Motorised spiral enteroscopy: pilot experience from a tertiary care centre in Singapore

INTRODUCTION

The small bowel has traditionally been inaccessible by conventional endoscopy. Advancements in video capsule endoscopy (VCE), computed tomography (CT) and magnetic resonance enteroclysis (MRE) have significantly improved the ability to detect small bowel pathology. Established modalities for small bowel endoscopy include single-balloon enteroscopy, double-balloon enteroscopy (DBE) and spiral enteroscopy.[1,2] Two important factors that restrict deep intubation are small bowel length, especially in relation to that of the endoscopes, and anatomy. Loop formation of the scope in the small bowel owing to its attachment to unfixed mesentery often limits effective forward advancement.[3]

The novel motorised spiral enteroscope system (Olympus Corp, Tokyo, Japan) makes it easier to overcome these factors by pleating the small bowel over the insertion tube via clockwise or anticlockwise motorised rotation of the spiral overtube, controlled by a foot pedal switch operated by the endoscopist. This facilitates efficient deep intubation of the small bowel.

METHODS

Six adult patients underwent endoscopic evaluation with motorised spiral enteroscopy (MSE) over a two-month period (March 2020 and April 2020) under the Department of Gastroenterology and Hepatology, Tan Tock Seng Hospital, Singapore. All procedures were performed by consultant endoscopists with experience in DBE, two of whom had prior training in MSE. All patients had prior positive small bowel imaging that required further evaluation with endoscopy and/or histology. All were reviewed by a gastroenterologist for procedural fitness and an anaesthesiologist for fitness for general anaesthesia (GA).

Patient demographics, procedural indications, type of sedation used, intraprocedural findings, therapeutic interventions (if any) and postprocedural outcomes were summarised after review of our institution's medical records. Data were de-identified and collated into a database by members of the study team in the Department of Gastroenterology and Hepatology, Tan Tock Seng Hospital. The study was approved by the institutional review board (National Healthcare Group Domain Specific Review Board reference no. 2020/00580).

Sample sizes, means and medians with interquartile ranges (IQR) were calculated for continuous variables. Proportions were calculated for categorical variables.

Technical success for an MSE procedure was defined as advancement of the scope beyond the duodenal-jejunal flexure in the antegrade approach, and beyond the ileocecal valve in the retrograde approach.[4] Procedural yield was defined as the percentage of procedures with endoscopic findings (with or without tissue sampling) that either correlated with small bowel imaging findings or served as important clinical information that altered management.

RESULTS

Seven MSE procedures (five antegrade, two retrograde) were performed on six patients (three male, three female). The mean age of the patients was 64 years. Four antegrade procedures and one combined bidirectional procedure were performed under GA, while one retrograde procedure was performed under moderate anaesthesia cover. Six MSE procedures achieved technical success, while one antegrade procedure was technically unsuccessful (Patient 6; owing to inability to pass the overtube through the proximal oesophagus), yielding a technical success rate of 85.7%. The median procedural time for technically successful procedures was 101 (IQR 65–121) minutes.

In one patient, total enteroscopy to the caecum was achieved via the antegrade approach (procedural time: 121 minutes). The overall procedural yield was 71.4% (five out of seven attempted procedures), with that of antegrade MSE being 60% (three out of five procedures). Except for proximal oesophageal mucosal injury in Patient 6, no serious adverse events (e.g. gastrointestinal haemorrhage, perforation, pancreatitis, death) occurred in the rest of the patients. Table 1 summarises the patient characteristics and procedural details. Individual case details are described.

Patient 1

A 53-year-old woman on prednisolone for Sweet's syndrome presented with iron-deficiency anaemia and recurrent intermittent haematochezia. Oesophagogastroduodenoscopy and abdominal CT imaging did not reveal any significant lesions. Ileo-colonoscopy only elucidated a small terminal ileal ulcer with non-specific histology. The VCE revealed ulcers in the ileum. Bi-directional DBE was unsuccessful in reaching the ileal ulcers owing to loop formation and faecal contamination. The MRE was unremarkable.

Antegrade MSE was limited by loop formation, and the mucosa appeared normal to the proximal ileum. Retrograde MSE revealed mid-ileal non-bleeding ulcers [Figure 1a] that corresponded to those seen on VCE. Ulcer biopsies showed

Table 1. Patient characteristics and procedural details.

No.	Age (yr)	Gender	Height (cm)	Weight (kg)	BMI (kg/m²)	ASA class	Indication for MSE	Procedure duration (min)
1	53	F	151	57.5	25.2	2	Overt obscure gastrointestinal bleed, suspected small bowel tumour on VCE	178
2	68	F	152	46.1	20.0	3	Jejunal mural nodule on enteroclysis, raised CA 19-9	121
3	69	M	168	53.9	19.0	2	Duodenal thickening on CT	31
4	69	M	165	85.9	31.5	3	Iron-deficiency anaemia, ileal ulcer on VCE	101
5	68	M	160	58.5	22.9	3	Ileal polyp on CT colonography	65
6	57	F	150	50.8	22.5	2	Jejunal polyp on CT enteroclysis	153 (with DBE)

ASA: American Society of Anaesthesiologists, BMI: body mass index, CA 19-9: cancer antigen 19-9, CT: computed tomography, DBE: double-balloon enteroscopy, F: female, M: male, MSE: motorised spiral enteroscopy, VCE: video capsule endoscopy

benign features. The consensus between the gastroenterology and dermatology teams was that the ileal ulcers were likely related to the patient's Sweet's syndrome, and she had been continued on immunosuppressive therapy at the time of writing.

Patient 2

A 68-year-old woman with bronchiectasis and raised cancer antigen (CA) 19-9 underwent abdominal CT imaging, which incidentally detected a 1-cm enhancing jejunal mural nodule. Antegrade DBE was able to reach only the proximal jejunum because of loop formation. Subsequent abdominal CT imaging could not detect the lesion. Total antegrade MSE to the caecum was achieved, with no lesion seen throughout the small bowel. Only focal lymphangiectasia was noted. The patient remained well on follow-up four months after MSE and was planned for CT enteroclysis for surveillance at the time of writing.

Patient 3

A 69-year-old man presented with postprandial vomiting, weight loss and anaemia. Computed tomography of the abdomen revealed circumferential diffuse wall thickening with shouldering from the third to fourth part of the duodenum. Antegrade MSE showed a circumferential stenosing ulcerated mass lesion with contact bleeding in the distal duodenum [Figure 1b]. Biopsies showed a tubulovillous tumour with high-grade dysplasia. The patient underwent a laparotomy with small bowel resection and duodenal-jejunal anastomosis. Histology confirmed invasive adenocarcinoma with mucinous features, and he was started on adjuvant chemotherapy.

Patient 4

A 69-year-old man with ischaemic heart disease, atrial fibrillation on aspirin and moderate obstructive sleep apnoea presented with iron-deficiency anaemia. Oesophagogastroduodenoscopy and colonoscopy were unremarkable, except for mild antral gastritis, and diminutive gastric and sigmoid colon polyps. The VCE showed a small ulcer in the mid-terminal ileum with surrounding inflammatory changes. Antegrade MSE was performed to the terminal ileum, where two small

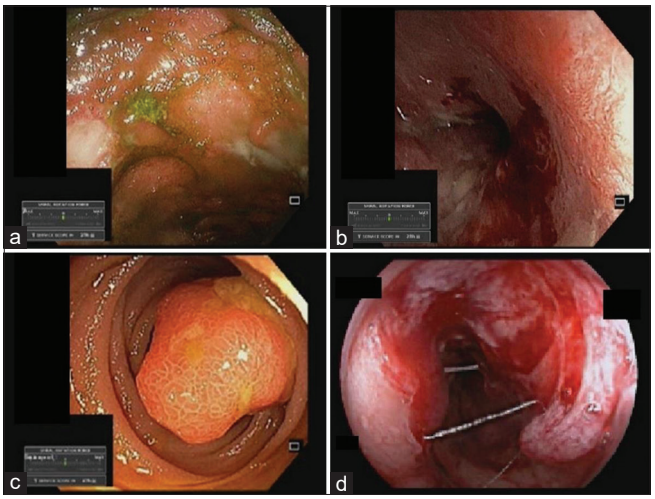

Figure 1: Endoscopic images show (a) ileal ulcers in Patient 1; (b) duodenal stricture in Patient 3; (c) pedunculated polyp seen on motorised spiral enteroscopy in Patient 5; and (d) mucosal trauma seen on scope withdrawal in Patient 6.

erosions were noted without active bleeding, corresponding to the findings on VCE. No other sinister lesions were found. The patient was not keen for retrograde enteroscopy. Aspirin-induced enteropathy was thought to be the aetiology of his small bowel ulcers. He remained well on follow-up four months after MSE, with normalisation of haemoglobin count on oral iron supplementation.

Patient 5

A 68-year-old man with ischaemic heart disease and previous percutaneous coronary intervention on aspirin presented with iron-deficiency anaemia. Oesophagogastroduodenoscopy was unremarkable. Computed tomography colonography revealed a pedunculated polyp measuring 1 cm in diameter in the distal ileum. No colonic lesions were seen. Retrograde MSE was performed. A 1.5-cm pedunculated polyp with a thick stalk was encountered approximately 15–20 cm from the ileocecal valve [Figure 1c]. This was removed with hot snare polypectomy after pre-injection of the base with adrenaline and an endoscopic clip was prophylactically applied to the polypectomy base. Histology showed a hamartomatous polyp.

Patient 6

A 57-year-old woman (height 150 cm, weight 50.8 kg) with prior synchronous left hemicolectomy and lung resection for a splenic flexure adenocarcinoma with solitary metastatic lung nodule was found to have an incidental 1.2-cm jejunal polyp on follow-up abdominal CT imaging. Antegrade MSE was attempted but failed to intubate the oesophagus. On withdrawal, superficial mucosal tears were noted along the proximal oesophagus, likely from prior MSE trauma [Figure 1d]. This was likely a result of the patient's small stature and the MSE overtube being relatively too large for her. Antegrade DBE was able to reach the mid-jejunum, where a pedunculated polyp was found and removed. The patient was admitted overnight for observation after large polypectomy. She remained well throughout the hospitalisation, with no sore throat, dysphagia, odynophagia or chest discomfort and was discharged the next day. Histology showed a hamartomatous polyp. She remained well at one-month follow-up, with stable haemoglobin count.

DISCUSSION

Magnetic spiral enteroscopy represents the latest iteration in the evolution of device-assisted enteroscopy. It provides an efficient, stable platform for intubation of the small bowel and therapeutic capabilities equivalent to those of conventional enteroscopy. With its 3.2-mm working channel and length comparable to that of standard colonoscopy (1,680 mm), it allows compatibility with standard endo-therapy instruments such as biopsy forceps, clips and thermal therapy devices. Table 2 describes the indications and contraindications for MSE.

Table 2. Indications and contraindications for MSE.

Indications	
Diagnostic	**Therapeutic**
• Endoscopic visualisation and/or tissue sampling of small bowel mucosal pathology (e.g. ulcers, malignancy, protein-losing enteropathy)	• Haemostasis of small bowel bleeding • Small bowel polypectomy • Foreign body removal • Stricture dilatation
Contraindications	
Absolute	**Relative**
• Poor fitness for general anaesthesia or deep sedation • Gut perforation • Coagulopathy • Feeding jejunostomy or intestinal instrumentation (e.g. stents) • Paediatric patients Antegrade approach • Microstomia or inability to accommodate mouthpiece • Oesophageal or gastric varices • Foregut stenosis • Deep mucosal lacerations • Eosinophilic oesophagitis Retrograde approach • Anal stenosis • Colonic stricture • Severe colitis • Rectal or colonic varices	• Pregnancy • Gut stricturing diseases (e.g. Crohn's disease, radiation enteritis) • Post-surgical altered anatomy Antegrade approach • History of dysphagia or oesophageal swallowing disorders Retrograde approach • Mild to moderate colitis

The first clinical case in which MSE was performed was reported by Neuhaus *et al*. in 2016.[5] Beyna *et al*.[6] reported a prospective pilot series of antegrade MSE in two tertiary referral centres. 140 procedures were performed on 132 consecutive patients over a 30-month period. The overall diagnostic yield was 74.2%, technical success rate was 97% and overall adverse event rate was 14.4%. Ramchandani *et al*.[7] reported a single-centre retrospective series of 61 patients who underwent antegrade and/or retrograde MSE over a six-month period, with an overall diagnostic yield of 65.5%, technical success rate of 93.4% and a minor adverse event rate of 24.5%. The motorised endoscope has also been trialled in diagnostic colonoscopy[8] and enteroscopy-assisted endoscopic retrograde cholangiopancreatography.[9]

Our study reports the pilot experience with MSE in an Asian tertiary centre with a predominantly Chinese population. High rates of deep intubation can be achieved with MSE using the antegrade approach. In our series, ileal intubation was achieved in 75% of technically successful antegrade procedures (Patients 1, 2 and 4), with total enteroscopy achieved in one case (Patient 2). The fourth case (Patient 3) had an anticipated distal duodenal stricture, with MSE primarily performed for tissue sampling. Similar high ileal intubation rates were reported by Beyna *et al*.[6] In their first 30 patients, an ileal intubation rate of 86.7% was achieved, with a mean total procedural time of 48.4 minutes. The total antegrade enteroscopy rate was 10.6%.

Retrograde MSE also appears to be safe and efficacious. Both our patients who underwent retrograde MSE tolerated the procedure well, without complications. Terminal ileal intubation was easily achieved with both patients in the left lateral position, with the scope advanced via gentle clockwise motorised rotation of the spiral segment after passage beyond the ileocecal valve. The device afforded a very stable position during polypectomy in Patient 5, contributing to procedural safety. Notably, in the study by Ramchandani *et al*.,[7] 100% (27/27) of retrograde procedures were technically successful, with no major adverse events.

An interesting observation was made by Beyna *et al*.[6] about the learning curve for MSE. No apparent significant effect on parameters such as depth of maximal insertion beyond the ligament of Treitz and total antegrade enteroscopy rate was observed with the increasing numbers of procedures performed. The authors speculate that adoption of the MSE technique may not be associated with a long learning curve of more than five to ten cases. Two recent cases that were

described involved patients with overt obscure gastrointestinal bleeding undergoing MSE, with both achieving total enteroscopy via the antegrade or combined approach.[10,11] In comparison with DBE, the literature suggests a steeper learning curve, with one systematic review of 12,823 procedures over ten years showing a pooled total enteroscopy rate (by combined or antegrade-only approach) of only 44.0%.[12] Our data, congruent with the current literature, suggest that greater efficiency and deeper intubation rates can be achieved with MSE compared with DBE.

Diagnostic and therapeutic yields vary with procedural indication as well as pre-test probability based on existing testing. The high procedural yield in our study is likely reflective of a pre-selected patient population, with all our MSE candidates having existing positive findings on small-bowel imaging. Similarly, in the study by Beyna *et al*.,[6] the overall diagnostic yield was 74.2%, with high rates in patients with suspicious findings on prior imaging (arteriovenous malformation 71%, polyps/neoplasia 52.4%, inflammatory lesions 52.2%). The diagnostic yield of antegrade MSE was 80% in patients with prior findings on MR imaging.

In comparison, yields for conventional device-assisted enteroscopy (DAE) vary in the literature, with DBE accounting for most published data. A meta-analysis in 2008 comparing DBE and capsule endoscopy showed a pooled overall yield of 57% for DBE.[13] The review by Xin *et al*.[12] showed an overall pooled detection rate for DBE of 68.1% for all small bowel disease, with inflammatory lesions accounting for the most common findings in patients with suspected mid-gastrointestinal bleeding in Eastern countries. Another recent systematic review and meta-analysis reported an overall diagnostic yield of 0.68 (95% confidence interval [CI] 0.59–0.76, $P = 0.000001$) and therapeutic yield of 0.45 (95% CI 0.39–0.52; $P = 0.00001$) for device-assisted enteroscopy in elderly patients.[14] Equivalent or even higher yield rates may be attainable with MSE with good case selection, as suggested by our results.

The adverse event rate (AER) for our study was 14.3%. This appears similar to the rate reported in the study by Beyna *et al*.[6] (overall AER 14.4%). This rate could be attributable to a proximal oesophageal mucosal injury during scope intubation in Patient 6, a lady of small build. It is likely that a size mismatch occurred between the relatively thicker spiral segment (31.1 mm total diameter with spiral fins) and the patient's upper oesophageal sphincter and oesophagus. It is uncertain, however, whether factors other than patient habitus contributed to this event. In Beyna *et al*.'s[6] series, one patient experienced a deep mucosal tear in the upper oesophagus as well but, like our patient, was clinically asymptomatic. A prospective analysis of 38 paediatric patients showed a modest linear correlation between body weight and oesophageal diameter.[15] No analogous studies for adults are available in the literature. We recommend that caution be exercised when undertaking MSE for patients of smaller habitus, even if no known foregut stenosis is present. In the studies by both Beyna *et al*.[6] and Ramchandani *et al*.,[7] routine bougienage of 18–20 mm was performed for all antegrade MSE procedures to minimise the risk of trauma from unexpected oesophageal strictures or reduced compliance to the rotating spiral overtube. Further studies are needed to assess whether the risks of this additional procedure are justified in all patients.

Our study has important limitations. Most importantly, as this was a retrospective, observational study of a small number of patients at a single tertiary centre, the results may not be generalisable to other centres. However, it is worth noting that high endoscopic yields were attainable despite our relative inexperience with this device, suggesting a short learning curve that may lower the barrier to competency with MSE. Further procedural details such as the depth of insertion beyond the ligament of Treitz in antegrade procedures, depth of insertion beyond the ileocecal valve in retrograde procedures and breakdown in timing for combined procedures were also not available, given the heterogeneity of recorded data. A longer follow-up duration to assess for adverse events is required. Our study also lacked a control group (e.g. with conventional DAE) for comparison of results. Future larger studies are needed to better assess the clinical efficacy and safety of this device, especially in the form of prospective randomised controlled trials.

In conclusion, MSE is a promising new technology that may reshape the field of small bowel endoscopy. Endoscopists should be alert to the possibility of a size mismatch between a patient's upper oesophageal sphincter and the spiral overtube, which may lead to oesophageal trauma. With growing interest and experience in this field, it is hoped that MSE will find its way into the therapeutic armamentarium of endoscopists, facilitating better treatment of patients with small bowel diseases.

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Conflicts of interest

There are no conflicts of interest.

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