RESEARCH

Comparing the bowel cleansing efficacy between sodium picosulfate vs. 2L polyethylene glycol electrolyte lavage solution for colonoscopy: a prospective observational study

Jing Shan[1*†], Yang Su[1,2†], Dan Luo[1,2], Lin Jiang[1], Chen Zhang[1], Yifeng Liu[1] and Xiaobin Sun[1]

Abstract

Background This study aimed to compare the bowel cleansing efficacy, adverse reactions, and patient compliance of two low-volume bowel preparation regimens, sodium picosulfate (PICO) and 2 L polyethylene glycol electrolyte lavage solution (2 L PEG-ELS).

Methods This single-center, prospective observational trial was conducted at the Gastrointestinal Endoscopy Center of The Third People's Hospital of Chengdu between May and October 2023. Patients undergoing colonoscopy were enrolled, with the primary outcome being the rate of adequate bowel cleansing, as assessed by the Boston Bowel Preparation Scale (BBPS) with three segments scoring ≥ 2. Secondary outcomes included polyp detection rate, adverse reactions, patient compliance, and the BBPS total and segment scores.

Results A total of 5423 patients were included, divided into the PICO group ($n = 739$) and the 2 L PEG-ELS group ($n = 4684$) based on the bowel preparation regimen they chose. There were no statistically significant differences between the PICO and 2 L PEG-ELS groups in adequate bowel cleansing rate (92.2% vs. 91.3%, $P = 0.437$) and polyp detection rate (42.2% vs. 45.5%, $P = 0.096$). However, the PICO group achieved a better performance in the BBPS scores of the total [(6.90 ± 1.19) vs. (6.81 ± 1.14), $P = 0.016$] and the right colon [(2.15 ± 0.53) vs. (2.11 ± 0.51), $P = 0.005$] compared to the 2 L PEG-ELS group. In terms of adverse reactions, the 2 L PEG-ELS group reported more nausea (11.7% vs. 5.7%, $P < 0.001$) and the PICO group reported more sleep disturbances (24.5% vs. 14.6%, $P < 0.001$), but the willingness to repeat the procedure with the same regimen was similar high in the 2 L PEG-ELS and PICO groups (99% vs. 99.2%, $P = 0.588$).

Conclusion In this prospective observational study, both PICO and 2 L PEG-ELS are safe and effective options for bowel cleansing in the Chinese population.

---

†Jing Shan and Yang Su contributed equally to this work.

*Correspondence:
Jing Shan
tulip-sj@163.com

Full list of author information is available at the end of the article

Background

Colorectal cancer (CRC) is a common malignant tumor of the gastrointestinal tract, ranking as the third leading cause of cancer-related deaths in China [1] and the second in the USA [2]. Colonoscopy is the preferred method for screening, diagnosing, and treating early colorectal cancer and precancerous lesions such as colorectal adenomas. Colonoscopy reduces CRC morbidity and mortality by 40% and 50% in U.S., respectively [3, 4]. However, adequate bowel preparation is the basis for a high-quality colonoscopy. Bowel cleansing is significantly associated with colorectal adenoma detection rate and polyp detection rate [5]. Inadequate bowel preparation will reduce the safety and efficacy of colonoscopy, resulting in a decreased cecal intubation rate and a adenoma miss rate of up to 47.9% [6, 7]. Studies have shown that the quality of bowel preparation is largely dependent on patient compliance, bowel preparation agent, and dose of medicine. Currently, there are numerous medicines available for bowel preparation, but they vary in volume, flavour, patient tolerability and dose of medicine.

Polyethylene glycol electrolyte lavage solution (PEG-ELS), as a osmotic laxative, cleanses the intestinal tract through oral intake of large amounts of liquid without affecting bowel absorption and secretion, and is the most widely used bowel cleansing agent in clinical practice today. The application of PEG-ELS differs across various regions. Specifically, PEG 4000 is predominantly used in China [8], whereas PEG 3350 in Europe and the USA [9], and there is no comparative research focusing on these two different types of PEG. Currently, Europe and the United States [10] recommend high-dose 4 L PEG-ELS regimen for good bowel cleansing effect. However, this regimen involves taking a large volume of fluid and poorly tolerated by patients, with approximately 33% of patients [11] unable to complete the bowel preparation at the prescribed dose, resulting in missed lesions. A randomized study in China demonstrated that 2 L PEG-ELS has a similar adequate bowel cleaning rate (88.1% vs. 87%), but less adverse event (22.5% vs. 42.2%) compared to 4 L PEG-ELS in population at low risk for inadequate bowel preparations [12]. So the guideline of China still recommend 2 L PEG-ELS for Chinese people [13]. However, the relatively large amount of oral liquid of the 2 L PEG-ELS with salty and bitter taste were still difficult to accept for some patients.

In recent years, a new low-volume bowel cleansing agent, sodium picosulfate (PICO), is newly marketed in China. PICO utilizes its dual laxative mechanisms to efficiently eliminate bowel fecal sludge and bubbles by softening the stool and stimulating colon peristalsis [14]. PICO relies on sulphate ions to provide osmolality and sodium supplementation to reduce the risk of electrolyte disorders. A large number of studies have shown that PICO not only improves bowel cleansing but also has better tolerability and palatability and a higher willingness to repeat by patients [15–17]. Till now, there have been several studies comparing PICO with 2 L PEG plus adjuvate, such as ascorbic acid [18] and bisacodyl [19], which showed no superiority in bowel cleaning efficacy but better tolerability. However there is a lack of comparison between PICO with 2 L PEG-ELS. Therefore, we conducted a prospective observational study to compare the effectiveness of bowel preparation between PICO and 2 L PEG-ELS, aiming to provide additional data to inform the choice of bowel preparation regimens for clinical use.

Methods

Study design

This study was a single-center prospective observational trial. Data were collected from patients who underwent colonoscopy with bowel preparation using either the PICO or 2 L PEG-ELS regimen between May 2023 and October 2023 at the Third People's Hospital of Chengdu, Sichuan Province, China. Doctors will inform the patient of the dosage and cost of each regimen, and the patient will choose the regimen by themselves. The study was approved by the Ethics Committee of the Third People's Hospital of Chengdu (2024-S-46), and written informed consent was obtained from all participants. Inclusion criteria required that the colonoscopy reached the cecum with a complete Boston Bowel Preparation Scale (BBPS) score. Exclusion criteria included failure to complete the colonoscopy due to difficulty in bowel intubation, absence of a complete BBPS score, and patients who had undergone bowel resection with anastomosis.

Patients and two bowel cleansing regimens

All patients received pre-colonoscopy education through verbal instructions and a WeChat applet. They were directed to consume a low-residue diet such as porridge, noodles, bread, and avoid eating vegetables and meat the day before the procedure. Patients in the PICO group were instructed to take two sachets of compounded sodium picosulfate (PICO) as a split dose. Each sachet contained 10 mg of sodium picosulfate, 3.5 g of magnesium oxide, and 12.0 g of citric acid, dissolved in 150 mL of cold water. The first sachet, mixed with 1500 mL of clear fluids, was consumed at 5:00 PM on the day before the procedure. The second sachet, with 750 mL of

Shan *et al. BMC Gastroenterology*   (2025) 25:164

Page 3 of 9

clear fluids, was taken four hours before the procedure. Dimethyl silicone oil can eliminate foam in the colon in order to improve the clarity of colonoscopy and increase the polyp detection rate [20, 21]. 5 g dimethyl silicone oil was added to 50 ml water to form a solution and taken after the final dose of the bowel cleansing agent.

Patients in the 2 L PEG-ELS group were instructed to prepare a solution using two boxes of polyethylene glycol electrolyte powder (trade name: Hengkang Zhengqing) dissolved in 2000 mL of water. Each box contained a total of three packets: packet A (0.74 g of potassium chloride and 1.68 g of sodium bicarbonate), packet B (1.46 g of sodium chloride and 5.68 g of sodium sulfate), and packet C (60 g of PEG 4000), produced by Jiangxi Hengkang Pharmaceutical Co., Ltd. PEG-ELS refers to the polyethylene glycol electrolyte lavage solution formed by dissolving PEG 4000 and electrolyte powder in water. The solution was taken in doses starting with 600 mL at 8:00 PM on the day before the procedure, followed by 200 mL every 10–15 min until 1000 mL finished. The same preparation was repeated four hours before the procedure on the following day, using the same dosing regimen. Dimethyl silicone oil was taken after the final dose of the bowel cleansing agent.

All patients were asked to complete a questionnaire before (while waiting, about half an hour) the colonoscopy, with informed consent obtained prior to participation. The patient questionnaire asked age, height, weight; Did you take the dimethyl silicone oil (Yes or No); What did you eat the day before the procedure; Did you difficulty falling asleep or sleep disruption from taking the bowel cleaning agent (Yes or No); Would you choose the same bowel preparation regimen again (Yes or No); Would you had family history of colon cancer (Yes or No); Would you had the bowel preparation-related adverse reactions (Nausea, vomiting, abdominal discomfort, others or No); What was your indications for colonoscopy (Screening, symptom, recheck, others); When was the time of the first defecation for you (< 1 h, 1–2 h, >2 h); Would you had the risk factors that might affect bowel preparation (Including a history of abdominal surgery, diabetes, Parkinson's disease, liver cirrhosis, constipation, use of tricyclic antidepressants, and physical impairment).

Observation indicators

The primary outcome was the adequate bowel cleansing rate between the two groups as assessed by the BBPS with three segments scoring ≥ 2. Colonoscopies were performed by experienced endoscopists who assessed bowel preparation using the BBPS, a validated and widely used measure of bowel cleansing, immediately after the procedure. Before we started this data collection, we trained all endoscopists on BBPS. All endoscopists were trained

to achieve homogeneity in the assessment of primary outcome indicators by learning the BBPS scoring criteria together and selecting endoscopic pictures (about 50 pictures) with different levels of BBPS scoring to be read together. The colon was divided into three segments (left colon, transverse colon, and right colon), each scored separately. Each section is scored on a scale of 0 to 3 based on cleanliness after cleaning maneuvers were completed. The definition for each score is: 0 = Unprepared colon segment with mucosa not seen due to solid stool that cannot be cleared. 1 = Portion of mucosa of the colon segment seen, but other areas of the colon segment not well seen due to staining, residual stool and/or opaque liquid. 2 = Minor amount of residual staining, small fragments of stool and/or opaque liquid, but mucosa of colon segment seen well. 3 = Entire mucosa of colon segment seen well with no residual staining, small fragments of stool or opaque liquid. This was evaluated during the withdrawal phase, after sufficient washing and suctioning. Three segments scoring ≥ 2 was considered indicative of adequate bowel preparation [22].

Secondary outcomes included the polyp detection rate, adverse reactions, patient compliance, and the BBPS total and segment scores. Bubble can affect the bowel observation, and the bowel air bubble score can help us to better assess the bowel preparation. The bowel air bubble score was categorized into four levels according to its impact on mucosal visibility: 0 (< 5%, Complete absence of bubbles and clear vision); 1 (5-25%, A sparse concentration of bubbles); 2 (25-50%, A moderate number of bubbles); 3 (> 50%, A significant number of bubbles that take up most of the endoscopic field of view) [21, 23, 24]. The polyp detection rate (PDR) was determined by the endoscopist during the procedure, with the lesion detection rate calculated as the percentage of patients in the study population who had at least one polyp detected. About adverse reactions, when patients come for a colonoscopy, we will ask them if they have any discomfort while taking purgatives (such as nausea, vomiting, abdominal discomfort, etc.). About patient compliance, we judged whether patients were taking purgatives correctly as required, whether they were following a low-residue diet requirements before the colonoscopy and whether they were taking dimethylsilicone oil as required.

Statistical analysis

All data analyses were performed using SPSS 25.0 (IBM Corporation, USA). Continuous variables were presented as mean ± standard deviation. Student's t-tests were applied for data conforming to a normal distribution, while Mann-Whitney tests were used for non-normally distributed data. Categorical variables were expressed as frequencies or percentages and analyzed using Pearson's χ^2 tests or Fisher's exact tests. Data were excluded

Shan *et al. BMC Gastroenterology*   (2025) 25:164

Page 4 of 9

if baseline records were incomplete or if patients chose to discontinue the study. A significance level of $\alpha = 0.05$ was used, with a two-sided P value < 0.05 considered statistically significant.

Results

Baseline characteristics of patients in the two groups
As shown in Fig. 1, a total of 5561 patients underwent colonoscopy, excluding 106 patients meeting the exclusion criteria and 32 patients with incomplete information, a total of 5423 patients were enrolled in the study finally, with 739 in the PICO group and 4684 in the 2 L PEG-ELS group. As shown in Table 1, the statistically significant differences between the baseline characteristics of the PICO and 2 L PEG-ELS groups were the mean age [(48.90 ± 13.74) vs. (53.02 ± 14.27), $P < 0.001$], indications for colonoscopy (symptom) (39.1% vs. 34.6%, $P = 0.017$),

history of diabetes (2.2% vs. 4.6%, $P = 0.002$), and history of abdominal surgery (31.9% vs. 20.7%, $P < 0.001$). And there was no statistically significant difference in the proportion of low-risk populations between the PICO and 2 L PEG-ELS groups (46.0% vs. 45.0%, $P = 0.595$).

Bowel cleansing effect
As shown in Table 2, there were no statistically significant difference in adequate bowel cleansing rate (92.2% vs. 91.3%,,$P = 0.437$) and the polyp detection rate (42.2% vs. 45.5%, $P = 0.096$) between the PICO and the 2 L PEG-ELS groups. However, the PICO group achieved a better performance in the BBPS scores of the total [(6.90 ± 1.19) vs. (6.81 ± 1.14), $P = 0.016$] and the right colon [(2.15 ± 0.53) vs. (2.11 ± 0.51), $P = 0.005$] compared to the 2 L PEG-ELS group. Notably, the time of the first defecation (> 2 h)
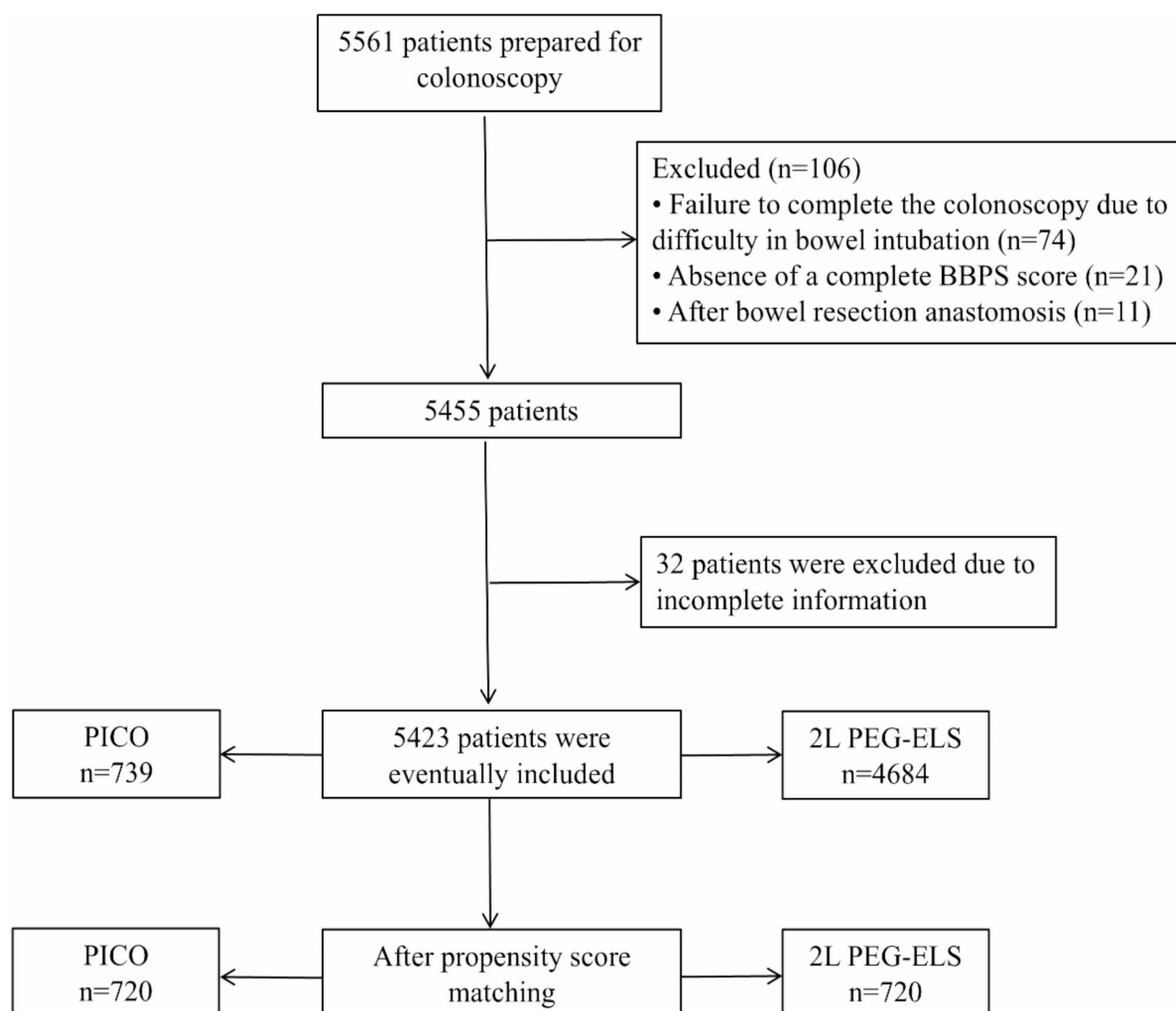

Fig. 1 Flow diagram of patients enrolled

Shan *et al. BMC Gastroenterology*   (2025) 25:164

Page 5 of 9

Table 1 Baseline data of patients

Baseline characteristics	PICO	2 L PEG-ELS	P value
n	739	4684	
Age (Mean ± SD, years)	48.90 ± 13.74	53.02 ± 14.27	< 0.001
Male gender (n, %)	340 (46.0)	2241 (47.8)	0.353
BMI (Mean ± SD, kg/m^2)	22.88 ± 3.09	23.17 ± 3.36	0.076
Family history of colon Cancer (n, %)	39 (5.3)	311 (6.6)	0.161
Indications for colonoscopy (n, %)			
Screening	180 (24.4)	1234 (26.3)	0.253
Symptom	289 (39.1)	1621 (34.6)	0.017
Recheck	130 (17.6)	929 (19.8)	0.153
Others	140 (18.9)	900 (19.2)	0.863
Dimethyl silicone oil use (n, %)	670 (90.7)	4226 (90.2)	0.707
Low-residue diet before procedure (n, %)	680 (92.0)	4221 (90.1)	0.103
Risk factors of suboptimal bowel preparation			
History of diabetes (n, %)	16 (2.2)	216 (4.6)	0.002
History of abdominal Surgery (n, %)	236 (31.9)	968 (20.7)	< 0.001
Liver cirrhosis (n, %)	0 (0)	6 (0.1)	0.705
Parkinson's disease (n, %)	0 (0)	1 (0)	1.000
Constipation (n, %)	0 (0)	18 (0.4)	0.179
Tricyclic antidepressents use (n, %)	1 (0.1)	3 (0.1)	1.000
Physical impairment (n, %)	0 (0)	3 (0.1)	1.000
The proportion of low-risk populations	340 (46)	2106 (45)	0.595

PICO, sodium picosulfate; PEG-ELS, polyethylene glycol electrolyte lavage solution; BMI, body mass index; SD, standard deviation. Symptom includes rectal bleeding, anemia, abdominal pain, changes in bowel habits, weight loss, etc. Recheck refers to reexamination after previous polypectomy or history of adenomatous polyps or cancer. Others refer to patients who are not within the range of symptoms we have listed, including belching, heartburn, elevated tumor markers, etc. The proportion of low-risk populations refers to those who have no risk factors for suboptimal bowel preparation. Unless otherwise noted, values all represent n (%)

Table 2 The effect of bowel cleansing

	PICO	2 L PEG-ELS	P value
n	739	4684	
Adequate bowel cleansing rate (n, %)	681 (92.2)	4276 (91.3)	0.437
BBPS score (Mean ± SD)			
Total score	6.90 ± 1.19	6.81 ± 1.14	0.016
Right colon	2.15 ± 0.53	2.11 ± 0.51	0.005
Transverse colon	2.53 ± 0.54	2.52 ± 0.55	0.463
Left colon	2.22 ± 0.52	2.19 ± 0.48	0.092
Polyp detection rate (n, %)	312 (42.2)	2131 (45.5)	0.096
Bowel air bubble score (n, %)			0.343
<5%	699 (94.6)	4388 (93.7)	
5–25%	34 (4.6)	252 (5.4)	
25–50%	4 (0.5)	33 (0.7)	
>50%	2 (0.3)	11 (0.2)	
Bowel preparation completion rate (n, %)			0.145
25–50%	0 (0)	3 (0.1)	
50–75%	1 (0.1)	22 (0.5)	
75–100%	738 (99.9)	4659 (99.5)	
Time of the first defecation (n, %)			< 0.001
<1 h	299 (40.5)	2498 (53.3)	
1–2 h	243 (32.9)	1385 (29.6)	
>2 h	197 (26.7)	801 (17.1)	

PICO, sodium picosulfate; PEG-ELS, polyethylene glycol electrolyte lavage solution; BBPS, boston bowel preparation scale; SD, standard deviation. Unless otherwise noted, values all represent n (%)

Shan *et al. BMC Gastroenterology*   (2025) 25:164

Page 6 of 9

Table 3 Adverse reactions in the two groups

	PICO	2 L PEG-ELS	P value
n	739	4684	
Adverse reactions			
Nausea (n, %)	42 (5.7)	549 (11.7)	< 0.001
Vomiting (n, %)	14 (1.9)	148 (3.2)	0.060
Abdominal discomfort (n, %)	29 (3.9)	181 (3.9)	0.937
Sleep disturbance (n, %)	181 (24.5)	685 (14.6)	< 0.001
Others (n, %)	21 (2.8)	140 (3.0)	0.827
Willingness to repeat (n, %)	733 (99.2)	4636 (99.0)	0.588

PICO, sodium picosulfate; PEG-ELS, polyethylene glycol electrolyte lavage solution; Unless otherwise noted, values all represent n (%)

Table 4 Results after propensity score matching and outcome indicators in the two groups

Baseline characteristics	PICO	2 L PEG-ELS	P value
n	720	720	
Age (Mean ± SD, years)	49.21 ± 13.75	49.80 ± 15.12	0.349
Male gender (n, %)	339 (47.1)	323 (44.9)	0.398
BMI (Mean ± SD, kg/m^2)	22.98 ± 3.06	22.91 ± 3.46	0.375
Family history of colon Cancer (n, %)	39 (5.4)	44 (6.1)	0.572
Indications for colonoscopy (n, %)			
Screening	175 (24.3)	181 (25.1)	0.714
Symptom	280 (38.9)	275 (38.2)	0.787
Recheck	130 (18.1)	124 (17.2)	0.678
Others	135 (18.8)	140 (19.4)	0.737
Dimethyl silicone oil use (n, %)	651 (90.4)	661 (91.8)	0.354
Low-residue diet before procedure (n, %)	661 (91.8)	660 (91.7)	0.924
Risk factors of suboptimal bowel preparation			
History of diabetes (n, %)	16 (2.2)	20 (2.8)	0.500
History of abdominal Surgery (n, %)	217 (30.1)	234 (32.5)	0.334
Liver cirrhosis (n, %)	0 (0)	0 (0)	-
Parkinson's disease (n, %)	0 (0)	0 (0)	-
Constipation (n, %)	0 (0)	0 (0)	-
Tricyclic antidepressents use (n, %)	1 (0.1)	0 (0)	1.000
Physical impairment (n, %)	0 (0)	0 (0)	-
BBPS score (Mean ± SD)			
Total score	6.90 ± 1.20	6.80 ± 1.10	0.042
Right colon	2.15 ± 0.53	2.10 ± 0.51	0.030
Transverse colon	2.53 ± 0.55	2.51 ± 0.55	0.238
Left colon	2.21 ± 0.51	2.20 ± 0.46	0.470

PICO, sodium picosulfate; PEG-ELS, polyethylene glycol electrolyte lavage solution. Symptom includes rectal bleeding, anemia, abdominal pain, changes in bowel habits, weight loss, etc. Recheck refers to reexamination after previous polypectomy or history of adenomatous polyps or cancer. Others refer to patients who are not within the range of symptoms we have listed, including belching, heartburn, elevated tumor markers, etc. Unless otherwise noted, values all represent n (%).-, not available

in the PICO group was significantly higher than the 2 L PEG-ELS group (26.7% vs. 17.1%, $P < 0.001$).

Adverse reactions

As shown in Table 3, the incidence of nausea was significantly lower in the PICO group compared to the 2 L PEG-ELS group (5.7% vs. 11.7%, $P < 0.001$), whereas patients in the PICO group experienced a higher rate of sleep disturbance (24.5% vs. 14.6%, $P < 0.001$). There was no statistically significant difference in rates of vomiting and abdominal discomfort between the two groups. And

the willingness to repeat the procedure was 99% in both groups, with no significant difference.

Propensity score matching (PSM)

To minimize the impact of baseline differences between the PICO and 2 L PEG-ELS groups, we re-analyzed the baseline characteristics using propensity score matching (PSM). As shown in Table 4, after PSM, there were no significant differences between the two groups across any baseline indicators, including age, reason for colonoscopy, history of diabetes, and history of abdominal surgery. Following propensity score matching, outcome

indicators such as adequate bowel cleansing rate, polyp detection rate, adverse reactions (nausea, vomiting, abdominal discomfort, etc.), and time to first defecation remained unchanged.

Discussion

This study is a prospective observational study, comparing bowel preparation using low-volume regimens of PICO and 2 L PEG-ELS in non-selective population in China. Our study found no statistically significant differences in adequate bowel cleansing rate (the primary outcome of the study) as measured by the BBPS (92.2% vs. 91.3%, $P = 0.437$), polyp detection rate (42.2% vs. 45.5%, $P = 0.096$), and patient compliance between the PICO and 2 L PEG-ELS groups.

The PICO group had statistically significantly better BBPS total scores [(6.90 ± 1.19) vs. (6.81 ± 1.14), $P = 0.016$] and the right segment scores [(2.15 ± 0.53) vs. (2.11 ± 0.51), $P = 0.005$]. And the BBPS score is more sensitive than the adequate bowel cleaning rate, which suggested that the PICO group might be better than the 2 L PEG-ELS group in bowel preparation.

At present, low-volume bowel cleansing regimens mainly included 1–2 L PEG plus adjuvants, PICO, oral sulfate solution, as listed in the guideline from European Society of Gastrointestinal Endoscopy (ESGE) [10]. A randomized, multicenter clinical trial has shown that PICO was comparable to 2L PEG/Bisacodyl in the bowel cleaning efficacy (97.99% vs. 95.33%, $P = 0.1093$), which was similar with our study [19]. Also, another randomized clinical trial has shown that PICO was superior to 2L PEG/Asc in the cleansing of right colon, which was also consistent with our study [18]. But still now, no study compared PICO with 2L PEG-ELS. Although, 4 L PEG-ELS was recommended in Europe and USA [25, 26], several randomized controlled studies and prospective, multicenter observational studies conducted in Asia have shown that the bowel preparation effect of 2L PEG-ELS was not inferior to 4 L PEG-ELS (92.2% vs. 91.3%, $P = 0.620$; 98.0% vs. 97.1%, $P < 0.001$; 75% vs.74.2%, $P = 1.000$) [12, 27, 28]. And in our previous study from China, the 2L PEG-ELS alone has been demonstrated to achieve an adequate rate of bowel preparation (91.6%) [29]. Thus 2L PEG-ELS is still recommended in the 2023 expert consensus on bowel preparation for colonoscopy released in China [30]. This big difference may be related to racial and body type variations. The BMI of Asian populations is lower than that of European and American populations, and our previous research has also shown that for patients with a high BMI (25–29.9 kg/m^2), the 3 L PEG is superior to the 2L PEG [31].

In terms of adverse effects, patients in the PICO group experienced less nausea compared to those in the 2 L PEG-ELS group, which was consistent with previous study [19]. The reason might be attributed to the fact that the PEG group ingested 2 L of PEG-ELS liquid with poor taste, while the PICO group ingested 2.25 L of clear liquid, such as water, and 300 ml PICO with orange flavor. Notably, this study found a higher incidence of sleep disturbance in the PICO group (24.5% vs. 14.6%, $P < 0.001$), a finding not extensively reported in prior research. Previous studies have suggested that PICO becomes metabolically active in the colon, where it is converted by colonic bacterial deacetylase to stimulate secretion and exert a laxative effect. Thus, compared to PEG-ELS, PICO has a slightly delayed onset [32]. And our study found that the PICO group had a slower time of the first defecation (> 2 h) (26.7% vs. 17.1%, $P < 0.001$), which might be related to a higher incidence of sleep disturbance in the PICO group. The faster dedication might cause more side effects, such as abdominal discomfort, and the slower dedication might cause more sleep disturbances. This is a trade-off patients will need to take into account.

According to the 2023 expert consensus on bowel preparation for colonoscopy [30], risk factors for inadequate bowel preparation in the Chinese population include chronic constipation, high-fiber diet before the procedure, $BMI > 25$ kg/m^2, age > 70 years, history of colon surgery, diabetes, Parkinson's disease, stroke, spinal cord injury and the use of tricyclic antidepressants or narcotics. Patients were considered as low risk if they did not have any of the above risk factors. Previous randomized controlled trials for low-volume bowel preparation were mostly based on populations at low risk for inadequate bowel preparations [12, 29]. However, it is unclear whether the conclusions can be extrapolate to the non-selective populations in real world. In this prospective observational study, we found the proportion of low-risk populations in both PICO and 2 L PEG-ELS groups was comparable (46% and 45%), with no statistically significantly different. Even after adjusting for baseline differences using PSM, the outcome indicators remained unchanged, indicating that both regimens are effective in achieving good bowel cleansing in non-selective populations undergoing colonoscopy in China.

In this study, the adequate bowel cleaning rate reached 91%, which met the minimum standard of ESGE, but still had a certain distance from 99%. One study showed that a combined regimen, PICO + 1 L PEG + Asc, achieved a 99% bowel cleansing rate [33]. And another study also achieved a 98% bowel cleansing rate by adequate bowel preparation instruction [27]. It is the direction of future research to further improve the adequate bowel cleaning rate and reduce the adverse reactions of patients by using complex preparations, increasing patient compliance and other aspects.

This study has the following limitations: [1] The study is a prospective observational study and not randomized.

Shan *et al. BMC Gastroenterology*   (2025) 25:164

Page 8 of 9

Bowel cleansing preparations were chosen independently by the patients, and the PICO group was relatively younger, possibly due to the higher cost of PICO, which may be more readily accepted by a younger population than by the elderly [2]. This study was conducted at a single center, and larger multi-center studies are needed to further validate the findings [3]. In our study, we fed patients dinner the day before the colonoscopy, which may have had an impact on bowel preparation.

Conclusion

In summary, there was no statistically significant difference between the PICO and 2 L PEG-ELS groups in adequate bowel cleansing rate as measured by the BBPS. However, the BBPS scores of the total and the right colon in the PICO group were better than the 2 L PEG-ELS group. Patients in the PICO group experienced less nausea but had a higher incidence of sleep disturbances compared to the 2 L PEG-ELS group. These findings suggest that both PICO and 2 L PEG-ELS are safe and effective low-volume bowel cleansing regimens suitable for the Chinese population.

Abbreviations
BBPS	Boston bowel preparation scale
BMI	Body mass index
PEG-ELS	Polyethylene glycol electrolyte lavage solution
PEG	Polyethylene glycol
PICO	Sodium picosulfate
SD	Standard deviation

Author contributions
YS: analysis and interpretation of the data and manuscript writing; DL: analysis and interpretation of the data; Lin Jiang, CZ and YL: Data collection and collation; XS: Conception and design of the study; JS: Conception and design of the study and funding support. All authors reviewed and confirmed the final version of the manuscript.

Data availability
The data can be provided by the corresponding author on resonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of the Third People's Hospital of Chengdu (2024-S-46). Written informed consent was obtained from all patients.

Consent for publication
Written informed consent was obtained from the patients, which will be provided upon reasonable request.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Gastroenterology, Affiliated Hospital of Southwest Jiaotong University, The Third People's Hospital of Chengdu, No. 82 Qinglong Street, Qingyang District, Chengdu 610014, Sichuan, China
[2]College of Medicine, Southwest Jiaotong University, Chengdu 610031, Sichuan, China

References
1. Gao R, Wu C, Zhu Y, Kong C, Zhu Y, Gao Y, et al. Integrated analysis of colorectal cancer reveals cross-cohort gut microbial signatures and associated serum metabolites. Gastroenterology. 2022;163(4):1024–e379.
2. Society AC. Cancer facts & figures 2023. Atlanta: American Cancer Society. 2023.
3. Nishihara R, Wu K, Lochhead P, Morikawa T, Liao X, Qian ZR, et al. Long-term colorectal-cancer incidence and mortality after lower endoscopy. N Engl J Med. 2013;369(12):1095–105.
4. Zauber AG, Winawer SJ, O'Brien MJ, Lansdorp-Vogelaar I, van Ballegooijen M, Hankey BF, et al. Colonoscopic polypectomy and long-term prevention of colorectal-cancer deaths. N Engl J Med. 2012;366(8):687–96.
5. Chen G, Zhao Y, Xie F, Shi W, Yang Y, Yang A, et al. Educating outpatients for bowel preparation before colonoscopy using conventional methods vs virtual reality videos plus conventional methods: a randomized clinical trial. JAMA Netw Open. 2021;4(11):e2135576.
6. Chokshi RV, Hovis CE, Hollander T, Early DS, Wang JS. Prevalence of missed adenomas in patients with inadequate bowel preparation on screening colonoscopy. Gastrointest Endosc. 2012;75(6):1197–203.
7. May FP, Shaukat A. State of the science on quality indicators for colonoscopy and how to achieve them. Am J Gastroenterol. 2020;115(8):1183–90.
8. Fang S, Song Y, Liu Y, Wang L. Randomized clinical trial: efficacy and tolerability of two different split dose of low-volume polyethylene glycol electrolytes for bowel preparation before colonoscopy in hospitalized children. Pediatr Res. 2020;90(1):171–5.
9. Gerard DP, Gerard SF, Raiser MW. High-dose polyethylene glycol-3350 and gatorade solutions for patients with previous inadequate bowel preparations for colonoscopy are safe and effective. BMC Gastroenterol. 2023;23(1).
10. Hassan C, East J, Radaelli F, Spada C, Benamouzig R, Bisschops R, et al. Bowel preparation for colonoscopy: European Society of Gastrointestinal Endoscopy (ESGE) guideline– update 2019. Endoscopy. 2019;51(08):775–94.
11. Jung Y, Kang SB, Yoon HJ, Cha JM. Improving the tolerability and safety of 1-L polyethylene glycol plus low-dose ascorbic acid for bowel preparation in a healthy population: a randomized multicenter clinical trial. Gastrointest Endosc. 2022;96(2):341–e501.
12. Kang X, Zhao L, Zhu Z, Leung F, Wang L, Wang X, et al. Same-day single dose of 2 liter polyethylene glycol is not inferior to the standard bowel preparation regimen in low-risk patients: a randomized, controlled trial. Am J Gastroenterol. 2018;113(4):601–10.
13. Li Z. Chinese guidelines for bowel preparation related to gastrobowel endoscopy practice (2019, Shanghai). Chin J Intern Med. 2019;58:485–95.
14. Okamoto N, Tanaka S, Abe H, Miyazaki H, Nakai T, Tsuda K, et al. Predicting inadequate bowel preparation when using sodium picosulfate plus magnesium citrate for colonoscopy: development and validation of a prediction score. Digestion. 2022;103(6):462–9.
15. Sun M, Yang G, Wang Y. Cleaning effect and tolerance of 16 bowel preparation regimens on adult patients before colonoscopy: a network meta-analysis. Int J Colorectal Dis. 2023;38(1):69.
16. O Kherad SR. M Martel. Polyethylene glycol versus sodium picosulfalte bowel preparation in the setting of a colorectal cancer screening program. Can J Gastroenterol Hepatol. 2015;29(7):384–90.
17. Hoy SMSL, Wagstaff AJ. Sodium picosulfate/magnesium citrate: a review of its use as a colorectal cleanser. Drugs. 2009;69(1):123–36.
18. Seo SI, Kang JG, Kim HS, Jang MK, Kim HY, Shin WG. Efficacy and tolerability of 2-L polyethylene glycol with ascorbic acid versus sodium picosulfate with magnesium citrate: a randomized controlled trial. Int J Colorectal Dis. 2018;33(5):541–8.
19. Hung SY, Chen HC, Chen WT. A randomized trial comparing the bowel cleansing efficacy of sodium picosulfate/magnesium citrate and polyethylene glycol/bisacodyl (The Bowklean Study). Sci Rep. 2020;10(1).

Shan *et al. BMC Gastroenterology*   (2025) 25:164

Page 9 of 9

20. Wang W. Effect of different application methods of dimethyl silicone oil on the effect of colonoscopy bowel preparation. Application Mod Med China. 2022;16(10):14–7.

21. Bai Y, Fang J, Zhao S-B, Wang D, Li Y-Q, Shi R-H et al. Impact of preprocedure Simethicone on adenoma detection rate during colonoscopy: a multicenter, endoscopist-blinded randomized controlled trial. Endoscopy. 2017;50(2):128–36.

22. Lai EJ, Calderwood AH, Doros G, Fix OK, Jacobson BC. The Boston bowel preparation scale: a valid and reliable instrument for colonoscopy-oriented research. Gastrointest Endosc. 2009;69(3):620–5.

23. Wenqi S, Bei Z, Yunrong W, Xinrong W, Yifan L, Weiwei W et al. Lactulose vs polyethylene glycol for bowel preparation: a single-center, prospective, randomized controlled study based on BMI. Clin Translational Gastroenterol. 2024;15(1).

24. Yoo IK, Jeen YT, Kang SH, Lee JH, Kim SH, Lee JM et al. Improving of bowel cleansing effect for polyethylene glycol with ascorbic acid using Simethicone. Medicine. 2016;95(28).

25. Parente F, Vailati C, Bargiggia S, Manes G, Fontana P, Masci E, et al. 2-litre polyethylene glycol-citrate-simethicone plus bisacodyl versus 4-litre polyethylene glycol as preparation for colonoscopy in chronic constipation. Dig Liver Disease. 2015;47(10):857–63.

26. Rex DK, Katz PO, Bertiger G, Vanner S, Hookey LC, Alderfer V, et al. Split-dose administration of a dual-action, low-volume bowel cleanser for colonoscopy: the SEE CLEAR I study. Gastrointest Endosc. 2013;78(1):132–41.

27. Theunissen F, Lantinga MA, ter Borg PCJ, Ouwendijk RJT, Siersema PD, Bruno MJ. Efficacy of different bowel preparation regimen volumes for colorectal cancer screening and compliance with European society of Gastrointestinal endoscopy performance measures. United Eur Gastroenterol J. 2023;11(5):448–57.

28. Seo EH, Kim TO, Park MJ, Heo NY, Park J, Yang SY. Low-Volume Morning-Only polyethylene glycol with specially designed test meals versus standard-Volume Split-Dose polyethylene glycol with standard diet for colonoscopy: A prospective, randomized trial. Digestion. 2013;88(2):110–8.

29. Zhang C, Chen X, Tang B, Shan J, Qin J, He J, et al. A novel ultra-low-volume regimen combining 1 L polyethylene glycol and linaclotide versus 2 L polyethylene glycol for colonoscopy cleansing in low-risk individuals: a randomized controlled trial. Gastrointest Endosc. 2023;97(5):952–e611.

30. Liu S. Expert consensus opinion on bowel preparation for colonoscopy (2023, Guangzhou). Chin J Gastrobowel Endoscopy. 2023;40:421–30.

31. Yan H, Huang H, Yang D, Chen Z, Liu C, Huang Z et al. 3 L split-dose polyethylene glycol is superior to 2 L polyethylene glycol in colonoscopic bowel preparation in relatively high-BMI (≥ 24 kg/m2) individuals: a multicenter randomized controlled trial. BMC Gastroenterol. 2023;23(1).

32. Sharara AI, El Reda ZD, Harb AH, Abou Fadel CG, Sarkis FS, Chalhoub JM, et al. The burden of bowel preparations in patients undergoing elective colonoscopy. United Eur Gastroenterol J. 2016;4(2):314–8.

33. Yamaguchi D, Hidaka H, Matsunaga T, Akutagawa T, Tanaka Y, Jubashi A, et al. Efficacy of elobixibat as bowel preparation agent for colonoscopy: prospective, randomized, multi-center study. Dig Endoscopy. 2021;34(1):171–9.

Publisher's note