Evaluation of the combined effect of factors influencing bowel preparation and adenoma detection rates in patients undergoing colonoscopy

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ABSTRACT

Background Colonoscopy is a commonly used modality for screening and surveillance of colorectal cancer (CRC). Therefore, it is essential to have adequate bowel preparation (prep) for the procedure which depends on type of bowel regimens, diet before colonoscopy and timing of the procedure.

Aims The purpose of this study is to analyse the effect of multiple factors on adenoma detection rate (ADR) and prep quality of colonoscopy. This is the also the first study determining outcomes based on various combinations of diet, timing of the procedure and bowel prep regimens.

Methods This is a retrospective single-centre observational study. Data about diet before procedure, bowel prep prep regimen and timing of the procedure was collected for patients coming for screening colonoscopy.

Results Patients with split prep had higher good prep rates (73.8% vs 56.2%) and higher ADRs (34.2% vs 29.9%) as compared with non-split prep. The good prep quality (65.6% vs 62.1%) and ADRs (31.9% vs 31.5%) were comparable in patients who received clear liquid diet as compared with low residue diet. The good results of bowel prep were obtained with split prep with either clear liquids or low residue diet irrespective of the timing of the procedure. The poor prep was noticed in patients who underwent procedure in afternoon, with a low restrictive diet and non-split bowel regimen.

Conclusions The current study adds to our knowledge about the combined effect of multiple variables affecting the bowel prep quality and ADR. It is imperative to opt for the best combination required for colonoscopy, as this will influence the effectiveness of colonoscopies regarding timely cancer detection and prevention.

INTRODUCTION

Cancer is the second leading cause of global mortality and leads to about 8.8 million deaths in the 2015. Colorectal cancer (CRC) is the third most common cancer. It is the second leading cause of cancer-related mortality and is responsible for about 8% of cancer-related deaths. CRC is a major health burden. The incidence is about 10% in males and 9.2% in females among all cancers. The lifetime likelihood of developing CRC is about 5%, with 90% of cancers developing after the age of 50 years. Timely
screening for adenomatous and serrated polyps, which may develop into CRC, reduces overall CRC incidence and mortality.5–7

Colonoscopy is a commonly used modality for screening and surveillance of CRC. It reduces the CRC mortality and morbidity by detecting precancerous lesions like adenomas at an early stage when they can be endoscopically resected and before these lesions develop into malignant lesions.7 The adenoma detection rate (ADR) is the percentage of patients aged ≥50 years undergoing first-time screening colonoscopy that have one or more conventional adenomas detected and removed. It is an acceptable benchmark for quality in colonoscopy. According to the current guidelines, the target ADR of physicians should be above 25%, that is, ≥20% for female and ≥30% for male patients.8

ADRs are significantly associated with the subsequent development of interval CRC.9 Corley et al reported inverse relationship of ADR and interval CRC by demonstrating that every 1.0% increase in the ADR was significantly associated with a 3.0% decrease in the risk of CRC (HR 0.97; 95% CI 0.96 to 0.98).10 Several factors contribute to the effectiveness of the colonoscopy which include increase in the bowel preparation (prep), meticulous inspection, withdrawal times and timing of the procedure.11–13 Bowel prep depends on the patient’s acceptance and understanding of the procedure. The quality of bowel prep determines the procedure duration, ADR and the need

Table 1 Study demographics based on the presence and absence of adenomas

|                        | Adenoma absent (N=1124) (%) | Adenoma present (N=518) (%) | Total (N=1642) (%) | P value |
|------------------------|-----------------------------|----------------------------|--------------------|---------|
| **Age**                |                             |                            |                    |         |
| 50–60                  | 696 (61.9)                  | 284 (54.8)                 | 980 (59.6)         | 0.054   |
| 60–70                  | 334 (29.7)                  | 179 (34.6)                 | 513 (31.2)         |         |
| 70 and above           | 94 (8.4)                    | 55 (10.6)                  | 149 (9.1)          |         |
| **Gender**             |                             |                            |                    |         |
| Female                 | 588 (52.4)                  | 216 (41.7)                 | 804 (49.0)         | <0.001  |
| Male                   | 535 (47.6)                  | 302 (58.3)                 | 837 (51.0)         |         |
| **Diabetes**           |                             |                            |                    |         |
| 311 (27.7)             | 168 (32.6)                  | 479 (29.2)                 | 0.052             |
| **Hypertension**       |                             |                            |                    |         |
| 645 (57.5)             | 327 (63.5)                  | 972 (59.4)                 | 0.025             |
| **BMI**                |                             |                            |                    |         |
| <25                    | 224 (20.9)                  | 105 (21.5)                 | 329 (21.1)         | 0.342   |
| 25–30                  | 372 (34.8)                  | 166 (34.0)                 | 538 (34.5)         |         |
| 30–40                  | 355 (33.2)                  | 176 (36.1)                 | 531 (34.1)         |         |
| >40                    | 119 (11.1)                  | 41 (8.4)                   | 160 (10.3)         |         |
| **Opiate use**         |                             |                            |                    | 0.502   |
| 51 (4.5)               | 19 (3.7)                    | 70 (4.3)                   | 28 (1.7)           |         |
| **History of abdominal surgery** |                         |                            |                    | 0.371   |
| 317 (28.2)             | 120 (23.2)                  | 437 (26.6)                 | 0.091             |
| **Anticholinergic drugs** |                         |                            |                    | 0.891   |
| 20 (1.8)               | 8 (1.5)                     | 28 (1.7)                   | 0.374             |
| **Tricyclic antidepressants** |                     |                            |                    | 0.189   |
| 24 (2.1)               | 7 (1.4)                     | 31 (1.9)                   | 0.258             |
| **Use of psychiatric meds** |                         |                            |                    | 0.242   |
| 137 (12.2)             | 76 (14.7)                   | 213 (13.0)                 | 0.931             |
| **Thyroid medications** |                         |                            |                    |         |
| 57 (5.1)               | 19 (3.7)                    | 76 (4.6)                   | 0.931             |
| **Laxatives**          |                             |                            |                    |         |
| 272 (24.2)             | 111 (21.4)                  | 383 (23.3)                 | 0.931             |
| **Use of antidiarrheal drugs** |                     |                            |                    | 0.299   |
| 5 (0.4)                | 0 (0.0)                     | 5 (0.3)                    | 0.220             |
| **Diet before colonoscopy** |                         |                            |                    | 0.066   |
| CLD                    | 235 (20.9)                  | 110 (21.2)                 | 345 (21.0)         |         |
| LRD                    | 889 (79.1)                  | 408 (78.8)                 | 1297 (79.0)        |         |
| **Bowel preparation regimen** |                     |                            |                    |         |
| NSDR                   | 713 (63.4)                  | 304 (58.7)                 | 1017 (61.9)        |         |
| SDR                    | 411 (36.6)                  | 214 (41.3)                 | 625 (38.1)         |         |
| **Timing of colonoscopy** |                         |                            |                    |         |
| AM                     | 465 (41.4)                  | 197 (38.0)                 | 662 (40.3)         | 0.220   |
| PM                     | 659 (58.6)                  | 321 (62.0)                 | 980 (59.7)         |         |

ADR, adenoma detection rate; AM, morning; BMI, body mass index; CLD, clear liquid diet; LRD, low residue diet; NSDR, non-split dose regimen; PM, afternoon; SDR, split-dose regimen.
Table 2  Outcomes based on bowel preparation regimen (SDR vs NSDR)

|                       | NSDR (N=1017) (%) | SDR (N=625) (%) | Total (N=1642) (%) | P value |
|-----------------------|-------------------|----------------|-------------------|---------|
| **Preparation quality** |                   |                |                   |         |
| Fair                  | 290 (28.5)        | 109 (17.4)     | 399 (24.3)        | <0.001  |
| Good                  | 572 (56.2)        | 461 (73.8)     | 1033 (62.9)       |         |
| Poor                  | 155 (15.2)        | 55 (8.8)       | 210 (12.8)        |         |
| **ADR**               | 29.9              | 34.2           | 31.5              | 0.074   |

ADR, adenoma detection rate; NSDR, non-split dose regimen; SDR, split-dose regimen.

te to follow-up. Careful examination of the colon with longer withdrawal time has been reported to increase the ADR in certain studies. ADR determines the safe intervals for scheduling surveillance colonoscopies.

The purpose of this study was to analyse the effect of multiple factors on ADR and prep quality of colonoscopy, individually and combined. This is the first study determining the outcomes based on various combinations of diet, the timing of the procedure and bowel prep types.

**METHODS**

This is a retrospective single-centre observational study. The period of study was 18 months between 1 January 2016 and 30 June 2017. The study was performed according to the Declaration of Helsinki.

**Patient selection**

The data was collected from the electronic medical records of patients and tabulated in Microsoft Excel. Findings at colonoscopy were extracted from the final procedure reports, and pathology information was extracted from the final pathology reports. Asymptomatic patients, aged between 50 and 80 years, undergoing screening colonoscopy were included in the study population. Symptomatic patients, patients with indications for therapeutic colonoscopy, such as rectal bleeding, iron-deficiency anaemia, inflammatory bowel disease, incomplete colonoscopy examination, CRC, chronic diarrhoea, and abnormal imaging, were excluded from the study. Patients with missing information/data were also excluded from the study. All the patients included underwent colonoscopies performed by four staff endoscopists at our institute. All the four endoscopists involved in the study are in practice for more than 5 years have consensus in reporting the quality of bowel prep. The average annual caecal intubation rate for all the four endoscopists was 98.95%. The average annual ADR of these endoscopists was 33%.

**Diet type**

Data were collected on whether the patient had received instructions for clear liquid diet (CLD) or low residue diet (LRD) for the day before the procedure (breakfast, lunch and dinner). All patients received verbal as well as written instructions regarding the diet and bowel prep regimen by the gastroenterologists and the registered nurses during the visit before the colonoscopy and it was made sure that the patient verbalised understanding. CLD is a refined regime of normal diet. It does not include any substances which can increase the bulk of stool like solids, dairy products and fruit juices containing pulp. LRD is also a modified version of the standard diet, and it includes a daily supple of less than 10–15 g fibre. Our dietary instructions given to the patients to consume LRD a day before colonoscopy included foods such as Jell-O (not red or green), boiled egg, scrambled egg, mashed potatoes, pancakes, apple juice, tea or coffee without milk, Gatorade, honey, popsicle, lemonade. The foods to avoid day before the colonoscopy included all solid foods, which cause residue in colon like vegetable soup, bread, dairy, fruits, vegetable, meat, rice. On the day of the procedure, patients were advised to take no solid food at all.

**Bowel prep regimen types**

Data were collected on whether the patients had received non-split dose regimen (NSDR), where the entire bowel prep was ingested the night before the procedure or split-dose regimen (SDR), where half of the bowel prep was ingested the night before the procedure and half on

Table 3  Outcomes based on the diet recommended before the colonoscopy (CLD vs LRD)

| Prep quality | CLD (N=345) (%) | LRD (N=1297) (%) | Total (N=1642) (%) | P value |
|--------------|----------------|----------------|-------------------|---------|
| Fair         | 81 (23.5)      | 318 (24.5)     | 399 (24.3)        | 0.340   |
| Good         | 227 (65.8)     | 806 (62.1)     | 1033 (62.9)       |         |
| Poor         | 37 (10.7)      | 173 (13.3)     | 210 (12.8)        |         |
| **ADR**      | 110 (31.9)     | 408 (31.5)     | 518 (31.5)        | 0.931   |

ADR, adenoma detection rate; CLD, clear liquid diet; LRD, low residue diet.
the morning of the procedure, 3 hours before the scheduled time of the colonoscopy.

The same bowel prep agent, polyethylene glycol (PEG), and dosage (238 g) were used in each group, making the only difference between groups the time of bowel prep ingestion.

**Timing of colonoscopy**
We collected the data on the timing of the procedure based on the scope insertion time. Morning colonoscopies were defined as those that started before 12 noon and afternoon colonoscopies as those that started after 12 noon.

**Quality of bowel prep**
To make the results more widely applicable, we used the four-point Aronchick scale of excellent, good, fair and poor that was described by the endoscopist in the report. For analysis purpose, we combined the excellent and good preps together. Adequate prep included excellent, good and fair bowel prep. Preparations reported as inadequate were grouped with poor prep. Comparison between the adequate and inadequate preps was done in the online supplementary table 2s-9s. The scoring was done after manual colon cleansing during colonoscopy. All the endoscopists involved in the study are in practice for more than 5 years and each endoscopist performs more than 1000 procedure every year and have consensus in reporting the quality of bowel prep. We also use specialised endoscopy software in our endoscopy unit. For all the procedures, verification of caecum intubation was documented with exact time in the electronic medical record and the photographic evidence.

**Adenoma detection rate**
ADR, which is the percentage of average-risk patients for CRC who are found to have at least one adenoma or adenocarcinoma during a screening colonoscopy was calculated for all patients. Sessile serrated polypl were included in the calculation of ADR.

**Statistical analysis**
Demographic information, clinical measurements, other potential confounders including age categories, gender, diabetes status, hypertension status, body mass index (BMI) values in categories, opiate usage status, abdominal surgery status, anticholinergic status, tricyclic antidepressants (TCAs) status, psych med status, thyroid disease, laxatives use, anti diarrhoeal use were stratified by adenoma status. The three interventions (diet, prep type and time) and the mediator (prep quality) were stratified by adenoma prevalence. Pearson’s $\chi^2$ tests were conducted to assess the association between adenoma status and other variables. The associations were tested by analysis of variance tests for continuous variables and Pearson’s $\chi^2$ tests for categorical variables. Baron-Kenny procedures were used to assess the mediational hypothesis between adenoma prevalence status and prep on diet, split status and time three interventions separately. Multiple logistic regressions were used to assess the association between adenoma prevalence and prep quality, the association between the preparation quality and intervention status and the association between adenoma prevalence and prep quality controlling intervention. All regression models were controlled for confounders including age, gender, diabetes status and hypotension.
status, BMI, opiate usage, abdominal surgery, TCAs, psych medication, thyroid, laxatives and antidiarrhoeal medication.

**RESULTS**

Table 1 shows the study population including the demographics, confounders, interventions and mediators stratified by the primary outcome (presence of adenomatous polyps). There were 518 patients with adenomas present and 1124 without any adenoma found on colonoscopy. The sample was mostly balanced in demographic and clinical information except for gender (more females), hypertension status and abdominal surgery. Most of the patients were on LRD (79%), non-split prep (61.9%) and did the colonoscopy in the afternoon (59.7%). We compared the outcomes based on prep type (table 2), diet type (table 3) and the timing of colonoscopy (table 4). Patients with split prep had higher good prep rates (73.8% vs 56.2%) and higher ADRs (34.2% vs 29.9%) as compared with non-split prep. The prep quality (good prep 65.8% vs 62.1%) and ADRs (31.9% vs 31.5%) were comparable in patients who received CLD as compared with LRD. Similarly, the timing of the procedure did not affect either the prep quality or the ADR.

Next, we evaluated various combinations of diet, prep type and timings to evaluate their effect on prep quality and ADR. Table 5 shows the outcomes based on various combinations of diet and prep types. We found that the prep quality was significantly superior when either CLD or LRD was used with split prep, though it did not translate into a significantly higher ADR. The worst prep quality was achieved by using a non-split prep with the procedure being done in the afternoon. There was no significant difference in prep quality and ADR when various combinations of diet and timing of procedure were evaluated (table 7).

In addition, we included all variables with all possible combinations to evaluate whether one was superior to others (table 8). We found that split prep with either CLD or LRD was associated with a significantly superior prep irrespective of the timing of procedure as compared with respective non-split prep groups. Interestingly, there were a significantly increased number of patients with a poor prep who underwent procedure in afternoon, with a LRD and non-split prep. There was no significant difference in ADR in any of the groups.

Table 9 indicates the result from the Baron-Kenny procedure. The multiple logistic regression indicates that the OR of having good or fair prep rather than poor was 1.90 (95% CI 1.34 to 2.68) with a split prep. But good or fair prep was not associated with higher adenoma prevalence. There was no effect of timing of procedure on either prep quality or ADR. Comparisons of outcomes between the adequate and inadequate prep is also mentioned in the online supplementary table 2s-9s.

**DISCUSSION**

This is the first study analysing the combined effect of multiple variables on the bowel prep quality and ADR. The quality of the bowel preparation is essential for the

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### Table 6

|                   | NSDR+PM (N=457) (%) | NSDR+AM (N=560) (%) | SDR+PM (N=523) (%) | SDR+AM (N=102) (%) | Total (N=1642) (%) | P value |
|-------------------|---------------------|---------------------|--------------------|--------------------|--------------------|---------|
| Preparation quality |                     |                     |                    |                    |                    |         |
| Fair              | 137 (30.0)          | 153 (27.3)          | 97 (18.5)          | 12 (11.8)          | 399 (24.3)         | <0.001  |
| Good              | 241 (52.7)          | 331 (59.1)          | 385 (73.6)         | 76 (74.5)          | 1033 (62.9)        |         |
| Poor              | 79 (17.3)           | 76 (13.6)           | 41 (7.8)           | 14 (13.7)          | 210 (12.8)         |         |
| ADR               | 137 (30.0)          | 167 (29.8)          | 184 (35.2)         | 30 (29.4)          | 518 (31.5)         | 0.194   |

ADR, adenoma detection rate; AM, morning; NSDR, non-split dose regimen; PM, afternoon; SDR, split-dose regimen.

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### Table 7

|                   | CLD+PM (N=190) (%) | CLD+AM (N=155) (%) | LRD+PM (N=790) (%) | LRD+AM (N=507) (%) | Total (N=1642) (%) | P value |
|-------------------|--------------------|--------------------|--------------------|--------------------|--------------------|---------|
| Preparation quality |                    |                    |                    |                    |                    |         |
| Fair              | 39 (20.5)          | 42 (27.1)          | 195 (24.7)         | 123 (24.3)         | 399 (24.3)         | 0.499   |
| Good              | 130 (68.4)         | 97 (62.6)          | 496 (62.8)         | 310 (61.1)         | 1033 (62.9)        |         |
| Poor              | 21 (11.1)          | 16 (10.3)          | 99 (12.5)          | 74 (14.6)          | 210 (12.8)         |         |
| ADR               | 58 (30.5)          | 52 (33.5)          | 263 (33.3)         | 145 (28.6)         | 518 (31.5)         | 0.317   |

ADR, adenoma detection rate; AM, morning; CLD, clear liquid diet; LRD, low residue diet; PM, afternoon.
Table 8

| Outcome based on bowel preparation regimen (SDR or NSDR), diet recommended before the colonoscopy (CLD or LRD) and timing of the procedure (AM or PM) | CLD+SDR+AM (N=17) (%) | CLD+SDR+PM (N=37) (%) | CLD+NSDR+AM (N=138) (%) | CLD+NSDR+PM (N=153) (%) | LRD+SDR+AM (N=85) (%) | LRD+SDR+PM (N=486) (%) | LRD+NSDR+AM (N=422) (%) | LRD+NSDR+PM (N=304) (%) | Total (N=1642) (%) | P value |
|---|---|---|---|---|---|---|---|---|---|---|
| Preparation quality | Fair | 13 (9.4) | 18 (11.8) | 3 (17.6) | 8 (21.6) | 63 (14.9) | 61 (12.9) | 63 (73.9) | 39 (12.9) | 399 (24.3) | <0.001 |
| | Good | 84 (60.5) | 104 (69.0) | 12 (70.6) | 26 (70.3) | 63 (14.9) | 61 (12.9) | 63 (73.9) | 39 (12.9) | 1033 (62.9) | <0.001 |
| | Poor | 13 (9.4) | 18 (11.8) | 3 (17.6) | 8 (21.6) | 63 (14.9) | 61 (12.9) | 63 (73.9) | 39 (12.9) | 210 (12.8) | <0.001 |
| ADR | 43 (31.4) | 51 (31.4) | 12 (70.6) | 20 (54.1) | 69 (15.5) | 40 (8.3) | 63 (76.5) | 39 (12.9) | 174 (10.7) | <0.001 |

ADR, adenoma detection rate; AM, morning; CLD, clear liquid diet; LRD, low residue diet; NSDR, non-split dose regimen; PM, afternoon; SDR, split-dose regimen.

Detection of the clinically significant neoplastic lesions. A meta-analysis by Sulz et al. reported that inadequate (poor/insufficient) bowel prep reduces the ADR. Reduction in the ADR was more obvious in early lesions as compared with advanced colonic lesions (OR 0.53, 95% CI 0.46 to 0.62, p<0.001). Inadequate bowel prep can reduce detection of high-risk cancerous lesions including adenomas. A study described the adenoma miss rate of 47.9% in patients with inadequate prep. However, in the same study, the ADR was higher on repeat colonoscopy with good prep but the mean time between colonoscopies was 340 days. A poor bowel prep not only results in procedure abortion/incompleteness but also causes significant economic and health burden.

Split regimen versus non-split regimen

In our study, SDR was associated with improved bowel cleaning. The patients with split prep had higher adequate prep rates (73.8% vs 56.2%) as compared with non-split prep. A meta-analysis of 29 studies also reported that adequate prep was obtained in 85% of patients in the split-dose group and 63% in the non-split dose group. The rate difference of 22% was found between degree of colon cleansing between split dose and non-split dose in this analysis.

We also found higher ADRs in the split prep group (34.2% vs 29.9%) as compared with the non-split prep group. This was consistent with previously published studies. Radaelli et al. conducted an RCT involving 690 patients and demonstrated that split regimen increases the detection of adenomas and clinically significant cancerous lesions and thereby enhancing the yield of colonoscopy. It was observed that at least one adenoma was significantly higher in the split dose group than in the non-split group (53.0% vs 40.9%, relative risk (RR) 1.22, 95% CI 1.03 to 1.46). In addition, the total numbers of both adenomas and advanced adenomas per subject were significantly higher in the split dose group (1.15 vs 0.8, p<0.001; 0.36 vs 0.22, p<0.001).

CLD versus LRD

Our study analysis revealed that the bowel prep quality (good prep 65.8% in the CLD vs 62.1% in the LRD) and ADR (31.9% in the CLD vs 31.5% LRD) were comparable in patients who received CLD when compared with LRD. This is consistent with the trial conducted by Stolpman et al. This randomised controlled trial reported that the quality of bowel prep with LRD was non-inferior to the bowel preparation with CLD. Adequate bowel prep was seen in 97% of patients in the CLD group and 94.5% in the LRD groups. In addition, polyp detection rates were comparable between the two groups (68% vs 65.4%).

Several previous studies also favoured these findings. Nguyen et al. did a meta-analysis and described interesting findings of significantly higher odds of tolerability (OR 1.92; 95% CI 1.36 to 2.70, p<0.01) and willingness to repeat prep (OR 1.86; 95% CI 1.54 to 2.59, p<0.01) in the LRD as compared with CLD. In addition, comparable
findings were seen in adequate bowel preps (OR 1.21; 95% CI 0.64 to 2.28, p=0.58) and adverse effects (OR 0.88; 95% CI 0.58 to 1.35, p=0.57) between these two groups. Another systematic review by Song et al reported similar findings. The combination of SDR+LDR has comparable though slightly better statistically significant results in bowel prep for colonoscopy as compared with SDR+CLD in our analysis (91.4% vs 88.9%, p<0.001). This is consistent with a recent RCT. In a prospective, randomised, single-centre non-inferiority trial, Walter et al concluded that the LRD a day before colonoscopy was non-inferior to CLD for getting adequate bowel cleansing using a split-dose regimen. In our study, ADR was non-inferior to CLD for getting adequate bowel cleansing using a split-dose regimen. However, it was seen that SDR+PM procedure was superior to SDR+CLD procedure (92.2% vs 87.2%, p<0.001). The ADR in our study between SDR+PM procedures were comparable to the NSDR+PM procedures (35.3%–30.0%, p=0.194).

### Table 9: OR and CIs from regression

| Timing of the procedure | Outcome on treatment | Mediator on treatment | Outcome on controlling treatment |
|-------------------------|----------------------|-----------------------|---------------------------------|
| AM                      | –                    | –                     | –                               |
| PM                      | 1.16 (0.93 to 1.45)  | 1.07 (0.79 to 1.46)  | 1.31 (0.93 to 1.84)             |
| Bowel preparation regimen | NSDR                 | –                     | –                               |
| Study                  | SDR                  | 1.25 (1.00 to 1.56)  | 1.90 (1.34 to 2.68) ***         |
| Diet recommended before colonoscopy | CLD                  | –                     | –                               |
| Study                  | LRD                  | 1.00 (0.76 to 1.32)  | 0.90 (0.60 to 1.37) 1.31 (0.94 to 1.84) |

Significance codes: ***p<0.001; **p<0.01; *p<0.05.
ADR, adenoma detection rate; AM, morning; CLD, clear liquid diet; LRD, low residue diet; NSDR, non-split dose regimen; PM, afternoon; SDR, split-dose regimen.

The study by Waye et al showed that colonoscopies in the PM were associated with poor prep and high incomplete colonoscopies rates. Our study did not show any effect of the timing of procedure on these outcomes. In our study, the best results for the bowel cleansing were seen with the combination of LRD+SDR+PM in 92.2% cases. The ADR was also highest with the same combination as compared with others, but results were not statistically significant.

### Morning versus afternoon procedures

In our study, the timing of the procedure (morning=AM vs afternoon=PM) did not affect the prep quality (86.4% vs 87.2%, p=0.466) and neither the ADR (29.8% vs 32.8%, p=0.220).

In contrast to our study, ADR was reported higher in the morning than in the afternoon in some previous studies.

Singh et al also reported that ADR was significantly higher in AM than in PM procedures. Interestingly, the difference in ADR between AM and PM procedures seems to apply mainly to affect only female patients in this study. However, no significant differences in ADR were found in male patients in the afternoon.

A randomised trial conducted by Matro et al evaluated SDR+PM procedures versus NSDR+PM procedures. They concluded that for patients undergoing colonoscopy in the afternoon, NSDR and SDR are clinically comparable with respect to bowel cleansing quality and ADR. In our study, however, it was seen that SDR+PM procedure was superior to NSDR+PM procedure (92.2% vs 87.2%, p<0.001). The ADR in our study between SDR+PM procedures were comparable to the NSDR+PM procedures (35.2%–30.0%, p=0.194).

### Conclusions and Recommendations

The current study adds to our knowledge about the combined effect of multiple variables affecting the bowel prep quality and ADR. It is imperative to opt for the best combination, as this will influence the effectiveness of colonoscopies regarding timely cancer detection and prevention. Prospective and randomised trials including larger and diverse patient populations, using objective scales of bowel quality assessment along with strategies enhancing dietary compliance are required for the further validations of these findings.
Contributors HT and AD contributed to the concept and design. HT, MUK and AD contributed to the drafting of the manuscript. BS, FE, UAP, SA, PN, AB and HA contributed to the acquisition of data. AZ was responsible for the statistical analysis. AD supervised the study. HT, MUK, AZ, JM, BB, AI, MD, BB and AD contributed to the analysis and interpretation of data. HT, MUK, JM, BB, AI, MD, BB and AD was responsible for the critical revision of the manuscript for important intellectual content.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent Not required.

Ethics approval The study was performed in agreement with the ethical guidelines of the Declaration of Helsinki and the protocol was approved by the local Ethics Committee (#12 14 17 12).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

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REFERENCES

1. World Health Organization, 2018. Available: https://www.who.int/news-room/fact-sheets/detail/cancer [Accessed 15 Apr 2018].
2. Toyoma Y, Okugawa Y, Goel A. DNA methylation and microRNA biomarkers for noninvasive detection of gastric and colorectal cancer. *Biochem Biophys Res Commun* 2014;455:43–57.
3. Siegel R, Desantis C, Jemal A. Colorectal cancer statistics, 2014. *CA Cancer J Clin* 2014;64:104–17.
4. Stewart BW, 2014. World cancer report. Available from: http://publications.iarc.fr/Non-Series-Publications/World-Cancer-Reports/World-Cancer-Report-2014 [Accessed 15 Apr 2018].
5. Hewitson P, Gla silica P, Watson E, et al. Cochrane systematic review of colorectal cancer screening using the fecal occult blood test (Hemocult): an update. *Am J Gastroenterol* 2008;103:1541–9.
6. Elmunzer BJ, Hayward RA, Schoenfeld PS, et al. Effect of flexible sigmoidoscopy-based screening on incidence and mortality of colorectal cancer: a systematic review and meta-analysis of randomized controlled trials. *PLoS Med* 2012;9:e1001352.
7. Zauberg AG, Winawer SJ, O’Brien MJ, et al. Colonic polypectomy and long-term prevention of colorectal-cancer deaths. *N Engl J Med* 2012;366:876–97.
8. Rex DK, Schoenfeld PS, Cohen J, et al. Quality indicators for colonoscopy. *Gastrointest Endosc* 2015;81:31–53.
9. Kaminski MF, Regula J, Kraszew ska E, et al. Quality indicators for colonoscopy and the risk of interval cancer. *N Engl J Med Overseas Ed* 2010;362:1795–803.
10. Corley DA, Jensen CD, Marks AR, et al. Adenoma detection rate and risk of colorectal cancer and death. *N Engl J Med Overseas Ed* 2014;370:1298–306.
11. Harewood GC, Sharma VK, de Garmo P. Impact of colonoscopy preparation quality on detection of suspected colonic neoplasia. *Gastrointest Endosc* 2003;58:76–9.
12. McLauchlan SA, Clements A, Austoker J. Patients’ experiences and reported barriers to colonoscopy in the screening context – a systematic review of the literature. *Patient Educ Couns* 2012;86:137–46.
13. Froehlich F, Wierzbach V, Govers JJ, et al. Impact of colonic cleansing on quality and diagnostic yield of colonoscopy: the European panel of appropriateness of gastrointestinal endoscopy European multicenter study. *Gastrointest Endosc* 2005;61:378–84.
14. Fatima H, Rex DK, Rothstein R, et al. Cecal insertion and withdrawal times with wide-angle versus standard colonoscopes: a randomized controlled trial. *Clin Gastroenterol Hepatol* 2008;6:109–14.
15. Lim G, Viney SK, Chapman BA, et al. A prospective study of endoscopy-blinded colonoscopy withdrawal times and polyp detection rates in a tertiary hospital. *N Z Med J* 2012;125:52-9.
16. Lee RH, Tang RS, Muthusamy VR, et al. Quality of colonoscopy withdrawal technique and variability in adenoma detection rates (with videos). *Gastrointest Endosc* 2011;74:128–34.
17. Lieberman DA, Rex DK, Winawer SJ, et al. Guidelines for colonoscopy surveillance after screening and polyectomy: a consensus update by the US Multi-Society Task Force on colorectal cancer. *Gastroenterology* 2012;143:844–57.
18. Rubin CE, Haggitt RC, Burmer GC, et al. DNA aneuploidy in colonic biopsies predicts future development of dysplasia in ulcerative colitis. *Gastroenterology* 1992;103:1611–20.
19. Mahan JR LK. Krause’s food & the nutrition care process e-book. Elsevier Health Sciences, 2016.
20. Marcia Nahkian Nelmis KFS. *Nutrition therapy and pathophysiology*. 3rd edn. Nelson Education, 2015.
21. Aronchick CA, Lipshutz WH, Wright SH, et al. A novel tabletted purgative for colonoscopic preparation: efficacy and safety comparisons with Coleyle and Fleet Phospho-Soda. *Gastrointest Endosc* 2000;52:346–52.
22. Pinto-Pais T. Adenoma detection rate: quality indicators for colonoscopy. *GE Port J Gastroenterol* 2017;24:53–4.
23. Sulz MC, Kröger A, Prakash M, et al. Meta-analysis of the effect of bowel preparation on adenoma detection: early adenomas affected stronger than advanced adenomas. *PLoS One* 2016;11:e0154149.
24. Chokshi RV, Hovis CE, Hollandar T, et al. Prevalence of missed adenomas in patients with inadequate bowel preparation on screening colonoscopy. *Gastrointest Endosc* 2012;75:1197–203.
25. Rex DK, Imperiale TF, Latinovich DR, et al. Impact of bowel preparation on efficiency and cost of colonoscopy. *Am J Gastroenterol* 2002;97:1998–700.
26. Bucci C, Rotondano G, Hassan C, et al. Optimal bowel cleansing for colonoscopy: split the dose! A series of meta-analyses of controlled studies. *Gastrointest Endosc* 2014;80:566–76.
27. Radaelli F, Paggi S, Hassan C, et al. Split-dose preparation for colonoscopy increases adenoma detection rate: a randomised controlled trial in an organised screening programme. *Gut* 2017;66:270–277.
28. Stolpman DR, Solem CA, Eastick D, et al. A randomized controlled trial comparing a low residue versus clear liquids for colonoscopy preparation: impact on tolerance, procedure time, and adenoma detection rate. *J Clin Gastroenterol* 2014;48:851–5.
29. Avalos DJ, Sussman DA, Lara LF, et al. Effect of diet liberalization on bowel preparation. *South Med J* 2017;110:399–407.
30. Nguyen DL, Jamal MM, Nguyen ET, et al. Low-residue versus clear liquid diet before colonoscopy: a meta-analysis of randomized, controlled trials. *Gastrointest Endosc* 2016;83:499–507.
31. Song GM, Tian X, Ma L, et al. Regime for bowel preparation in patients scheduled to colonoscopy: low-residue diet or clear liquid diet? Evidence from systematic review with power analysis. *Medicine* 2016;95:e2432.
32. Walter J, Francis G, Matro R, et al. The impact of diet liberalization on bowel preparation for colonoscopy. *Endosc Int Open* 2017;05:E253–E260.
33. Sanaka MR, Deepinder F, Thota PN, et al. Adenomas are detected more often in morning than in afternoon colonoscopy. *The American Journal of Gastroenterology* 2009;104:1659–64.
34. Singh S, Dhawan M, Chowdhry M. Differences between morning and afternoon colonoscopies for adenoma detection in female and male patients. *Ann Gastroenterol* 2016;29.
35. Matro R, Shnitser A, Spodik M, et al. Efficacy of morning-only compared with split-dose polyethylene glycol electrolyte solution for afternoon colonoscopy: a randomized controlled single-blind study. *Am J Gastroenterol* 2010;105:1954–61.
36. Waye JD. Should all colonoscopies be performed in the morning? *Nat Clin Pract Gastroenterol Hepatol* 2007;4:366–7.
37. Mitchell RM, McCallion K, Gardiner KR, et al. Successful colonoscopy; completion rates and reasons for incompletion. *Ulster Med J* 2002;71:34.
38. Jain D, Goyal A, Uribe J. Obesity and cecal intubation time. *Clin Endosc* 2016;49:187–90.
39. Liu X, Luo H, Zhang L, et al. Telephone-based re-education on the day before colonoscopy improves the quality of bowel preparation and the Polyp detection rate: a prospective, colonoscopist-blinded, randomized, controlled study. *Gut* 2014;63:195–30.
40. Park J, Kim T-O, Lee N-Y, et al. The effectiveness of short message service to assure the preparation-to-colonoscopy interval before bowel preparation for colonoscopy. *Gastrointest Endosc Pract* 2015;2015:1–8.

8 Tariq H, et al. *BMJ Open Gastro* 2019;6:e000254. doi:10.1136/bmjgast-2018-000254