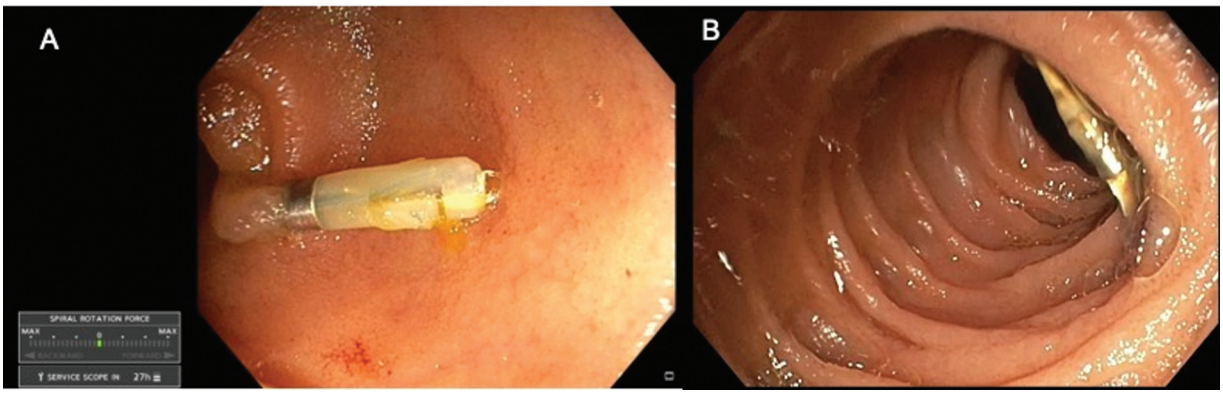

Fig. 4 Total enteroscopy: (**A**) marking clip placed during retrograde enteroscopy and (**B**) visualization of the same marking clip during antegrade enteroscopy.

overtube reaches the incisors. This activates the clockwise spiral movements of the overtube and aids in forward propulsion of the enteroscope. Maneuvers like transient deflation of the cuff of the endotracheal tube and gentle extension of the neck to straighten the pathway might be needed for smooth negotiation of the entire overtube deep into the esophagus and stomach. A gentle forward push is maintained while the forward pedal is activated to propel the enteroscope forward. When the double marker at the 80-cm location of the enteroscope reaches incisors, it confirms that the entire overtube has crossed the esophagogastric junction (EGJ). During the entire procedure, we should remember that the scope tip is 16 cm ahead of the tip of the spiral overtube as this is important while negotiating any stricture segment. CO_2 insufflation would cause more distension and bloating up of the small bowel leading to an ineffective procedure. So, as soon as the scope tip reaches the duodenum, CO_2 is switched off and the small bowel is distended with intermittent water instillation. This would allow better lubrication between the overtube and small bowel mucosa leading to better scope-bowel engagement. PSE is propelled distally by continuous activation of the forward pedal, gentle push onto the scope, intermittent water instillation, gentle massage-like movements on the anterior abdominal wall, and also sometimes by position change of patient. Through the procedure, the operator should be vigilant of the signal on the force gauze that appears on the monitor in the picture-in-picture mode. Whenever excessive pressure is sensed on the overtube while negotiating a stricture or flexure or bend or a loop, the limit function gets active and the rotation ceases. The operator may follow the above-described maneuvers in various combinations to overcome these challenges and continue to perform the enteroscope. Appropriate therapeutic intervention is performed whenever needed during the procedure. The procedure is continued till the area of interest or till the maximum insertion point is reached. The operator may stop the procedure at the maximal insertion point whenever it is perceived that further advancement of PSE is not possible in the deep small bowel despite normal-looking lumen. If a total enteroscopy or retrograde enteroscopy is warranted, then this area is marked either with a clip or tattooing ink and this point is tried to reach via the retrograde route in the same session or on a different day (►**Fig. 4A,B**). During scope withdrawal, the backward pedal is activated which causes anticlockwise rotation of the spiral overtube. Additional application of gentle backward traction on the scope, CO_2 insufflation into the small bowel, and gentle wiggling movements of the scope tip using the wheels would allow smooth withdrawal of the scope. The small bowel is examined during both insertion and withdrawal of the enteroscope and appropriate interventions may be performed. For monitoring of end-tidal CO_2, body temperature is necessary during the procedure. Fluoroscopy may be used whenever deemed necessary to estimate the depth of insertion (►**Fig. 5**), negotiating small bowel in surgically altered anatomy, presence of any bend or any complication like perforation, etc. As the scope is nearing the 80-cm mark at the incisors, care should be taken to ensure that the scope is entirely in the stomach as this would avoid simultaneous engagement of the spiral overtube at the pylorus and EGJ which would lead to difficult withdrawal of scope. Maneuvers like neck extension and cuff deflation might be required during withdrawal of the scope also. Similar steps might be applied while performing

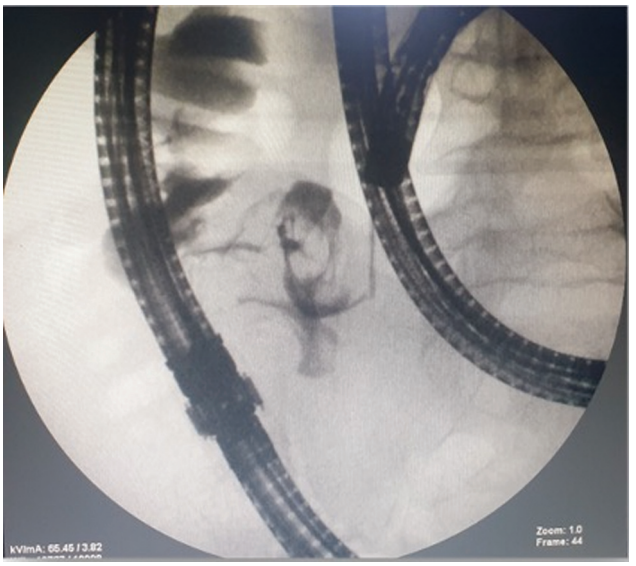

Fig. 5 Use of fluoroscopy +/− contrast instillation to note the whorls and confirm the position and direction of the scope and its tip.

Table 2 Differences in the principles and procedure steps between PSE and BAE

	PSE	BAE
Principle	Rotational movements	Push-pull technique
Operator	Single	≥2
Periodic delooping of scope	May be needed during negotiation at high-pressure segments	Needed during each cycle of inflation and deflation
Accessories used	Standard length	Long dedicated accessories
Scope stability	Stable	Unstable
Safety in post-surgical anatomy	Limited literature	Extensive literature
Routine preprocedure esophageal dilation	Strongly advised	Advised only if there are strictures
General anesthesia	Mandatory especially in antegrade procedures	Not mandatory
Control of movements	Foot pedal-controlled movements	Manual control with operators hands
High-pressure alarm signal	Visual, rotational movements cease	Visual and auditory
Withdrawal during emergency situations	Not possible	Possible
Luminal insufflation during insertion	Water	Air/CO_2
Luminal insufflation during withdrawal	CO_2	Air/CO_2
Check for dental alignment and jaw opening	Mandatory to fit in wide mouth piece	Not mandatory
Procedure time	Appears to be quicker	Longer
Confirmation of overtube position in stomach while withdrawal	Advised to inspect the 80-cm mark at scope	Not needed
Gentle neck extension	Frequently needed to allow passage of spiral overtube	Not always required
Deflation of cuff of endotracheal tube	Frequently needed to allow passage of spiral overtube	Not always required

Abbreviation: BAE, balloon-assisted enteroscope; PSE, power spiral enteroscope.

retrograde route of PSE as well except the need to watch for the 80-cm mark. Standard length accessories like clips, injection needles, balloon dilators, snares, forceps, coagulation probe, etc., can be passed through the working channel of PSE to perform appropriate therapeutic interventions wherever necessary. Any adverse events like mucosal abrasions, lacerations, tears, perforation, etc., need to be identified and tackled, if necessary, in the same session. The patient is observed in the recovery room for few hours and started on an oral diet and discharged as per the clinical condition.

Power Spiral Enteroscope versus Balloon-Assisted Enteroscope: Important Technical Differences in Procedure

Balloon-assisted enteroscope (BAE) and PSE are entirely different with respect to technology and scope specifications. This brings us to the point of noting important differences in the technical and procedural steps which are detailed in ►**Table 2**.

Performance of Power Spiral Enteroscope: Current Evidence

To date, no comparative study is available between PSE and other enteroscopes in terms of performance, safety, and efficacy, diagnostic and therapeutic yield, procedure time, depth of maximum insertion (DMI), etc. The published literature on PSE suggests that median DMI is between 450 and 521 cm (distal to the ligament of Treitz via antegrade route) and 120 and 140 cm (proximal to ileocecal valve) which is achieved in 40 and 61 minutes (via antegrade route) and 35 and 90 minutes (via retrograde route). Total enteroscopy rates ranges between 10.6 and 70%. Most common indications for PSE include small bowel bleeding, unexplained pain abdomen, chronic diarrhea, etc. We commonly come across ulcers, strictures (►**Fig. 6**), angiodysplasias

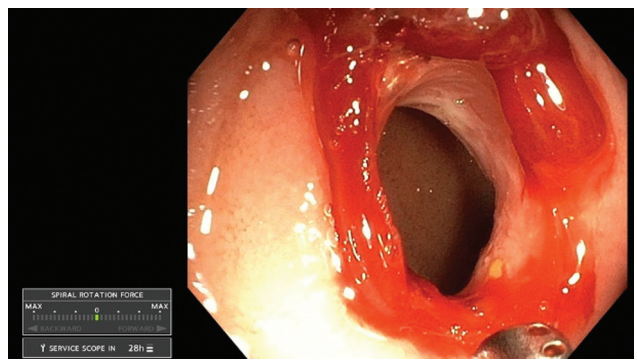

Fig. 6 Ulcers with stricture in small bowel.

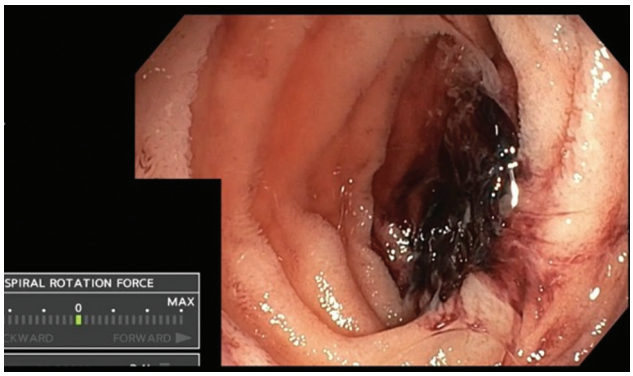

Fig. 7 Jejunal angiodysplasias with recent hemorrhage.

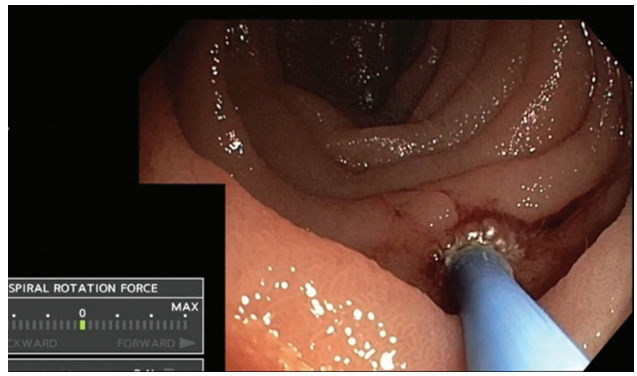

Fig. 9 Argon plasma coagulation of the jejunal angiodysplasias.

(►**Fig. 7**), tumors (►**Fig. 8**), etc., which warrant tissue sampling. The most common therapeutic interventions performed are argon plasma coagulation (►**Fig. 9**), endoclip application, endoscopic mucosal resection, polypectomy (►**Fig. 10**), stricture dilatation, etc.[9–22] Biliary interventions can be performed in surgically altered anatomy with careful negotiation of PSE across the surgical anastomotic site (►**Fig. 11**). It is usually a safe procedure. The most common adverse events reported are mucosal abrasions and lacerations (►**Fig. 12**). Rarely severe adverse events like bowel perforation are also reported.[9] A detailed summary of currently available literature is summarized in ►**Tables 3** and **4**. In addition to enteroscopy, PSE is also described for colonoscopic examination.[23] Mean procedure time was 20.8 minutes, and cecal intubation was achieved in 96.7%. Cecum was reached in 7.1 minutes. In total, 3.3% required external manual compression during the procedure. The adenoma detection rate was 46.7%. Interventions like endoscopic mucosal resection, forceps polypectomy, etc., were performed in 20 out of 30 patients.

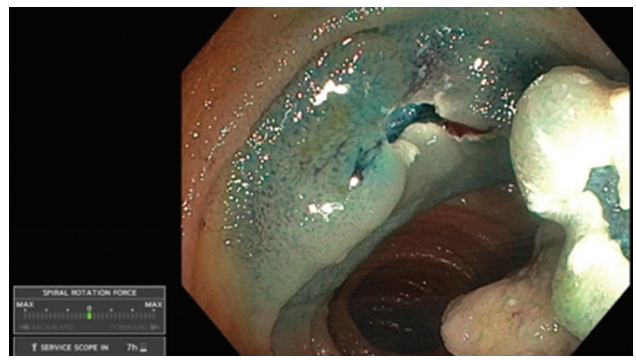

Fig. 10 Polypectomy in jejunum.

Power Spiral Enteroscope: Advantages and Improvements

PSE has arrived with some advancements and advantages which were lacking with BAE. Shorter scope length, the requirement of only a single operator, better ergonomics due to controlled motorized propulsion of enteroscope even in the deep small bowel, stable scope position, shorter procedure time, usage of endoscopic accessories of standard length, etc., represent the advantages of PSE. Due to these advantages, PSE becomes an attractive option to consider for small bowel enteroscopy.[9,10]

Power Spiral Enteroscope: Shortcomings and Scope for Improvement in Future

A shorter length of scope and motorized control of rotational movements of the spiral overtube make PSE an attractive

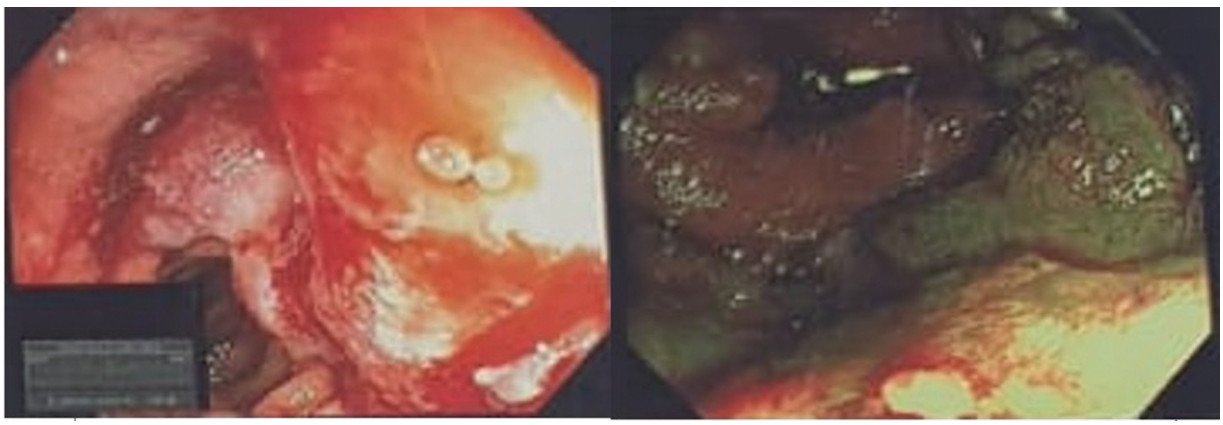

Fig. 8 Jejunal tumor (adenocarcinoma) on white light examination and narrow band imaging.

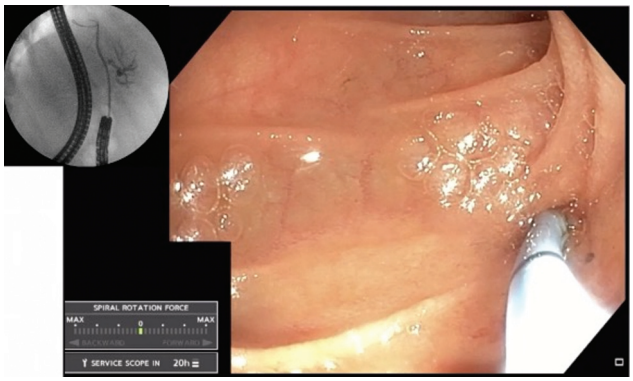

Fig. 11 PSE-guided ERCP in patient with hepaticojejunostomy. ERCP, endoscopic retrograde cholangiopancreatography; PSE, power spiral enteroscope.

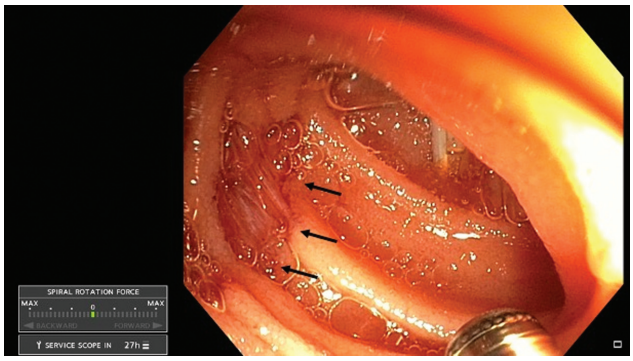

Fig. 12 Ileal mucosal laceration noted upon withdrawal during retrograde PSE. PSE, power spiral enteroscope.

Table 3 Performance of PSE (cohort studies)

Author name		Prasad et al[11] (2020)	Ramchandani et al[10] (2020)	Beyna et al[12] (2020)	Beyna et al[9] (2021)	Giordano et al[13] (2020)	Our experience (Abstract submitted to ESGE Days 2022)
n		14	61	30	132	28	44
Mean age (years)		55.57	45.67	64	68	57	42.98
Male gender (*n*)		10M	43M	14M	74M	17M	33M
Study design		case series	Retrospective	Prospective	Prospective	Prospective	Retrospective
Procedure indications							
Route of procedure (%)	Antegrade	35.71	55.7	100	97	67.9	29.54
	Retrograde	28.57	8.1	80		32.1	40.9
	Bidirectional	35.71	36	80			29.54
Tissue sampling (%)		57.14	50.8	46.7			79.55
Median depth of maximal insertion (centimeters)	Antegrade		465	490	450	521	211
	Retrograde		140	120	No		119
Procedure time (minutes)	Antegrade	61.1	40	51	54		46.12
	Retrograde	90	35	40	No		35.09
Total enteroscopy (%)		35.71	60.6	70	10.6		13.36
Adverse events (*n*)		Mild odynophagia (3) Superficial mucosal abrasion (3) Hypothermia (3) Pancreatitis (1)	Superficial mucosal injury and throat discomfort (15)	Deep mucosal tears (3) Hematoma of jejunal wall (1) Mild swallowing discomfort (1)	Deep mucosal tears (3) Mild bradycardia and arterial hypotension (3) Mild abdominal pain (4) Fever (3) Mild swallowing discomfort (3) Mild acute parotitis (1) Perforation (1) Mallory-Weiss tear (1)		Cricopharyngeal laceration ($n=2$) Ileal mucosal laceration ($n=1$) Hypothermia ($n=1$)

Abbreviation: ESGE, European Society of Gastrointestinal Endoscopy.

option for performing small bowel enteroscopy. But there are certain important points to note that might cause procedure challenges in certain patient populations.

(1) The spiral overtube is wider and more rigid compared with the balloon overtube. This was designed to offer better coupling and engagement of scope and small bowel/colon. A dedicated wider mouthpiece is needed to facilitate a smooth insertion of the enteroscope. A rotational coupler is a segment to offer more resistance during scope navigation. We noted during our initial experience that there might be some technical and procedure challenges in patients with low body mass index, thick and short neck, and dental malalignment. Also, there is no widespread evidence available about its safety and challenges faced in postoperative anatomy and

Table 4 Performance of PSE (case reports)

Author name	Age	Indication	Intervention	Procedure time	Route	Adverse events
González-Suárez et al[14]	56	Polypoid lesion in mid jejunum identified by capsule endoscopy	resection of polyp	50 minutes	Antegrade	No
González-Suárez et al[15]	48	angioectasias in the jejunum and ileum	Treating vascular lesions, biopsy	less than 1 hour	Antegrade	No
Rodge et al[16]	59	Active bleeding of jejunum suggestive of Dieulafoy's lesion	Hemoclip application		Antegrade	No
Inavolu et al[17]	36	CE device in proximal ileal loop	CE retrieval and stricture dilatation		Antegrade	No
Steiner et al[18]	73	biliary stones, pain, and cholestasis			Antegrade	Disconnection of spiral overtube. Retrieved using through the scope balloon
Mans et al[19]	71	Iron deficiency anemia, Occult GI bleed	Angiodysplasia treated with APC		Antegrade	No
Beyna et al[20]	78	Obstructive jaundice post Roux-en-Y reconstructive surgery and high bilateral bilioenteric anastomosis	Stricture in right and left hepatic duct managed with balloon dilation	51 minutes	Antegrade	no
Neuhaus et al[8]	48	Angiodysplasia in jejunum identified by small bowel capsule endoscopy	APC done		Antegrade	no
Viesca et al[21]	70	melena and hematochezia	Control of bleed and biopsy		Antegrade, Retrograde, Total enteroscopy done	pulmonary embolism
Tang et al[22]	87	Small bowel bleeding	Multiple ulcers in the small bowel	58 minutes	Antegrade, total enteroscopy done	

pediatric patients. Literature reported more frequent mucosal lacerations/injury with PSE. A thinner and less rigid spiral overtube might be needed in a certain population as described above to facilitate a smooth and safe insertion and withdrawal of the scope.

(2) The small bowel is curled and pleated over the spiral overtube and the scope behind, immediate withdrawal of the scope in emergency untoward situations like cardiorespiratory arrest requiring cardiopulmonary resuscitation, block of the endotracheal tube, or accidental dislodgment of the endotracheal tube in the middle of the procedure.

(3) CO_2 insufflation is recommended for usage during the PSE procedure. This requires monitoring of end-tidal CO_2, and thus, the procedure is performed under general anesthesia. Candidates who are at poor anesthesia risk might not tolerate the procedure.

Conclusion

PSE is the new kid on the block for the evaluation of small bowel mucosa. It comes with a spiral overtube which works with a rotational principle completely controlled by the operator using a foot pedal. It appears to be quick, safe, and offers a stable working platform using standard endoscopic accessories and can be performed by a single operator. Currently, the evidence is limited to areas like Europe and India and more data about its performance, safety, and efficacy are needed from other parts of the world. Randomized trials comparing PSE and BAE are needed to understand the role of PSE visa-vis BAE in small bowel enteroscopy. More evidence is needed in patients with postoperative anatomy and in children.

Conflict of Interest
None declared.

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