

RESEARCH ARTICLE

Impact of bowel preparation type on the quality of colonoscopy: a multicenter community-based study

Daniel Martin, MD¹, Saqib Walayat, MD¹, Zohair Ahmed, MD²,
Sonu Dhillon, MD¹, Carl V. Asche, PhD^{2,3,4}, Srinivas Puli, MD¹ and
Jinma Ren, PhD^{2,3*}

¹Department of Gastroenterology, OSF Saint Francis Medical Center, Peoria, IL, USA; ²Department of Internal Medicine, University of Illinois College of Medicine at Peoria, Peoria, IL, USA; ³Center for Outcomes Research, University of Illinois College of Medicine at Peoria, Peoria, IL, USA; ⁴Department of Pharmacy Systems, Outcomes And Policy, University of Illinois at Chicago College of Pharmacy, Chicago, IL, USA

Background: High-quality bowel preparation is crucial for achieving the goals of colonoscopy. However, choosing a bowel preparation in clinical practice can be challenging because of the many formulations. This study aims to assess the impact the type of bowel preparation on the quality of colonoscopy in a community hospital setting.

Methods: A retrospective, observational study was conducted utilizing a colonoscopy screening/surveillance database in central Illinois during the period of January 1, 2010, to March 31, 2014. Patients without bowel preparation assessment were excluded from this study. Controlling for the confounders, generalized linear models were used to estimate the adjusted impact [odds ratio (OR)] of bowel preparation type on the quality of preparation (excellent, good, fair, and poor), and on the detection of advanced adenoma. The association between the time of withdrawal after insertion and the quality of preparation was also examined using a linear model.

Results: A total of 28,368 colonoscopies; half the patients were male, and the average age was 61 ± 9 years. Polyethylene glycol (PEG) was used in the majority (70.2%) of bowel preparations, followed by sodium sulfate (21.4%), sodium phosphate (2.5%), magnesium sulfate (0.4%), and others. Compared with PEG, magnesium sulfate had a poorer quality of bowel preparations (OR = 0.6, 95% CI 0.4–0.9; $p < 0.05$), whereas the quality of bowel preparation was significantly improved by using sodium sulfate (OR = 5.7, 95% CI 5.4–6.1; $p < 0.001$) and sodium phosphate (OR = 2.1, 95% CI 1.8–2.5; $p < 0.001$). For those who had adequate bowel preparation, the better quality of preparation significantly increased the detection rate of advanced adenoma (5.0, 3.6, and 2.9% for excellent, good, and fair, respectively).

Conclusion: When possible, sodium sulfate-based preparations should be recommended in the community setting for colonoscopy because of their high quality of bowel preparation.

Keywords: *sodium sulfate; polyethylene glycol; bowel prep; colonoscopy*

*Correspondence to: Jinma Ren, Center for Outcomes Research/Department of Medicine, University of Illinois College of Medicine at Peoria, One Illini Drive, Box 1649, Peoria, IL 61656, USA, Email: jinmaren@uic.edu

Received: 21 January 2016; Accepted: 22 March 2016; Published: 25 April 2016

Colorectal cancer is the third most commonly diagnosed cancer in the United States. It is also the third leading cause of cancer-related mortality (1). The incidence of colorectal cancer has been dramatically reduced by early detection methods, especially colonoscopy, which is considered the gold standard (2, 3). From the year 2002 to 2010, the percentage of population adequately undergoing age-appropriate screening for colon cancer went up to 65.4%, while the colorectal cancer incidence and mortality declined (4). In patients aged more than 50 years, screening for colorectal

cancer is the most common indication of colonoscopy while in those less than 50, it is most commonly performed for symptoms of abdominal pain and rectal bleeding (3).

According to the national polyp study, the risk of colon cancer decreases by 76–90% in patients who underwent a clearing colonoscopy (5). A Norwegian study also reported similar findings, as patients with polyp removal on colonoscopy had lower fatalities compared with the general population (6). One of the most important determinants of a high-quality screening exam is the adenoma detection rate as it is inversely related to the

risk of interval colorectal cancer. According to a recent study, each 1.0% increase in the rate of adenoma detection leads to a 3% decrease in the risk of colorectal cancer (7).

The quality of bowel preparation plays a crucial role in adenoma detection rate and enhances the outcomes of a screening exam. A poor bowel preparation results in increased insertion and withdrawal time, lower adenoma detection rates, and shorter interval for repeat colonoscopy (8). Associated with poorer preparations are diminished patient outcomes, more time wasted on suctioning and washing, and increased overall costs (8). Imperfect bowel preparations were associated with a 12 and 22% increase in the total direct cost of colonoscopy in private and public hospitals, respectively (8). It is estimated that in about 20–24% of all colonoscopies, the bowel preparation is inadequate leading to prolonged cecal intubation times and increased overall procedure time with decreased procedure efficacy (9, 10). In a prospective study, it was found that patients with incomplete or poor bowel preparation were independently associated with a lower polyp detection rate and more adenomas going undetected (OR = 3.04, 95% CI 1.04 to 8.88) (9, 10). In patients with inadequate bowel preparation, adenoma miss rates have been found to be as high as 42–47.9% (10, 11).

There has been a debate as to which bowel preparation is the most effective with polyethylene glycol (PEG)-based preparations being used more commonly due to their limited side effects (12–15). In this retrospective observational study, we compared the clinical efficacies of preps based on PEG, sodium sulfate, sodium phosphate, and magnesium for bowel cleansing, and their impact on detecting advanced adenoma and colorectal cancer in multicenter community-based hospitals in central Illinois.

Methods

Study design

This was a population-based, observational study in central Illinois representing a population of about 1.4 million persons. This study utilized a well-administrated database of colonoscopy screening and surveillance from seven hospitals and medical centers, in which 28,782 colonoscopies were enrolled during the period from January 2010 to March 2014 and included their examination histories. The quality of preparation based on the Boston Bowel Preparation scale was evaluated for each bowel preparation type. This study also examined the influence of preparation quality on exam completion and the time of withdrawal after insertion.

Data collection

Shared reporting of colonoscopies (screening and surveillance) in central Illinois was established by the development of a quality of health index database in 2010. The database was initially created by Quality Quest for Health

of Illinois and included seven participating sites: the Central Illinois Endoscopy Center, Decatur Digestive Disease Center, Decatur Memorial Hospital, Methodist Medical Center of Illinois, OSF Saint Francis Medical Center, Pekin Hospital, and Proctor Hospital in the central Illinois. Each site was responsible for abstracting data through their own screening and surveillance colonoscopies and then entering data into the Central Illinois Colonoscopy ACCESS database and electronically transferring data to Quality Quest for Health of Illinois. The database is currently managed by the Department of Medicine in the University of Illinois College of Medicine at Peoria.

The information in the database which was used in this study includes age in years (exam year), gender, previous and current procedure date, personal history of CRC (yes/no), family history of CRC including first and second degree relatives (yes/no), bowel preparation type, bowel preparation assessment (excellent, good, fair, and poor), examination completion (yes/no), American Society of Anesthesiology (ASA) classification score with a range of 1 to 5, and time of withdrawal after insertion (minutes).

Ethical issues

All the data in the database were de-identified. This was a retrospective study where results would not change the course of patient care or current patient outcomes. No risk was involved in collecting patient data as information was the minimum necessary information for research purposes. Also, this study was approved by the Institutional Review Board (IRB) at the University of Illinois College of Medicine at Peoria.

Exclusion criteria

A total of 414 without bowel preparation assessments were excluded resulting in a final dataset that included 28,368 colonoscopies.

Statistical analysis

In order to examine the influence of bowel preparation type on the quality of prep, ordinal logistic regressions were used to estimate odds ratio (OR) and 95% confidence interval (95% CI) compared with its reference group. We employed a logistic regression model to analyze the association between exam completion and preparation quality. A log transformation was used for the time of withdrawal after insertion due to its skewed distribution. Then we conducted a general linear model regression to see if high-quality bowel preparation could decrease the time of withdrawal after insertion. For all the above models, we also did multivariable analyses, which controlled age, gender, ASA score, family history of colorectal cancer, personal history of colorectal cancer, and adenoma detection during the last colonoscopy.

A secondary analysis was performed to examine the impact of preparation quality on detecting any adenoma

or advanced adenoma. Advanced adenoma was defined as a villous/tubulovillous adenoma, severely/high-grade dysplastic polyp, or colorectal cancer based on the polyp histopathology. We excluded those had inadequate preparation (poor) from the secondary analysis because of its low exam completion. After univariate analysis, multivariable logistic regression was used to calculate predicted detection rate of advanced adenoma, and adjusted OR and 95% CI by the level of bowel preparation quality controlling for the above confounders and the time of withdrawal after insertion.

All analyses were conducted with SAS 9.4 (by SAS Institute Inc., Cary, NC, USA). Variables were reported as mean, standard deviation, median, and range for continuous variables, and percentage for categorical variables. A two-tailed *p*-value was calculated for all tests and $p \leq 0.05$ was considered as being of statistical significance.

Results

Demographics

A total of 28,368 colonoscopies; half the patients were male, and the average age was 61 ± 9 years. More than half (56%) did not have a history of prior colonoscopy. The majority (75%) lived with mild-to-moderate medical conditions (ASA score = 2).

The most popular bowel preparation type was PEG-based preparations (70.2%), followed by sodium sulfate-based preparations (21.4%), sodium phosphate-based preparations (2.5%), and magnesium-based preparations (0.4%). The demographics were not consistent among different bowel preparation types (Table 1). Patients who selected sodium phosphate-based preparations were a little younger than others. Around 21.5% of patients who chose magnesium-based preparation were in poor conditions (ASA > 2), which was higher than others.

Bowel preparation type

As it was shown in Table 2, sodium sulfate-based preparations and sodium phosphate-based preparations had six and two times better quality of preparation than PEG-based formulations, respectively (OR = 5.7, 95% CI 5.4–6.1; OR = 2.1, 95% CI 1.8–2.5). Magnesium-based preparation was not as good as PEG-based preps in the quality of preparations (Table 3).

In PEG-based preparation, MoviPrep was better than other PEG-based preparations (OR = 1.3, 95% CI 1.2–1.4). In magnesium-based preparation, no significant difference was found between magnesium citrate only and magnesium citrate with Dulcolax (OR = 0.6, 95% CI 0.3–1.6). In sodium sulfate-based preparation, the effect of Visicol tabs was very similar with Osmoprep (OR = 0.9, 95% CI 0.7–1.2).

Exam completion

A better bowel preparation significantly increased the rate of exam completion (Table 4). Only 88.4% completed exams when the bowel preparation was poor, whereas 99.5% completed exams when the bowel preparation was excellent. The rate of exam completion was also acceptable when the bowel preparation was good or fair.

Time of withdrawal after insertion

The time of withdrawal after insertion was the shortest when bowel preparation assessment was excellent (10.4 ± 5.5 min), followed by good bowel preparation (11.0 ± 6.0 min), poor bowel preparation (12.2 ± 8.5 min), and fair bowel preparation (13.5 ± 7.7 min). See Table 5.

Detection of adenoma and advanced adenoma

Our general polyp detection rate was 44.1% (12,525/28,386), while adenoma detection rate in fair, good, and excellent preps was 51.7, 58.3, and 54.7, respectively. Although the differences of adenoma detection rate among them were not large, the good and excellent preps still increased the likelihood of adenoma detection than the fair prep (OR = 1.1, 95% CI 1.0–1.2; OR = 1.3, 95% CI 1.2–1.4, respectively). As shown in Table 6, we found that the better quality of bowel preparation could significantly increase the detection rate of advanced adenoma (5.0, 3.6, and 2.9% for excellent, good, and fair, respectively).

Discussion

This study compares the impact of bowel preparation type on the quality of colonoscopy in a large, population-based cohort of colonoscopies that were conducted in clinical practice. Considering the fact that the national colorectal roundtable set a goal of increasing colorectal screening to 80% by 2018, the use of screening colonoscopies will continue to increase. It is thus imperative that an excellent bowel preparation is readily available. This will save valuable resources and also play an essential part in improving clinical outcomes and reducing the disease burden of colorectal cancer (11, 16).

A meta-analysis of 104 studies from 1985 to 2010 showed no difference in the efficacy between sodium phosphate-based preparations and PEG (OR = 0.82, 95% CI 0.56–1.21; $p = 0.36$). In addition, PEG-based preparations were found to provide a better cleaning of the proximal portion of the colon (12, 17). Other studies have shown sodium phosphate-based preparations to be superior in terms of bowel preparation and rates of complete examination (12, 18). In addition to this, sodium- and magnesium-based preparations are slightly cheaper as compared with PEG-containing preparations (19). Our results show that sodium sulfate- and sodium phosphate-based preparations had six and two times better quality of bowel preparation when compared with PEG-based preparation, respectively (OR = 5.7, 95% CI 5.4–6.1;

Table 1. Demographics

Items	All population		Column percentage for subgroups ^a						<i>P</i> ^b
	Num.	(%)	A	B	C	D	E	F	
Age in years									
< 50	863	3.0	2.9	1.9	5.8	3.2	2.5	3.5	<0.0001
50–59	12,511	44.1	43.8	44.9	51.9	44.8	42.9	40.3	
60–69	9,395	33.1	33.0	38.3	31.1	33.6	35.4	32.6	
≥ 70	5,617	19.8	20.3	15.0	11.2	18.4	19.3	23.6	
Gender									
Male	14,099	49.7	50.5	46.7	34.0	48.9	41.6	50.6	<0.0001
Female	14,286	50.3	49.5	53.3	66.1	51.1	58.4	49.4	
Not recorded	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
ASA score ^c									
1	4,625	16.3	18.1	12.2	23.3	10.5	9.0	13.6	<0.0001
2	21,296	75.0	72.8	64.5	72.3	83.2	76.4	73.0	
3	2,194	7.7	8.1	21.5	3.1	5.9	13.0	11.2	
4	47	0.2	0.1	0.0	0.3	0.2	0.6	0.4	
5	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Not recorded	222	0.8	0.9	1.9	1.0	0.2	0.9	1.8	
Colonoscopy history									
Yes	12,578	44.3	43.4	38.3	47.8	46.0	43.8	48.8	<0.0001
No	15,760	55.5	56.4	61.7	52.2	54.0	56.2	50.3	
Not recorded	48	0.2	0.2	0.0	0.0	0.0	0.0	1.0	
Personal history of CRC									
Yes	1,087	3.8	3.9	6.5	7.2	2.9	3.7	4.1	<0.0001
No	27,299	96.2	96.1	93.5	92.8	97.1	96.3	95.9	
Family CRC history									
Yes	4,178	14.7	15.8	18.7	18.4	10.6	16.2	14.1	<0.0001
No	24,208	85.3	84.2	81.3	81.6	89.4	83.8	85.9	
Adenoma detection during last colonoscopy									
0	23,389	82.4	79.0	92.5	83.5	91.5	84.5	90.1	<0.0001
1–2 small (< 1 cm)	2,886	10.2	12.3	4.7	9.3	4.5	9.0	5.5	
3+ or any big	2,111	7.4	8.7	2.8	7.2	4.0	6.5	4.4	

^aSubgroups A: PEG-based preparations, *n* = 19,912; B: magnesium-based preparations, *n* = 107; C: sodium phosphate-based preparations, *n* = 707; D: sodium sulfate-based preparations, *n* = 6,081; E: other preparations, *n* = 322; F: not recorded, *n* = 1,257.

^bMissing values were excluded for *p*-value calculation.

^cAmerican Society of Anesthesiology (ASA) classification score was defined as five levels (1 = healthy, no comorbidities; 2 = mild-to-moderate medical conditions controlled; 3 = disease severely limits activities; 4 = severe life-threatening disorders; 5 = moribund).

Table 2. Influence of bowel preparations type on the quality of preparations

Bowel preparations type	<i>N</i>	Bowel prep assessment (%)				Unadjusted OR (95% CI)	Adjusted OR (95% CI)*
		Excellent	Good	Fair	Poor		
PEG-based preparations	19,912	14.5	71.4	12.1	1.9	Ref	Ref
Magnesium-based preparations	107	11.2	65.4	21.5	1.9	0.6 (0.4–0.9)	0.6 (0.4–0.9)
Sodium phosphate-based preparations	707	31.8	58.1	8.1	2.0	2.2 (1.9–2.6)	2.1 (1.8–2.5)
Sodium sulfate-based preparations	6,081	55.8	37.4	5.4	1.4	6.1 (5.7–6.4)	5.7 (5.4–6.1)
Other preparations	322	26.7	52.2	17.1	4.0	1.2 (0.9–1.5)	1.2 (0.9–1.5)
Not recorded	1,257	33.2	50.0	13.3	3.5	1.9 (1.7–2.1)	1.9 (1.6–2.1)

*Ordinal logistic regression was used to calculate the odds ratio (OR) and 95% confidence interval (95% CI) controlling for age, gender, American Society of Anesthesiology classification score, family history of colorectal cancer, personal history of colorectal cancer, and adenoma detection during the last colonoscopy.

Table 3. Influence of bowel preparations subtype on the quality of preparations

Bowel preparations type	N	Bowel prep Assessment (%)				Unadjusted OR (95% CI)*	Adjusted OR (95% CI)*
		Excellent	Good	Fair	Poor		
PEG-based preparation							
MoviPrep	8,274	17.6	69.7	11.0	1.8	1.4 (1.3–1.4)	1.3 (1.2–1.4)
Other PEG-based preparations	11,638	12.4	72.7	12.9	2.1	Ref	Ref
Magnesium-based preparations							
Mag Citrate	42	9.5	66.7	23.8	0.0	0.9 (0.4–2.0)	0.6 (0.3–1.6)
Mag Citrate with Dulcolax	65	12.3	64.6	20.0	3.1	Ref	Ref
Sodium sulfate-based preparations							
Visicol tabs	340	34.1	52.4	11.8	1.8	1.0 (0.7–1.3)	0.9 (0.7–1.2)
Osmoprep	367	29.7	63.5	4.6	2.2	Ref	Ref

*Ordinal logistic regression was used to calculate the odds ratio (OR) and 95% confidence interval (95% CI) controlling for age, gender, American Society of Anesthesiology classification score, family history of colorectal cancer, personal history of colorectal cancer, and adenoma detection during the last colonoscopy.

OR = 2.1, 95% CI 1.8–2.5). Magnesium-based preparations were found to be inferior to PEG-based formulations (OR = 0.6, 95% CI 0.4–0.9).

PEG was most commonly used in our study (70.2% patients). PEG- and sodium-based bowel preparations had acceptable levels of bowel cleanliness, mostly ranging from fair to good with a good response in 60–70% of the patients, independent of the type of preparation being used. In our study, 19,912 patients used PEG-based preparation and out of these only 14.5% had excellent preparations, where as 31.8 and 55.8% with sodium phosphate- and sodium sulfate-based formulations had excellent preparations, respectively. These results were consistent with several previous studies in which patients with sodium-based preparations had better results as well as superior completion rates (12, 20). Excellent bowel preparation was found in 58% (CI 49–67%) of the patients taking sodium phosphate tablets, 42.1% (CI 33–51%) for sodium phosphate solution, and 33.7% (CI 26–41%) for those who had used 4 L PEG (20). In a meta-analysis of seven randomized trials comparing sodium phosphate and PEG solution, the relative risk of having an excellent preparation was 1.28 (95% CI 1.11–1.48) in favor of

sodium phosphate (NNT = 10) (18). Similarly, other studies have shown that sodium phosphate is also superior to sodium picosulfate in terms of bowel purging activity with a similar side-effect profile (21, 22).

Completion rates of colonoscopy did not vary significantly between fair, good, and excellent preparations (99.5, 99.4, and 99.1%, respectively) but had almost a 12% decline in patients with poor preparation (88.4%). These results are in contrast to a recent study in which completion rates were significantly lower in patients with fair and poor bowel preparations (75.4 and 72.1%, respectively) as compared with those with good and excellent bowel preparations (99.7 and 99.9%, respectively; $p < 0.001$) (23). This difference could possibly be because of smaller number of patients in their study (23). Other studies have reported a completion rate of 90% in people with intermediate and high-quality preparations while completion rates of 70% in those with low-quality bowel preparations (24). Our study clearly shows that withdrawal times were faster in patients with excellent and good preparation (10.4 ± 5.5 and 11.0 ± 6.0 min, respectively) while those with fair and poor preparation had longer withdrawal times after insertion (13.5 ± 7.7 and

Table 4. Association between preparations quality and exam completion

Bowel preparations assessment	N	Complete exam (%)	Not complete exam (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)*
Excellent	7,025	99.5	0.5	27.8 (18.0–42.7)	26.6 (17.1–41.4)
Good	17,774	99.4	0.6	21.6 (15.6–29.9)	18.9 (13.5–26.5)
Fair	3,043	99.1	0.9	14.1 (8.9–22.2)	13.8 (8.7–21.8)
Poor	544	88.4	11.6	Ref	Ref

*Logistic regression was used to calculate the odds ratio (OR) and 95% confidence interval (95% CI) controlling for age, gender, American Society of Anesthesiology classification score, family history of colorectal cancer, personal history of colorectal cancer, and adenoma detection during the last colonoscopy.

Table 5. Association between preparations quality and time of withdrawal after insertion

Bowel preparations assessment	N	Mean \pm SD (minute) ^A	Median/range (minute)	Unadjusted P	Adjusted P*
Excellent	6,989	10.4 \pm 5.5	9 (0–70)	Ref	Ref
Good	17,651	11.0 \pm 6.0	9 (0–71)	<0.001	<0.001
Fair	3,017	13.5 \pm 7.7	11 (0–73)	<0.001	<0.001
Poor	499	12.2 \pm 8.5	10 (0–57)	0.346	0.937

^ASD is standard deviation.

*General linear model was used to estimate the time of withdrawal after insertion at each level of bowel preparations quality controlling for age, gender, American Society of Anesthesiology classification score, family history of colorectal cancer, personal history of colorectal cancer, and adenoma detection during the last colonoscopy.

12.2 \pm 8.5, respectively). The longer withdrawal time in fair preparation could be due to higher completion rates and effort by physicians in patients with poor preparation of which only 88.4% underwent complete examination as compared with 99% of those with fair preparation who underwent complete exam.

Previous studies have shown that inadequate bowel preparation decreases the adenoma detection rate (25–27). Other studies have also suggested that the adenoma detection rate is comparable in patients with fair-quality bowel preparation and those with adequate bowel preparation (25, 28). The overall adenoma detection rate in our study was 44.1% which is comparable with other studies and well above the 30% mark set by the American College of Gastroenterology Task Force (29). This supports the fact that the quality of colonoscopic examination in our study was consistent with national standards. We found better bowel preparations could increase the detection rate of adenoma, especially advanced adenoma. Advanced adenoma detection rate was 2.9% in those with fair bowel prep as compared with 3.6 and 5% in those with good and excellent bowel preparations, respectively. Our results clearly suggest that the odds of finding an advanced polyp in a patient with excellent bowel preparation was almost two times higher compared with those with fair prep (OR = 1.8, 95% CI 1.5–2.1).

The limitations of our study include the retrospective design of the study. We did not record whether the patients

received split-dose preparation or nightly preparations in the case of PEG-based preparations. We did not measure true adenoma missed rates by performing follow-up colonoscopies in patients with poor or fair bowel preparation. Side effects due to various bowel preparations were also not recorded. Other confounding factors that could have altered outcomes include concomitant laxative use, hydration variability, and differences in patient compliance across various groups and hospitals.

In summary, while PEG-based preparations continue to be used most commonly, the search for an ideal bowel purge, which is inexpensive, offers good outcomes with a high success rate, with relatively no side effects continues to be a goal for physicians. We recommend that sodium-based bowel preparations should be used whenever possible as sodium-based preparations appear superior to PEG- and magnesium-based preparations according to our study results. Further, the findings suggest that adequate bowel preparation not only improves withdrawal times but also enhances the adenoma detection rate in specifically advanced adenomas. In addition, our results also support the finding that patients with fair bowel preparation should also be screened earlier to enhance the chances of detecting any missed adenomas. With an increasing population of patients entering into colorectal cancer screening age, the volume of screening colonoscopies will increase. Continued exploration for an optimal bowel

Table 6. Association between preparations quality and detection rate of advanced adenoma/adenoma detection rate

Bowel Preparation Assessment	N	Advanced adenoma detection			Adenoma detection rate		
		Predicted rate (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)*	Predicted rate (%)	Unadjusted RR (95% CI)	Adjusted RR (95% CI)*
Excellent	7,025	5.0	1.2 (1.1–1.4)	1.8 (1.5–2.1)	54.7	0.7 (0.6–0.7)	1.1 (1.0–1.2)
Good	17,774	3.6	1.3 (1.1–1.5)	1.3 (1.1–1.5)	58.3	0.9 (0.8–0.9)	1.3 (1.2–1.4)
Fair	3,043	2.9	Ref	Ref	51.7	Ref	Ref

*Logistic regression was used to calculate the odds ratio (OR), 95% confidence interval (95% CI), and predicted detection rate controlling for age, gender, American Society of Anesthesiology classification score, family history of colorectal cancer, personal history of colorectal cancer, adenoma detection during the last colonoscopy, and time of withdrawal after insertion.

preparation remains essential for continued reduction in colorectal cancer.

Authors' contributions

The study was conceptualized and designed by DM, JR, and SD. The manuscript was drafted and revised by SW, JR, DM, CA, SD, ZA, and SP. Statistical analysis was done by JR, and data were acquired by CA and JR.

Acknowledgements

We thank all individuals who participated in this study and Karen Fenelon for her support of data management.

Conflict of interest and funding

All authors have disclosed that they have no significant relationships with or financial interests in any commercial companies related to this study or article. Post presentation was at the Digestive Disease Week (DDW) 2015 conference in Washington, DC (May 16–19, 2015).

References

- Siegel R, Ma J, Zou Z, Jemal A. Global cancer statistics, 2014. *CA Cancer J Clin* 2014; 64(1): 9–29.
- Kahi CJ, Imperiale TF, Juliar BE, Rex DK. Effect of screening colonoscopy on colorectal cancer incidence and mortality. *Clin Gastroenterol Hepatol* 2009; 7(7): 770–5.
- Lieberman DA, Holub J, Eisen G, Kraemer D, Morris CD. Utilization of colonoscopy in the United States: Results from a national consortium. *Gastrointest Endosc* 2005; 62(6): 875–83.
- Centers for Disease Control and Prevention. Vital signs: Colorectal cancer screening, incidence, and mortality – United States, 2002–2010. *MMWR Morb Mortal Wkly Rep* 2011; 60: 884–90.
- Winawer SJ, Zauber AG, Ho MN, O'Brien MJ, Gottlieb LS, Sternberg SS, et al. Prevention of colorectal cancer by colonoscopic polypectomy. *N Engl J Med* 1993; 329(27): 1977–81.
- de Groen PC, Li YJ, Xirasagar S. Long-term colorectal-cancer mortality after adenoma removal. *N Engl J Med* 2014; 371(21): 2035–7.
- Corley DA, Jensen CD, Marks AR, Zhao WK, Lee JK, Doubeni CA, et al. Adenoma detection rate and risk of colorectal cancer and death. *N Engl J Med* 2014; 370(14): 1298–306.
- Rex DK, Imperiale TF, Latinovich DR, Bratcher LL. Impact of bowel preparation on efficiency and cost of colonoscopy. *Am J Gastroenterol* 2002; 97(7): 1696–700.
- Hong SN, Sung IK, Kim JH, Choe WH, Kim BK, Ko SY, et al. The effect of the bowel preparation status on the risk of missing polyp and adenoma during screening colonoscopy: A tandem colonoscopic study. *Clin Endosc* 2012; 45(4): 404–11.
- Lebwohl B, Kastrinos F, Glick M, Rosenbaum AJ, Wang T, Neugut AI. The impact of suboptimal bowel preparation on adenoma miss rates and the factors associated with early repeat colonoscopy. *Gastrointest Endosc* 2011; 73(6): 1207–14.
- Peery AF, Crockett SD, Barritt AS, Dellon ES, Eluri S, Gangarosa LM, et al. Burden of gastrointestinal, liver, and pancreatic diseases in the United States. *Gastroenterology* 2015; 149(7): 1731–41.
- Belsey J, Crosta C, Epstein O, Fischbach W, Layer P, Parente F, et al. Meta-analysis: The relative efficacy of oral bowel preparations for colonoscopy 1985–2010. *Aliment Pharmacol Ther* 2012; 35(2): 222–37.
- Tan JY, Tjandra JJ. Which is the optimal bowel preparation for colonoscopy – A meta-analysis. *Colorectal Dis* 2006; 8(4): 247–58.
- Thomson A, Naidoo P, Crotty B. Bowel preparation for colonoscopy: A randomized prospective trial comparing sodium phosphate and polyethylene glycol in a predominantly elderly population. *J Gastroenterol Hepatol* 1996; 11(2): 103–7.
- Sharara AI, Mrad RR. The modern bowel preparation in colonoscopy. *Gastroenterol Clin North Am* 2013; 42(3): 577–98.
- Ortman JM, Velkoff VA, Hogan H. An aging nation: The older population in the United States, p. 25–1140. Washington, DC: US Census Bureau; 2014.
- Belsey J, Epstein O, Heresbach D. Systematic review: Oral bowel preparation for colonoscopy. *Aliment Pharmacol Ther* 2007; 25(4): 373–84.
- Hsu CW, Imperiale TF. Meta-analysis and cost comparison of polyethylene glycol lavage versus sodium phosphate for colonoscopy preparation. *Gastrointest Endosc* 1998; 48(3): 276–82.
- Barkun A, Chiba N, Enns R, Marcon M, Natsheh S, Pham C, et al. Commonly used preparations for colonoscopy: Efficacy, tolerability and safety – A Canadian Association of Gastroenterology position paper. *Can J Gastroenterol* 2006; 20(11): 699.
- Juluri R, Eckert G, Imperiale TF. Polyethylene glycol vs. sodium phosphate for bowel preparation: A treatment arm meta-analysis of randomized controlled trials. *BMC Gastroenterol* 2011; 11(1): 38.
- Yoshioka K, Connolly AB, Ogunbiyi OA, Hasegawa H, Morton DG, Keighley MR. Randomized trial of oral sodium phosphate compared with oral sodium picosulphate (Picolax) for elective colorectal surgery and colonoscopy. *Dig Surg* 2000; 17(1): 66–70.
- Tjandra JJ, Chan M, Tagkalidis PP. Oral sodium phosphate (Fleet®) is a superior colonoscopy preparation to Pico-prep® (sodium picosulfate-based preparation). *Dis Colon Rectum* 2006; 49(5): 616–20.
- Rai T, Navaneethan U, Gohel T, Podugu A, Thota PN, Kiran RP, et al. Effect of quality of bowel preparation on quality indicators of adenoma detection rates and colonoscopy completion rates. *Gastroenterol Rep* 2015; 12: gov002.
- Froehlich F, Wietlisbach V, Gonvers JJ, Burnand B, Vader JP. 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(3): 378–84.
- Sherer EA, Imler TD, Imperiale TF. The effect of colonoscopy preparation quality on adenoma detection rates. *Gastrointest Endosc* 2012; 75(3): 545–53.
- Harewood GC, Sharma VK, de Garmo P. Impact of colonoscopy preparation quality on detection of suspected colonic neoplasia. *Gastrointest Endosc* 2003; 58(1): 76–9.
- Johnson DA, Barkun AN, Cohen LB, Dominitz JA, Kaltenbach T, Martel M, et al. Optimizing adequacy of bowel cleansing for colonoscopy: Recommendations from the US multi-society task force on colorectal cancer. *Am J Gastroenterol* 2014; 147(4): 903–24.
- Anderson JC, Butterly LF, Robinson CM, Goodrich M, Weiss JE. Impact of fair bowel preparation quality on adenoma and serrated polyp detection: Data from the New Hampshire Colonoscopy Registry by using a standardized preparation-quality rating. *Gastrointest Endosc* 2014; 80(3): 463–70.
- Chaptini L, Laine L. Can I improve my adenoma detection rate? *J Clin Gastroenterol* 2015; 49(4): 270–81.