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Bowel preparation after mid-gut tubing enhanced the efficacy and compliance of magnetic resonance enterography in Crohn's disease: a randomized controlled trial

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Abstract

Background: Magnetic resonance enterography (MRE) has become a routine intestinal imaging examination for Crohn's disease (CD). Sufficient bowel preparation is fundamental for MRE.

Objectives: To compare the efficacy and compliance of bowel preparation between through a mid-gut tube and oral administration for MRE in CD.

Design: This was an open-label, prospective, multicenter, randomized controlled trial.

Methods: Eligible patients were randomized at a 1:1 ratio into an oral group (bowel preparation by oral administration) and a tubing group (bowel preparation through a mid-gut tube). Bowel preparation for MRE included bowel cleaning and bowel distention. The primary outcomes were the degree of discomfort and grade of bowel distention. The secondary outcomes were diagnostic accuracy rate through MRE, mental stress, and bowel preparation method preference.

Results: A total of 95 CD patients were included in the final analysis. Subjects in the tubing group complained of less vomiting during bowel preparation than those in the oral group ($p < 0.05$). The degree of nausea and bloating during bowel cleaning for MRE was lower in the tubing group than in the oral group (all $p < 0.05$). The distention grade was higher in the tubing group compared to the oral group in the splenic flexure of the colon and rectosigmoid colon. The tubing group demonstrated a higher overall diagnostic sensitivity in ulcers compared to the oral group ($p = 0.048$). Additionally, bowel preparation via the mid-gut tube ameliorated mental stress ($p = 0.020$) and increased bowel preparation preference ($p < 0.001$).

Conclusion: Bowel preparation through the mid-gut tube enhanced the efficacy and compliance for MRE in CD. This study highlighted the concept of physician-patient satisfaction using mid-gut tube for proper bowel preparation for MRE, enteral nutrition and microbial therapy.

Trial registration: ClinicalTrials.gov, NCT03541733, registered 5 May 2018.

Keywords: Crohn's disease, diagnostic imaging, magnetic resonance imaging, mid-gut, transendoscopic enteral tubing

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Introduction

Crohn's disease (CD) is a chronic inflammatory disease of the gastrointestinal tract with increasing incidence worldwide.[1] Assessment of disease severity and prognostic factors for complications is paramount to guide therapeutic decisions.[1,2] Magnetic resonance enterography (MRE) has become a routine bowel imaging test to evaluate

patients with established or suspected CD.[3] High-quality MRE could improve the accuracy of disease activity assessment in small bowel CD.[4]

Sufficient bowel distention is fundamental for MRE examination in CD, as collapsed loops may hide lesions or mimic disease.[5,6] Bowel distention and motion artifacts are two key imaging parameters that impact the quality of images obtained through MRE.[7] For decades, the landscape of bowel distention has been dominated by administering contrast solution orally for MRE across many countries.[8] In clinical practice, some patients may not tolerate a large volume of oral fluid, leading to adverse symptoms such as nausea, vomiting, bloating, abdominal pain, and diarrhea.[5,9,10] Moreover, distention of the distal small bowel, where diseases are most likely to occur, can still be poor.[5] This might not only affect the diagnostic accuracy for the disease but also aggravate the mental stress of patients.[5] Hence, there is a pressing need to evaluate the optimal method of contrast administration.

In addition to administering contrast solution orally, bowel distention can be achieved via taking contrast solution through a mid-gut tube, which has been shown to ensure consistently better luminal distention than the oral method.[8,11,12] Traditionally mid-gut tubing, such as nasojejunal tubing and nasoduodenal tubing, can be operated under fluoroscopic or electromagnetic guidance, which is considered to be unpleasant and time-consuming.[12,13] Transendoscopic enteral tubing (TET) in the mid-gut is a novel and quick technique of enteral tubing under endoscopy, with a mean procedure time of 4.2 ± 1.9 min.[14] It is mainly used for repeated fecal microbiota transplantations (FMTs) in patients.[15–17] Furthermore, the mid-gut TET can also be used as a perfect delivery method for enteral nutrition support, a large volume laxative, and contrast solution for bowel preparation for MRE.[5] The aim of this study, therefore, was to evaluate the efficacy and compliance of bowel preparation through mid-gut TET for MRE in patients with CD.

Materials and methods

Study design and participants

This was an open-label, multicenter, randomized controlled trial (RCT) conducted in China. The study design has previously been described in a published study.[5] Patients were screened and enrolled from June 2018 to February 2023. The institutional review board of the Second Affiliated Hospital of Nanjing Medical University and Jiangnan University Medical Center approved the protocol, which was in accordance with the principles of the Declaration of Helsinki. All patients provided written informed consent. All authors had access to the study data and reviewed and approved the final manuscript. It was reported according to the Consolidated Standards of Reporting Trails (CONSORT) guidelines,[18] and the checklist is available as Supplemental Material.

Eligible patients were $\geqslant$14 years old with a diagnosis of CD in need of MRE examination and mid-gut tubing (prepared for FMT and/or enteral nutrition). Patients were not eligible if they (1) were unable to understand or provide informed consent; (2) had difficulty in swallowing or dysphagia; (3) were allergic to laxative and/or contrast; (4) were claustrophobic or pregnant or had implanted metal objects or a cardiac pacemaker precluding performance of MRE; and (5) had a known or suspected intestinal obstruction or severe stricture.

Randomization and masking

Eligible patients were randomized in a 1:1 ratio into the oral group (bowel preparation by oral administration) and tubing group (bowel preparation through a mid-gut tube). Randomization was carried out using sealed envelopes containing computer-generated allocation numbers. Owing to the practical barriers to masking, subjects, and the endoscopist who inserted the mid-gut TET were not blinded as to treatment allocation. The blinded people were two experienced radiologists who assessed bowel distention, two experienced endoscopists who evaluated colonoscopy results, study staff responsible for data collection, and statisticians.

Interventions

Patients underwent the TET procedure under anesthesia. All patients in both groups needed this mid-gut tube for frequent FMTs and/or enteral nutrition support. The TET tube was inserted in the mid-gut in the tubing group before

bowel preparation for MRE. For patients in the oral group, a TET tube was placed in the mid-gut after MRE. Two to three milliliters of liquid paraffin oil (medical use level) was injected into TET tube and then the matched guide wire was inserted into the tube (8F, FMT-DT-N-27/1350; FMT Medical, Nanjing, China).[14] Then the tube was coated with paraffin oil by medical gauze and was inserted into the esophagus through nasal orifice under gastroscopic vision in oral cavity. The endoscope was then synchronously advanced to the stomach following the tube. The tube should be advanced into the distal duodenum with or without assistant of grasping forceps. The tube was fixed on the pylorus wall by one titanium clip when the targeting circle (25 or 20 cm to the distal tip of the tube) for fixation was located at the pylorus. The endoscopy assistant then held the tube for avoiding any migration, while the endoscope slowly withdrawn. After the fixation, the guide wire should be pulled out partially until the tip of the guide wire within the tube was pulled into the stomach (almost 25–30 cm), which could be confirmed under endoscopic vision. The endoscope should be inserted into duodenum for confirming no buckling changes of the soft tube within the intestinal cavity. The endoscope could be taken out of the body with the stable controlling of the tube from the assistant. The guide wire was required to be taken out of the tube slowly after the endoscope was out of mouth. Finally, the medical tape was used to fix the tube on nose.

Bowel preparation for MRE included bowel cleaning and bowel distention. Patients were instructed to take in a total of 2000-mL polyethylene glycol (PEG) solution (68.56 g Klean prep/L; Wanhe Pharmaceutical Co., Ltd., Shenzhen, China) through a mid-gut tube or orally before bowel distention to remove stool and other impurities that might mimic lesions during the procedure. In addition, 1500 mL of 3% mannitol solution (China Resources Shuanghe Pharmaceutical Co., Ltd., Hong Kong SAR, China) was administered through TET tubes or orally gradually for 60 min before MRE for bowel distention (Supplemental Figure 1).

After finishing mannitol administration, all patients underwent MRE. The MRE procedure was carried out per protocol. Patients underwent a colonoscopy examination within 24 h after MRE when they were evaluated as suitable for colonoscopy by the endoscopist.

Outcome measures

The primary outcome measures included the following: (1) degree of discomfort before/during/after bowel preparation for MRE. We used a visual 5-grade scale to describe the severity of nausea, vomiting, bloating, and abdominal pain (1 = none, 2 = very mild, 3 = mild, 4 = moderate, and 5 = severe) during bowel preparation, respectively. The visual 5-grade scale was also used to describe the severity of abdominal pain and diarrhea after bowel preparation; (2) grade of bowel distention evaluated by a 5-grade scale (1 = 0%–20% segmental distention, 2 = 20%–40% distention, 3 = 40%–60% distention, 4 = 60%–80% distention, 5 = 80%–100% distention).[12,13] The distention grades of bowel segments, including the jejunum, proximal ileum, distal ileum, right part colon, left part colon, hepatic flexure of colon, splenic flexure of colon, and rectosigmoid colon, were assessed by two experienced radiologists.

The secondary outcome measures included the following: (1) the diagnostic accuracy rate, including sensitivity (ability to correctly identify the presence of the disease) and specificity (ability to correctly identify the absence of the disease), through MRE confirmed by colonoscopy among five segments: the terminal ileum, ileocecal junction, hepatic flexure of colon, splenic flexure of colon, and rectosigmoid colon. The colonoscopy results were evaluated by two experienced endoscopists. One endoscopist assessed the findings in real time during the colonoscopy procedure, while the other evaluated the results by thoroughly examining the post-procedure report; (2) the correlation of MRE activity grade[19] and Harvey–Bradshaw index (HBI); (3) mental stress before bowel preparation using a visual 5-grade scale (1 denotes no stress at all and 5 denotes very severe stress); and (4) patients' preference for the method of bowel preparation.

Other outcome measures included the following: (1) the complete rate and diagnostic accuracy of fistula between MRE and colonoscopy. The complete rate of colonoscopy was defined as the cecal intubation rate; (2) risk factors for adverse symptoms. We divided all subjects into a group with

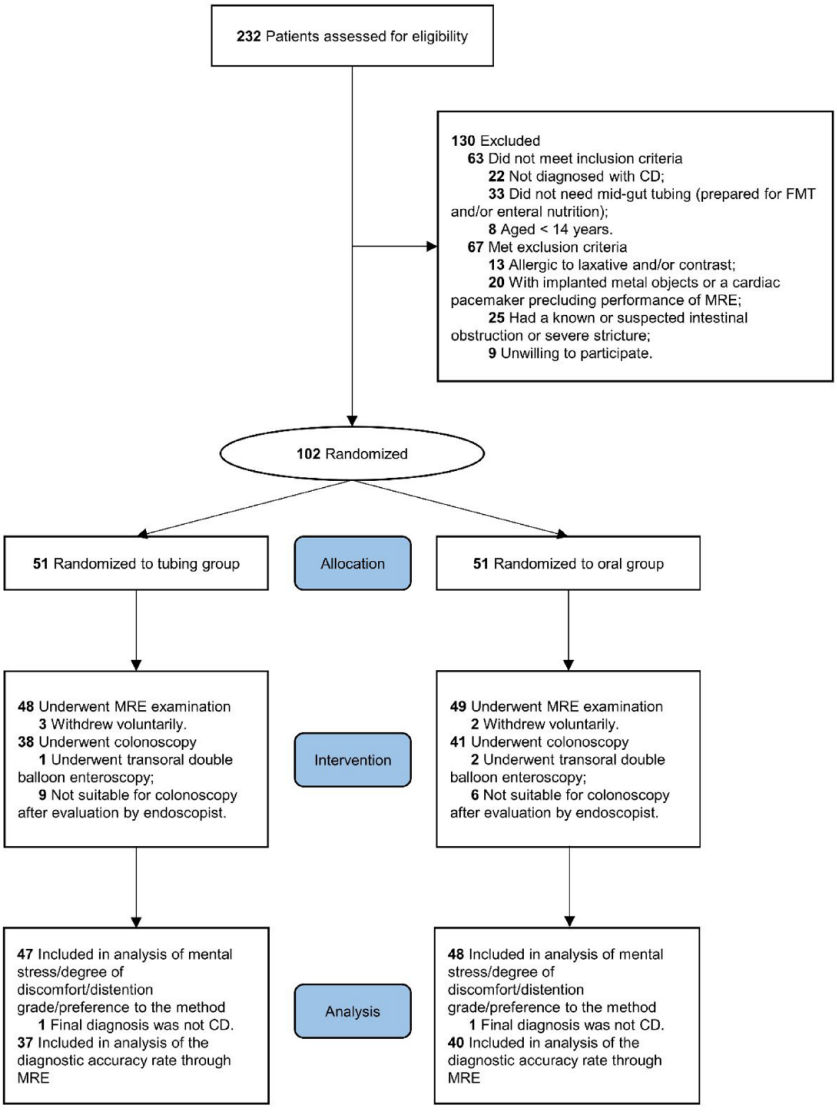

Figure 1. CONSORT diagram.
CD, Crohn's disease; FMT, fecal microbiota transplantation; MRE, magnetic resonance enterography.

adverse symptoms (⩾2 grade) and a group without adverse symptoms (=1 grade), and performed univariate and multivariate analyses to explore risk factors for each adverse symptom.

Information on demographic characteristics, medical history, and pertinent clinical conditions was collected at the screening visit. The day after the MRE examination was finished, the included patients were instructed to answer a questionnaire about their mental stress, preference for the method, and discomfort (such as nausea, vomiting, bloating, abdominal pain, and diarrhea) before/during/after the bowel preparation for MRE.

Statistical analysis

The description of the sample by group was conducted using statistics such as the means and standard deviations or medians and interquartile ranges for the quantitative variables and frequencies and percentages for the qualitative variables. For comparisons between groups at baseline and outcomes, *t* tests or Mann–Whitney *U* tests were used for continuous variables, depending on normality, and Chi-square tests or Fisher's tests were used for categorical variables. The correlation between MRE activity grade and HBI was analyzed using linear regression. Univariate analyses and stepwise logistic regression analyses were

used to explore risk factors for each adverse symptom. All statistical analyses were performed using SPSS software (version 26.0; SPSS Inc., Chicago, IL, USA). A two-sided p significance was set at $p < 0.05$. All analyses for the primary and prespecified secondary outcomes were performed masked to allocation and prior to breaking the study blind.

Results

Patient flow and baseline characteristics

Of 232 patients screened, 102 met eligibility requirements and underwent randomization, 51 to the tubing group and 51 to the oral group (Figure 1). After randomization, three patients in the tubing group and two in the oral group withdrew voluntarily from the study. Eighteen patients did not undergo colonoscopy, of whom 3 patients underwent transoral double-balloon enteroscopy, after evaluation by the endoscopist. The final diagnoses of two patients were not CD. The baseline characteristics of the patients were comparable among the groups (Table 1).

Primary outcomes

A total of 95 CD patients (47 in the tubing group and 48 in the oral group) underwent MRE examination. During bowel cleaning, the degrees of nausea, vomiting, and bloating in the tubing group were significantly lower than those in the oral group ($p < 0.001$, $p = 0.020$, $p = 0.012$; Figure 2(a)). Subjects in the tubing group complained of less vomiting during bowel distention than those in the oral group ($p = 0.017$; Figure 2(a)). No significant difference in the degree of discomfort was observed after bowel preparation between the two groups (Figure 2(a)). Patients reported a higher degree of nausea during bowel cleaning than that during bowel distention ($p = 0.012$; Supplemental Figure 2).

Among the five bowel segments (i.e., jejunum, proximal ileum, distal ileum, right part colon, and left part colon), the distention grade of the right part colon ranked the highest, followed by the distal ileum and the left part colon (Figure 2(b)). The distention quality of the jejunum and proximal ileum was relatively poor. While no significant difference was observed in the distention grade of the five bowel segments, including the right and left parts of the colon, between the tubing group and oral group, it is noteworthy that the distention grade was higher in the tubing group compared to the oral group in the splenic flexure of the colon and rectosigmoid colon (Figure 2(c)).

Secondary outcomes

Colonoscopy or transanal double-balloon enteroscopy was performed in 77 CD patients, but cecal intubations were not achieved in 3 of them due to severe stricture or intestinal adhesions (Supplemental Table 1). The tubing group demonstrated a higher overall diagnostic sensitivity in ulcers compared to the oral group ($p = 0.048$; Table 2). However, no significant difference was observed in the overall diagnostic sensitivity for pseudopolyps and strictures, as well as the overall diagnostic specificity between the two groups. On the segment level, the sensitivity for detecting ulcers in the splenic flexure of the colon was higher in the tubing group compared to the oral group. Furthermore, the tubing group exhibited a higher diagnostic specificity in the hepatic flexure of the colon compared to the oral group. Notably, in patients with moderate MRE activity, bowel preparation through TET improved the diagnostic sensitivity for detecting ulcers.

No significant difference in MRE activity grade was observed between the tubing group and the oral group (Figure 3(a)). Additionally, there was no significant correlation between MRE activity grade and the HBI ($p = 0.074$; Figure 3(b)). Compared to orally administering bowel preparation, the application of mid-gut TET reduced the mental stress of patients before bowel preparation ($p = 0.020$; Figure 4(a)). Furthermore, when patients were asked to choose between tubing or the oral method of bowel preparation, a higher number of individuals in the tubing group expressed a preference for the tubing method compared to those in the oral group who preferred the oral method (97.87% vs 56.25%, $p < 0.001$; Figure 4(b)).

MRE versus colonoscopy

Among 77 patients who underwent both MRE examination and colonoscopy, the complete rate of MRE examination was 100%, while the complete rate of colonoscopy was 96.10% (Figure 4(c)). A total of 39 fistulas attributed to CD were

Table 1. Baseline demographics and clinical characteristics of the study subjects.

Variable	Tubing group ($n=47$)	Oral group ($n=48$)	p Value
Age (years), mean (SD)	33.00 (11.77)	34.35 (12.76)	0.592
Female, *n* (%)	14 (29.79)	10 (20.83)	0.315
Body mass index (kg/m^2), mean (SD)	19.14 (3.28)	19.78 (2.26)	0.155
Disease duration (years), mean (SD)	6.86 (4.93)	5.87 (4.21)	0.295
Harvey–Bradshaw index, mean (SD)	4.64 (2.75)	4.08 (2.49)	0.305
Age at diagnosis, *n* (%)			
A1 (age $<$ 17 years)	8 (17.02)	3 (6.25)	0.101
A2 (age between 17 and 40 years)	36 (76.60)	38 (79.17)	0.763
A3 (age $>$ 40 years)	3 (6.38)	7 (15.58)	0.333
Location, *n* (%)			
L1 (ileal)	14 (29.79)	9 (18.75)	0.209
L2 (colonic)	2 (4.26)	4 (8.33)	0.693
L3 (ileocolonic)	30 (63.83)	36 (75.00)	0.237
L4 (upper gastrointestinal tract) $\pm$ (L1–L3)	4 (8.51)	5 (10.42)	1.000
Behavior, *n* (%)			
B1 (non-stricturing, non-penetrating)	7 (14.89)	7 (14.58)	0.966
B2 (stricturing)	33 (70.21)	32 (66.67)	0.710
B3 (penetrating)	14 (29.79)	23 (47.92)	0.070
Perianal disease	15 (31.91)	17 (35.42)	0.718
Current medication, *n* (%)			
None	11 (23.40)	10 (20.83)	0.763
Mesalazine	20 (42.55)	24 (50.00)	0.467
Systematic corticosteroids	2 (4.26)	4 (8.33)	0.693
Immunomodulator	16 (34.04)	16 (33.33)	0.942
Anti-tumor necrosis factor	1 (2.13)	4 (8.33)	0.371
Previous Crohn's disease-related surgery, *n* (%)	17 (36.17)	16 (33.33)	0.772
Number of bowel preparation experiences, mean (SD)	3.79 (1.52)	3.63 (1.77)	0.633

SD, standard deviation.

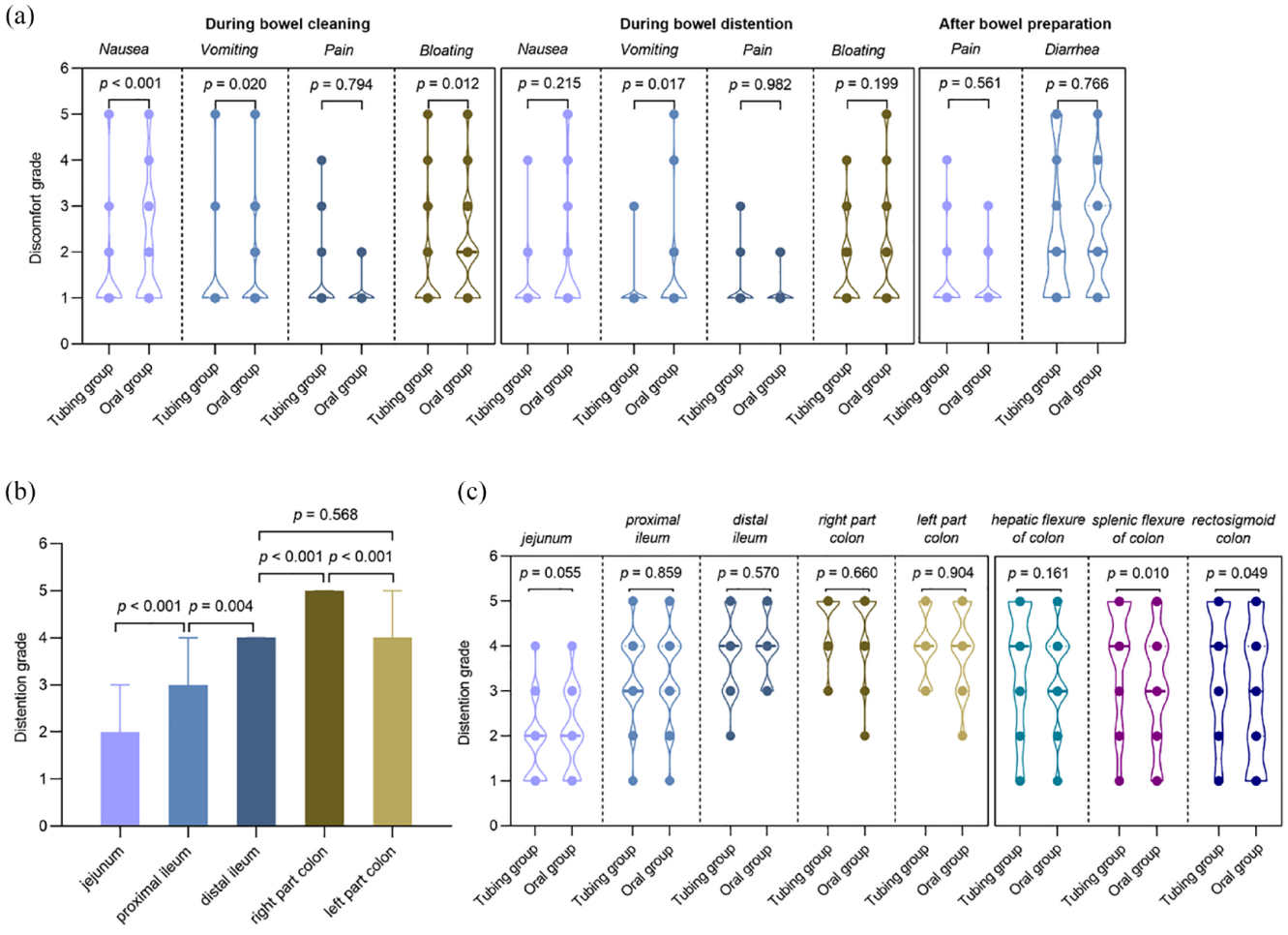

Figure 2. (a) Degree of discomfort before/during/after bowel preparation using a visual 5-grade scale (1 = none, 2 = very mild, 3 = mild, 4 = moderate, and 5 = severe) between the tubing group and the oral group. (b) Grade of bowel distention among five bowel segments during MRE examination using a 5-grade scale (1 = 0%–20% segmental distention, 2 = 20%–40% distention, 3 = 40%–60% distention, 4 = 60%–80% distention, 5 = 80%–100% distention). (c) Grade of bowel distention between the tubing and oral group using a 5-grade scale.
MRE, magnetic resonance enterography.

Table 2. The diagnostic accuracy rate through MRE confirmed by colonoscopy.

Diagnostic accuracy	Sensitivity									Specificity		
	Ulcers			Pseudopolyps			Strictures					
	Tubing group	Oral group	*p* Value	Tubing group	Oral group	*p* Value	Tubing group	Oral group	*p* Value	Tubing group	Oral group	*p* Value
Overall	83.33%	65.00%	0.048	78.95%	81.40%	1.000	70.83%	100.00%	0.071	79.49%	67.11%	0.120
Position												
Terminal ileum	88.24%	93.33%	1.000	100.00%	71.43%	0.470	85.71%	100.00%	1.000	28.57%	33.33%	1.000
Ileocecal junction	77.78%	92.31%	0.544	75.00%	86.67%	0.628	50.00%	100.00%	0.077	72.73%	62.50%	1.000
Hepatic flexure of colon	75.00%	50.00%	0.380	87.50%	87.50%	1.000	66.67%	100.00%	1.000	100.00%	72.22%	0.017

(Continued)

Table 2. (Continued)

Diagnostic accuracy	Sensitivity									Specificity		
	Ulcers			Pseudopolyps			Strictures					
	Tubing group	Oral group	*p* Value	Tubing group	Oral group	*p* Value	Tubing group	Oral group	*p* Value	Tubing group	Oral group	*p* Value
Splenic flexure of colon	87.50%	37.50%	0.020	50.00%	83.33%	0.546	100.00%	100.00%	1.000	90.48%	80.95%	0.663
Rectosigmoid colon	83.33%	42.86%	0.266	85.71%	71.43%	1.000	66.67%	100.00%	1.000	68.42%	65.00%	1.000
MRE activity grade												
Mild	100.00%	66.67%	1.000	60.00%	–	–	–	–	–	85.71%	46.15%	0.158
Moderate	88.24%	45.45%	0.008	75.00%	50.00%	0.234	100.00%	100.00%	1.000	82.76%	66.67%	0.327
Severe	78.57%	78.13%	1.000	87.50%	90.91%	1.000	69.57%	100.00%	0.075	71.43%	70.27%	1.000

MRE, magnetic resonance enterography.

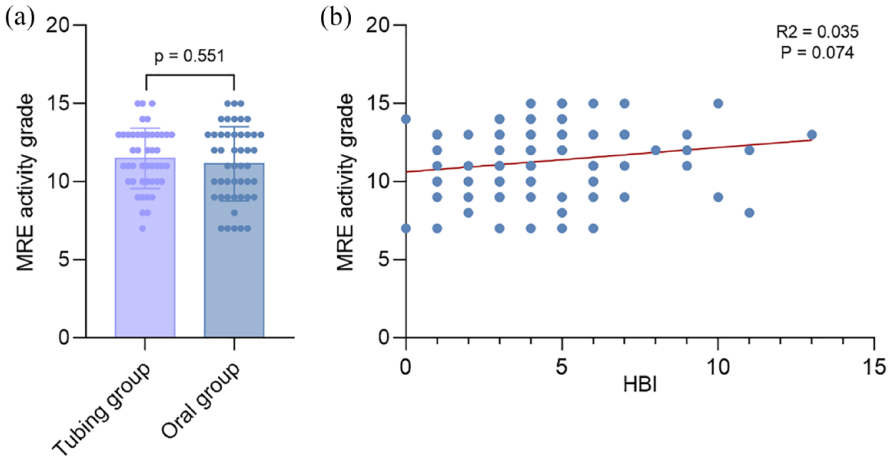

Figure 3. (a) MRE activity grade between tubing group and oral group. (b) The correlation between MRE activity grade and HBI.
HBI, Harvey–Bradshaw index; MRE, magnetic resonance enterography.

discovered (Figure 4(d)). MRE identified 36 of them while colonoscopy identified only 10 ($p = 0.013$).

Risk factors for adverse symptoms

Univariate analyses of factors potentially associated with each adverse symptom are summarized in Supplemental Table 2. Five independent factors (bowel preparation after mid-gut tubing, mental stress (grade = 1), weight, height, and body mass index (BMI)) were negatively associated with adverse symptoms during bowel preparation, while the HBI and colonic CD were positive risk factors that were independently associated with adverse symptoms after bowel preparation (Figure 5).

Discussion

This was an RCT to compare patients' compliance and experience as well as the efficacy of

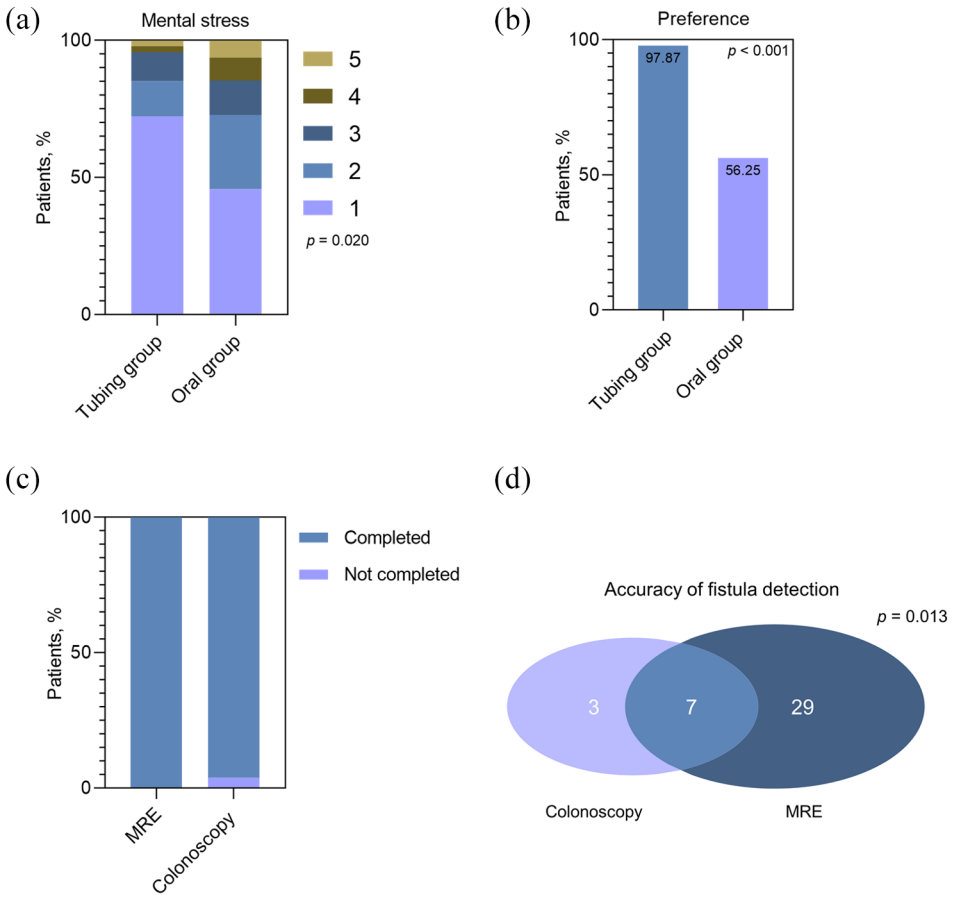

Figure 4. (a) Mental stress of patients between the tubing and oral groups using a visual 5-grade scale (1 denotes no stress at all and 5 denotes very severe stress). (b) Preference for the method of bowel preparation between the tubing and oral groups. (c) Complete rate of MRE examination was 100%, while complete rate of colonoscopy, defined as cecal intubation rate, was 96.10%. (d) Detection accuracy of fistula between MRE and colonoscopy.
MRE, magnetic resonance enterography.

bowel preparation for MRE through administering contrast solution after mid-gut tubing or orally in CD. Our data showed that compared with oral ingestion, bowel preparation via mid-gut TET could not only relieve the adverse symptoms and alleviate the mental stress of patients, but also significantly improve the overall diagnostic sensitivity in ulcers through MRE.

It has long been discussed in the literature whether the administration of contrast solution after mid-gut tubing is preferable to taking contrast solution orally.[11–13,20] MRE after conventional nasojejunal tubing, referred to as magnetic resonance enteroclysis in the past, is frequently considered a stressful, costly, and time-consuming procedure.[21,22] Another disadvantage of magnetic resonance enteroclysis is that it involves the use of radiation during the intubation procedure, thus increasing the radiation burden on patients.[22] In our study, we used a novel, convenient, and safe procedure technique of enteral tubing, named mid-gut TET, under gastroscopy. As reported, the success rate of the procedure was 98.8% (85/86) and 97.7% (84/86) of patients tolerated and were satisfied with the procedure.[14] Additionally, 10 cases of procedure were enough for training of general endoscopist to shorten the procedure time (7.0 vs 4.0 min, $p < 0.05$).[14] In this study, the mid-gut TET tube could serve as the delivery method of FMT, enteral nutrition, and laxative agents and contrast solution for MRE bowel preparation. The disadvantages of TET insertion also exist, such

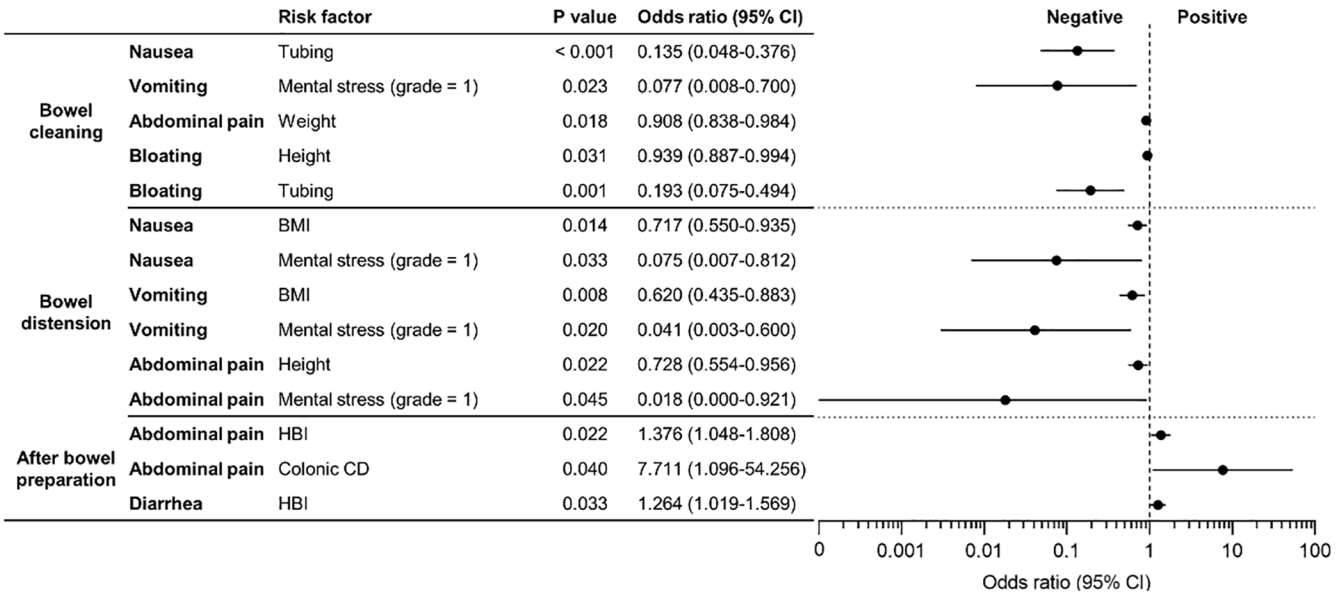

Figure 5. Independent risk factors for adverse symptoms.
BMI, body mass index; CD, Crohn's disease; CI, confidence interval; HBI, Harvey–Bradshaw index.

as anesthetic risks. However, in this trial, patients in both groups faced the same level of risks and potential complications.

Bowel cleaning in this trial might be helpful in detecting lesions for MRE, especially in the colon, and is essential for successful colonoscopy screening.[9,23] According to Miles et al.[24]'s study, the worst part of the MRE scan was drinking enteric contrast beforehand and the associated side effects such as diarrhea, abdominal pain, and bloating. In our study, the protocol of bowel preparation through the mid-gut tube enabled patients to ingest laxative agents and contrast compounds at a constant infusion rate of 25 mL/min, lower than the general infusion rate of 80–150 mL/min,[12] which might explain the relatively milder adverse symptoms during both the procedure of bowel cleaning and bowel distention. We also found that patients complained of a lower degree of nausea during bowel distention than that during bowel cleaning. One possible explanation for this could be that the taste of PEG was perceived as poorer compared to that of mannitol, and the volume of the PEG solution (2000 mL) was larger than that of the mannitol solution (1500 mL).

In fact, few studies comparing MRE per os and magnetic resonance enteroclysis have demonstrated a tendency to obtain better small-bowel distention via magnetic resonance enteroclysis.[11,12] However, our study did not support this view. Better distention quality was found in the colon and distal ileum than in other bowel segments. In addition, it is noteworthy that the distention grade was higher in the tubing group compared to the oral group specifically in the splenic flexure of the colon and rectosigmoid colon. The likely explanation could be that the slot from ingesting mannitol to performing the MRE examination was long enough that mannitol mostly filled the lower digestive tract. For patients with CD whose lesion was suspected or established in the small intestine, it might be better to drink or infuse mannitol later before MRE. Future research needs to discuss the optimal timepoint of bowel distention before MRE to achieve the best results for CD patients with lesions located at different sites.

We found that the tubing group demonstrated a higher overall diagnostic sensitivity in ulcers compared to the oral group. On the segment level, the tubing group exhibited a higher diagnostic specificity in the hepatic flexure of the colon and higher sensitivity for detecting ulcers in the splenic flexure of the colon compared to the oral group. Notably, in patients with moderate MRE activity, bowel preparation through TET improved the diagnostic sensitivity for detecting ulcers. Higher

bowel distention could explain higher sensitivity for detecting ulcers in the splenic flexure of the colon in the tubing group. While intestinal filling is a crucial factor affecting the detection rate of lesions during MRE, several other factors, such as patient motion, bowel preparation, and patient characteristics, can also impact the quality and accuracy of MRE results. We recognized the significance of considering the role of bowel cleaning when interpreting the higher specificity observed in the hepatic flexure of the colon in the tubing group. Unlike the previous studies that compared the diagnostic value of MRE confined to the terminal ileum,[11,13] our trial included five lesion sites of the colon and terminal ileum, which made the results more comprehensive. In addition, we used the results of colonoscopy as the gold standard to evaluate the consistency rate of MRE detection. We hope this could help make the evaluation of lesions detected by MRE more rigorous. In fact, the diagnostic accuracy could be made on correlating validated MRE and colonoscopy scoring system. We utilized MRE activity grade[19] to evaluate CD activity and have explored its correlation with HBI. Our findings indicated a lack of correlation between MRE activity grade and HBI. In this trial, we did not utilize endoscopic scores such as Simple Endoscopic Score for Crohn's Disease (SES-CD) as an outcome measure, as it was not initially included in our protocol, which was a limitation of this study.

Patient experience would impact compliance and acceptability, thus influencing the utility of MRE. After being informed that laxative agents and contrast solution were infused via the TET tube, the patients' mental stress was relieved significantly. In addition, bowel preparation via mid-gut TET was more acceptable than oral administration. Our data suggested that intubating the TET tube ahead of bowel preparation and applying it in infusing laxative agents and contrast solution could enhance their compliance and acceptability, thus increasing the utility of MRE examination.

High mental stress, low weight, low height, low BMI, high HBI, and colonic CD were independent risk factors for adverse symptoms during bowel preparation in patients with CD in the present study. This new finding could prove clinically relevant and could be useful for a priori identification of patients who would benefit from bowel preparation after mid-gut TET. However, this finding needs to be validated in other patient cohorts in the future.

In this trial, MRE examination had an obvious advantage in detecting fistulas. Our study indicated that MRE could be the first choice for CD patients complicated with lumen stenosis that endoscopy could not get through, or those with suspected fistula. However, in most cases, incorporating both MRE and colonoscopy is probably the best choice for assessing and monitoring the disease activity of CD.[25]

There are several limitations to the present study. First, the study population was patients with CD in need of mid-gut tubing because we did not want to increase the additional economic and psychological burden of patients. A future comparison can be made in patients who did not need a mid-gut tube but need to have one inserted purely for MRE in terms of the associated risk, costs, and scheduling impact. Second, not all randomized patients completed the outcome assessments, although our dropout was low (7/102). Third, the methods of bowel preparation were open-label because of practical barriers to masking. Possible influences on study outcomes are unclear, although compliance and completion rates were similar between the two groups.

In conclusion, administering contrast solution after mid-gut tubing is superior to taking contrast solution orally in terms of enhancing the efficacy through MRE and the compliance of patients with CD. Mid-gut tube-based bowel preparation could therefore be recommended for patients needing MRE who: (1) have already been inserted with a mid-gut tube, or (2) have difficulty in drinking laxative agents and/or contrast solution, or (3) require mid-gut delivery of enteral nutrition/drug/food. These findings may also translate to other diseases that need MRE examination and other luminal investigations requiring bowel preparation, such as computed tomographic enterography.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the principles of the Declaration of Helsinki, and the

protocol was approved by the institutional review board of the Second Affiliated Hospital of Nanjing Medical University and Jiangnan University Medical Center with the reference ID: 2017-IIT-003-LP-01. Written informed consent to participate was obtained from all participants.

Consent for publication

We have obtained written informed consent to publish from all participants but the written consent itself should be held in the patient's hospital record.

Author contributions

Yun Wang: Investigation; Project administration; Validation; Visualization; Writing – original draft.

Min Dai: Conceptualization; Funding acquisition; Methodology; Project administration; Writing – review & editing.

Minghui Zheng: Data curation; Methodology; Validation; Writing – review & editing.

Yan Jin: Methodology; Project administration; Resources; Supervision; Writing – review & editing.

Quan Wen: Project administration; Writing – review & editing.

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Competing interests

F.Z. conceived the concept of GenFMTer, transendoscopic enteral tubing, and related devices. Other authors declare that they have no conflict of interest.

Availability of data and materials

The data are available upon reasonable request to the corresponding author (Prof. Faming Zhang).

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Supplemental material

Supplemental material for this article is available online.

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