Title

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Journal

Journal of the American College of Surgeons, 220(5)

ISSN

1072-7515

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Publication Date

2015-05-01

DOI

10.1016/j.jamcollsurg.2015.02.008

Peer reviewed

Nationwide Analysis of Outcomes of Bowel Preparation in Colon Surgery

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BACKGROUND: There are limited data comparing the outcomes of preoperative oral antibiotic bowel preparation (OBP) and mechanical bowel preparation (MBP) in colorectal surgery. We sought to identify the relationship between preoperative bowel preparations (BP) and postoperative complications in colon cancer surgery.

STUDY DESIGN: The NSQIP database was used to examine the clinical data of colon cancer patients undergoing scheduled colon resection during 2012 to 2013. Multivariate regression analysis was performed to identify correlations between BP and postoperative complications.

RESULTS: We evaluated a total of 5,021 patients who underwent elective colon resection. Of these, 44.8% had only MBP, 2.3% had only OBP, 27.6% had both MBP and OBP, and 25.3% of patients did not have any type of BP. In multivariate analysis of data, MBP and OBP were not associated with decreased risk of postoperative complications in right side (adjusted odds ratio [AOR] 0.80, 0.30, $p = 0.08$, 0.10, respectively) or left side colon resections (AOR 1.02, 0.68, $p = 0.81$, 0.24, respectively). However, the combination of MBP and OBP before left side colon resections resulted in a significantly decreased risk of overall morbidity (AOR 0.63, $p < 0.01$), superficial surgical site infection (AOR 0.31, $p < 0.01$), anastomosis leakage (AOR 0.44, $p < 0.01$), and intra-abdominal infections (AOR 0.44, $p < 0.01$).

CONCLUSIONS: Our analysis revealed that solitary mechanical bowel preparation and solitary oral bowel preparation had no significant effects on major postoperative complications after colon cancer resection. However, a combination of mechanical and oral antibiotic preparations showed a significant decrease in postoperative morbidity.

Infectious complications after colorectal resections are some of the most severe postoperative complications, leading to an increase in mortality, morbidity, hospital cost, and length of hospitalization.[1,2] Infectious complications, with a 40% incidence rate, were one of the main causes of mortality and morbidity in patients undergoing colorectal surgery in the first half of the 20th century.[2-4] Improvements in perioperative care and surgical techniques during the last few decades have significantly decreased postoperative infectious complications. However, infectious complications still remain a major cause of morbidity in colorectal patients.[1,2] Given this ongoing problem, it is important to recognize risk factors and effective risk reduction strategies for infectious

complications before surgery in an effort to reduce the morbidity and mortality of these patients.

Mechanical and oral antibiotic bowel preparations have been used by surgeons for decades in an attempt to decrease postoperative infectious complications.[2] However, during the last 2 decades, there has been growing controversy regarding the effects of mechanical bowel preparation (MBP) on postoperative infectious complications.[2,5-9] Moreover, some recent studies reported that MBP is actually harmful to colorectal surgery patients.[6,8,10,11] Although several studies have reported no benefits of MBP for elective colorectal surgery, its use remains widespread among surgeons.[12,13] The strategies for limiting MBP in clinical practice across Europe and the United States have been met with resistance.[14] In a survey of the members of the American Society of Colon and Rectal Surgeons in the United States in 2003, 99% of respondent surgeons reported that they use MBP routinely.[12] In a multinational survey in Europe and the US, more than 85% of colorectal patients underwent preoperative MBP in 2006.[14] Although that trend has changed in recent years, most of the change has been limited to right side resections, even though the data do not allow that distinction. It is unclear why surgeons have not changed their practice.[15] The major hurdles may be a reluctance to change.[15] Recent guidelines did not suggest discarding MBP entirely, but they did suggest that MBP should not be used routinely in colonic surgery.[16-18] Deciding whether MBP is needed in elective colorectal surgery is difficult. Therefore, this study aimed to report the contemporary status of MBP and oral antibiotic bowel preparation (OBP) in the United States (US), and to investigate associations between these bowel preparations (BPs) with postoperative complications in right side and left side colon cancer resections.

Abbreviations and Acronyms
AOR = adjusted odds ratio
BP = bowel preparation
MBP = mechanical bowel preparation
OBP = oral antibiotic bowel preparation
SSI = surgical site infection

METHODS

This study was performed using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database for 2012 and 2013. The ACS NSQIP is a large, validated outcomes-based program that provides preoperative to 30-day postoperative surgical outcomes based on clinical data to improve the quality of surgical care in the United States.[19] This study evaluated patients who had colon cancer and underwent elective colon resections using the appropriate procedure codes as specified by the Current Procedural Terminology (CPT) codes. Patients who had colon procedures were defined based on the following CPT codes: 44140-44147, 44204-44208, 44160, and 44213. Patients who underwent colon surgery without colon resection, patients with missing data regarding preoperative BP, and patients younger than 18 years were excluded from this study (Fig. 1).

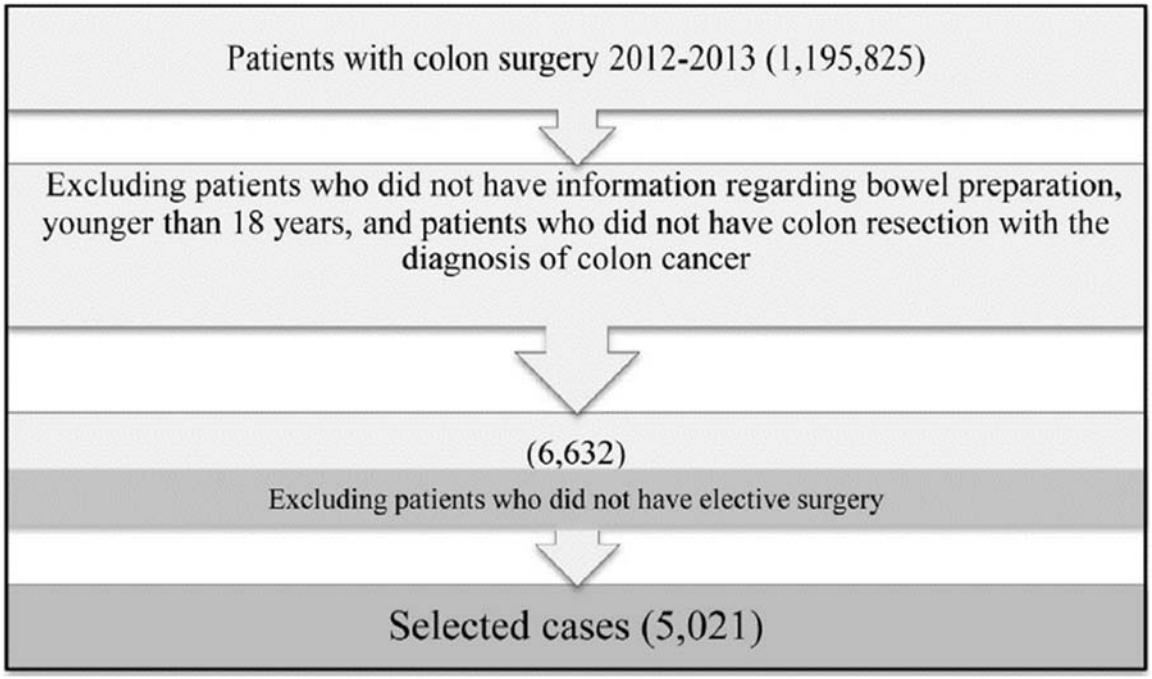

Figure 1. Inclusion and exclusion criteria in case selection for the study.

Patient diagnoses were defined based on the International Classification of Diseases, 9th Revision, clinical modifications (ICD-9-CM) codes of 153.0-153.9, 154.0, 154.1, 230.3, and 230.4. We categorized patients into 4 groups: patients who had MBP only, patients who had OBP only, patients who had a combination of mechanical and oral antibiotic BP, and patients who did not have any BP. Also, procedures were categorized into 2 groups: right side colon resections (cecum, ascending colon, hepatic flexure colon, and transverse colon) and left side colon resections (splenic flexure, descending colon, sigmoid, and rectosigmoid junction).

Preoperative factors analyzed in the study included patient characteristics (age, sex, and race) and comorbidity conditions, which included history of congestive heart failure within 30 days before surgery, renal failure with need for dialysis, history of dyspnea within the 30 days before surgery, bleeding disorder, steroid use within the 30 days before surgery, diabetes mellitus, preoperative sepsis (systemic inflammatory response syndrome, sepsis, or septic shock within 48 hours before surgery), weight loss (more than 10% in last 6 months), history of severe COPD, current smoker within 1 year, ascites within 30 days before surgery, weight loss, hypertension requiring medication, American Society of Anesthesiologists (ASA) class, partial or complete dependency before surgery as a measure of functional health status, and bleeding disorders. Operative factors analyzed included surgical approach (open vs laparoscopic), cancer stage, and wound classification (clean, clean/contaminated, contaminated, and dirty/infected). The primary end points investigated included mortality, overall morbidity, anastomosis leakage, postoperative superficial surgical site infection (SSI), organ space SSI, wound disruption, deep vein thrombosis, pneumonia, unplanned intubation, ventilator dependency more than 48 hours, pulmonary embolism, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, progressive renal insufficiency, sepsis, septic shock, hemorrhagic complications, return to operation room, urinary tract

infections, and prolonged hospitalization (longer than 30 days). The overall rates of each complication according to the use of BPs and resection were examined. Risk adjusted analysis was performed to compare the outcomes of patients who did not have BPs with patients who had MBP or OBP.

Statistical analysis

Statistical analysis was performed with the SPSS software, Version 22 (SPSS, Inc). Logistic regression analysis was used to estimate the association between preoperative BPs and each outcome, including in-hospital mortality and all of the considered postoperative complications. Values of $p < 0.05$ were considered statistically significant. For each outcome, the adjusted odds ratio (AOR) with 95% confidence interval was calculated and reported to estimate the relative risk associated with BPs. Adjustments were made for hypertension, smoking, diabetes mellitus, COPD, congestive heart failure, weight loss, ascites, preoperative sepsis, dyspnea, renal failure need dialysis, steroid use, American Society of Anesthesiologists (ASA) score, dependency before surgery, bleeding disorders, type of the admission, cancer stage, surgical approach (open vs laparoscopic), wound classification, age, sex, and race.

RESULTS

A total of 5,021 patients who underwent elective colon resection during 2012 to 2013 were identified. The median patient age was 66 years old; the majority of the patients were Caucasian (86.9%) and male (53.8%). The most common colon cancer stage was stage 3 (33%) followed by stage 2 (28.1%). The most common comorbidities included hypertension (52.4%) and diabetes (18%). Demographic data of patients are reported in Table 1. Overall, 72.4% of patients had MBP with or without OBP. Also, the rate of MBP was significantly higher in left side resections compared with right side colon resections (76.9% vs 65.7%). Among patients who underwent colon resection, 117 (2.3%) had only OBP, 2,248 (44.8%) had only MBP, 1,386 (27.6%) had MBP and OBP, and 1,270 (25.3%) did not have any BP. The mortality rates for patients with OBP, MBP, MBP and OBP, and patients without any BP were 1.7%, 1.2%, 1.1%, and 2.5%, respectively (Table 2).

Table 1. Demographics of Patients with Diagnosis of Colon Cancer after Colon Resection

Variables	Patients without BP (n = 1,270)	Patients with mechanical BP (n = 2,248)	Patients with oral antibiotic BP (n = 117)	Patients with mechanical and oral antibiotic BP (n = 1,386)
Age, y				
Mean	67±13	65±13	66±14	64±13
Median	67	65	66	65
Male, n (%)	665 (52.4)	1,229 (54.7)	60 (51.3)	746 (53.8)
Race, n (%)				
White	883 (86.2)	1,768 (86.6)	86 (81.1)	1,158 (88.2)
Black or African American	100 (9.8)	145 (7.1)	13 (12.3)	97 (7.4)
Asian	41 (4)	119 (5.8)	7 (6.6)	50 (3.8)
Others	0	10 (0.4)	0	10 (0.6)
Comorbidity, n (%)				
ASA score > 2	686 (54.1)	1,245 (55.5)	69 (59)	766 (55.3)
Hypertension	683 (53.8)	1,182 (52.6)	65 (55.6)	699 (50.4)
Diabetes mellitus	214 (16.9)	419 (18.6)	20 (17.1)	250 (18)
Smoking	175 (13.8)	298 (13.3)	14 (12)	211 (15.2)
Dyspnea	114 (9)	181 (8.1)	8 (6.8)	111 (8)
COPD	62 (4.9)	123 (5.5)	4 (3.4)	78 (5.6)
Weight loss	59 (4.6)	116 (5.2)	5 (4.3)	73 (5.3)
Bleeding disorder	44 (3.5)	78 (3.5)	6 (5.1)	36 (2.6)
Steroid use	35 (2.8)	67 (3)	4 (3.4)	38 (2.7)
Dependency before surgery*	25 (2)	34 (1.5)	3 (2.6)	28 (2)
Preoperative sepsis†	18 (1.4)	31 (0.8)	1 (0.9)	26 (1.1)
Congestive heart failure	9 (0.7)	16 (0.7)	0	12 (0.9)
Ascites	5 (0.4)	11 (0.5)	0	2 (0.1)
Renal failure need to dialysis	2 (0.2)	7 (0.3)	3 (2.6)	2 (0.1)
Surgical technique, n (%)				
Laparoscopic surgery	768 (60.5)	1,408 (62.6)	65 (55.6)	790 (57)
Open surgery	502 (39.5)	840 (37.4)	52 (44.4)	596 (43)
Colon cancer stage, n (%)				
1	122 (20.3)	225 (23.7)	13 (26.5)	168 (24.6)
2	183 (30.6)	254 (26.7)	14 (28.6)	191 (28)
3	185 (30.8)	320 (33.7)	14 (28.6)	234 (34.4)
4	110 (18.3)	151 (15.9)	8 (16.3)	89 (13)

*Partial or complete dependency before surgery.

†Preoperative sepsis, septic shock, or systemic inflammatory response syndrome.

ASA, American Society of Anesthesiologists; BP, bowel preparation.

Table 2. Postoperative Complications of Colon Cancer Patients Who Underwent Colectomy by Type of Bowel Preparations

	Patients without BP (n = 1,270)		Patients with mechanical BP (n = 2,248)		Patients with oral antibiotic BP (n = 117)		Patients with mechanical and oral antibiotic BP (n = 1,386)	
Complication	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Mortality	32	2.5	28	1.2	2	1.7	15	1.1
Overall morbidity	368	29.0	592	26.3	23	19.8	274	19.8
Infectious*	218	17.2	361	16.1	14	12	126	9.1
Hemorrhagic	142	11.2	212	9.4	10	8.5	118	8.5
Superficial SSI	104	8.2	150	6.7	3	2.6	31	2.2
Organ space SSI	73	5.7	116	5.2	4	3.4	43	3.1
Anastomosis leakage	65	5.1	110	4.9	4	3.4	34	2.5
Return to operation room	60	4.7	120	5.3	6	5.1	58	4.2
Sepsis	42	3.3	71	3.2	4	3.4	33	2.4
Unplanned intubation	30	2.4	39	1.7	3	2.6	26	1.9
Urinary tract infection	28	2.2	71	3.2	3	2.6	33	2.4
Pneumonia	25	2.0	44	2.0	1	0.9	18	1.3
Hospitalization > 30 d	23	1.8	27	1.2	0	0	11	0.8
Deep vein thrombosis	19	1.5	24	1.1	0	0	21	1.5
Septic shock	19	1.5	32	1.4	2	1.7	16	1.2
Ventilator dependency	18	1.4	36	1.6	2	1.7	17	1.2
Cardiac arrest	12	0.9	14	0.6	1	0.9	7	0.5
Wound disruption	11	0.9	18	0.8	1	0.9	6	0.4
Myocardial infarction	9	0.7	19	0.8	0	0	6	0.4
Pulmonary embolism	4	0.3	12	0.5	0	0	18	1.3
PRI	4	0.3	14	0.6	1	0.9	13	0.9

*Pneumonia, sepsis, septic shock, superficial SSI, organ space SSI, urinary tract infection, and pneumonia.
BP, bowel preparation; PRI, progressive renal insufficiency; SSI, surgical site infection.

After risk adjustment, different types of BPs did not have significant effects on mortality of patients (Tables 3 and 4). However, compared with patients without BPs, patients who had combination of MBP and OBP had significantly lower morbidity rates (Tables 3 and 4).

The mean lengths of hospitalization for patients with OBP, MBP, MBP and OBP, and patients without any BPs were 7, 7, 6, and 7 days, respectively. Patients who had MBP and OBP, after risk adjustment, had a 1-day shorter mean hospitalization compared with patients without any BPs (mean difference 0.52 to 1.41, $p < 0.01$).

The risk-adjusted analysis for postsurgical complications associated with BPs by type of the resection is reported in Tables 3 and 4. Postoperative intra-abdominal infections (AOR 0.44, $p < 0.01$), anastomosis leakage (AOR 0.44, $p < 0.01$), and superficial surgical site infection (SSI) (AOR 0.31, $p < 0.01$) were significantly lower in patients who had a combination of MBP and OBP and underwent left side colon resection (Fig. 2 and Table 4). Also, patients who had the combination of MBP and OBP and underwent right side colon resection had a significantly lower rate of superficial SSI compared with patients who did not have any BPs (AOR 0.14, $p < 0.01$) (Table 3).

The risk-adjusted analysis for postsurgical complications associated with MBP and OBP according to the side of colon resection (right and left) is reported in Tables 3 and 4. The MBP and OBP did not have significant associations with any postoperative complications.

DISCUSSION

Although OBP and MBP separately did not have any associations with mortality or overall major morbidity of colon resection patients, our results showed that a combination of OBP and MBP was associated with decreased risk of morbidity in both right side and left side colon resections. The benefits of the combination of OBP and MBP in right side colon resections are limited to the decreased risk of SSI. However, the combination of OBP and MBP in left side colon resections is associated with significant decrease in complications such as intra-abdominal infection, superficial SSI, and anastomosis leakage. Similar to previously published reports, we found no meaningful benefits of using solitary MBP. However, the effect of a combination of MBP and OBP was not assessed in recent clinical trials. Considering the results of a recently published retrospective study in Michigan, which reported similar results regarding benefits of MBP and OBP use, further large, randomized, and prospective clinical trial studies are needed to validate these findings.[20]

Our results confirm the recent published report of a significant decrease in the rates of superficial and organ space SSI with the use of a dual BP, by Kim and colleagues.[20] These investigators, analyzing 2,475 patients who had colectomy, found that patients receiving dual BP are less likely to have any SSI and organ space infection. Surprisingly, they reported that patients receiving full preparation are also less likely to develop postoperative C difficile colitis.[20] Considering the retrospective nature of our study, it is not possible to establish a causal link between dual preoperative BP and postoperative SSI, and further clinical studies are needed to validate these findings.

The combination of MBP and OBP has more benefits in decreasing postoperative complications of left side colon resections compared with right side colon resections. This study found a significant decrease in risks of superficial SSI, intra-abdominal infections, and anastomosis leakage with the combination of MBP and OBP in left side colon resections. However, the benefits of BP in right side colon resections are limited to a decrease in superficial SSI. This finding may be related to the differences in the kind and number of bacterial content in the luminal contents between the right colon and left colon due to differences in physiology and motility between the right colon and left colon, which create different environments for bacteria.[21-23]

A total of 72.4% of patients who underwent colon resection had mechanical BP with or without OBP. Comparing our results with the multinational survey in Europe and the US from 2006, which reported that more than 85% of patients underwent mechanical BP, it appears there is a growing trend toward decreasing the use of preoperative MBP and more selective use of BP among surgeons.14,18 However, the rate of MBP use in our study demonstrates that most surgeons have not discarded the use of MBP entirely. When comparing mechanical BP in right side colon resections with left side colon resections, the rate of mechanical BP was significantly higher in left side resections (76.9% vs 65.7%). This can be explained by some surgeons discontinuing use of MBP for right side colon surgery, apparently in response to international trials.

Table 3. Risk Adjusted Analysis of Outcomes Associated with Bowel Preparation in Patients with Colon Cancer after Right Side Colon Resections

	Patients with oral antibiotic BP		Patients with mechanical BP		Patients with mechanical and oral antibiotic BP	
Complication	AOR (95% CI)	p Value	AOR (95% CI)	p Value	AOR (95% CI)	p Value
Mortality	0.75 (0.06–9.50)	0.83	0.73 (0.32–1.66)	0.46	0.58 (0.21–1.56)	0.28
Overall morbidity	0.30 (0.12–1.74)	0.10	0.80 (0.63–1.03)	0.08	0.65 (0.49–0.87)	<0.01
Infectious*	0.23 (0.05–1.08)	0.06	0.91 (0.67–1.24)	0.56	0.48 (0.32–0.72)	<0.01
Superficial SSI	0.91 (0.89–1)	0.33	0.72 (0.48–1.09)	0.12	0.14 (0.06–0.33)	<0.01
Anastomosis leakage	0.54 (0.06–4.46)	0.56	1.07 (0.58–1.97)	0.82	0.68 (0.30–1.50)	0.34
Wound disruption	0.99 (0.98–1)	0.49	0.57 (0.15–2.18)	0.42	0.99 (0.98–1)	0.49
Ventilator dependency	0.99 (0.98–1)	0.49	2.63 (0.82–8.41)	0.10	2.52 (0.68–9.26)	0.16
PRI	0.99 (0.99–1)	0.63	0.36 (0.04–2.72)	0.32	1.54 (0.28–8.35)	0.61
Hospitalization > 30 d	0.98 (0.97–1)	0.33	1.14 (0.38–3.38)	0.80	0.97 (0.27–3.46)	0.96
Sepsis	2.08 (0.38–11.41)	0.39	1.62 (0.76–3.44)	0.20	1.10 (0.45–2.67)	0.83
Myocardial infarction	0.99 (0.98–1)	0.57	2.16 (0.62–7.44)	0.22	0.57 (0.08–3.66)	0.55
Septic shock	0.98 (0.97–1)	0.43	1.51 (0.59–3.84)	0.38	1.04 (0.34–3.12)	0.94
Organ space SSI	0.63 (0.07–5.13)	0.67	1.02 (0.56–1.85)	0.92	0.75 (0.36–1.57)	0.45
Unplanned intubation	0.59 (0.05–5.95)	0.65	0.91 (0.45–1.82)	0.79	1.113 (0.52–2.45)	0.75
Deep vein thrombosis	0.98 (0.96–1)	0.31	0.85 (0.36–1.99)	0.72	1.12 (0.47–2.67)	0.79
Hemorrhagic	0.51 (0.17–1.55)	0.23	0.71 (0.50–1)	0.06	0.79 (0.54–1.16)	0.24
Pneumonia	0.98 (0.97–1)	0.35	1.57 (0.70–3.50)	0.27	0.64 (0.22–1.85)	0.41
Pulmonary embolism	0.99 (0.99–1)	0.69	2.15 (0.28–16.47)	0.46	3.96 (0.73–21.40)	0.10
Return to operation room	0.95 (0.94–1)	0.14	1.15 (0.67–1.99)	0.59	0.95 (0.50–1.80)	0.87
Cardiac arrest	1.84 (0.05–58.3)	0.72	1.29 (0.34–4.84)	0.70	0.41 (0.05–3.29)	0.40
Urinary tract infection	1.09 (0.13–8.57)	0.93	1.50 (0.72–3.13)	0.26	1.33 (0.56–3.15)	0.51

*Pneumonia, sepsis, septic shock, superficial SSI, organ space SSI, urinary tract infection, and pneumonia.

AOR, adjusted odds ratio; BP, bowel preparation; PRI, progressive renal insufficiency; SSI, surgical site infection.

Table 4. Risk Adjusted Analysis of Outcomes Associated with Bowel Preparation in Colon Cancer Patients after Left Side Colon Resections

	Patients with oral antibiotic BP		Patients with mechanical BP		Patients with mechanical and oral antibiotic BP	
Complication	AOR (95% CI)	p Value	AOR (95% CI)	p Value	AOR (95% CI)	p Value
Mortality	0.56 (0.07–4.35)	0.58	0.47 (0.19–1.13)	0.09	0.42 (0.13–1.33)	0.14
Overall morbidity	0.68 (0.35–1.30)	0.24	1.02 (0.81–1.29)	0.81	0.63 (0.48–0.83)	<0.01
Infectious*	0.69 (0.32–1.44)	0.32	0.91 (0.70–1.18)	0.49	0.48 (0.34–0.66)	<0.01
Organ space SSI	0.63 (0.17–2.26)	0.48	0.74 (0.51–1.09)	0.13	0.44 (0.26–0.73)	<0.01
Superficial SSI	0.36 (0.10–1.35)	0.13	0.84 (0.57–1.23)	0.38	0.31 (0.18–0.53)	<0.01
Anastomosis leakage	0.56 (0.13–2.34)	0.43	0.89 (0.59–1.34)	0.59	0.44 (0.25–0.78)	<0.01
Wound disruption	0.50 (0.009–29.38)	0.74	1.19 (0.37–3.79)	0.75	1.37 (0.34–5.55)	0.65
Ventilator dependency	1.63 (0.26–10.01)	0.59	0.66 (0.31–1.43)	0.29	0.40 (0.15–1.07)	0.07
PRI	9.31 (0.57–150)	0.06	4.57 (0.55–37.4)	0.15	7.80 (0.80–75.7)	0.07
Hospitalization > 30 d	0.98 (0.97–1)	0.27	0.70 (0.30–1.60)	0.40	0.40 (0.12–1.31)	0.13
Sepsis	0.56 (0.12–2.48)	0.45	0.70 (0.42–1.16)	0.17	0.59 (0.31–1.10)	0.09
Myocardial infarction	0.99 (0.98–1)	0.45	0.84 (0.23–3)	0.79	0.73 (0.16–3.23)	0.68
Septic shock	1.23 (0.17–8.77)	0.83	0.77 (0.32–1.83)	0.56	0.73 (0.26–2.07)	0.56
Unplanned intubation	0.48 (0.04–4.87)	0.53	0.62 (0.27–1.40)	0.25	0.71 (0.27–1.87)	0.49
Deep vein thrombosis	0.99 (0.98–1)	0.41	0.91 (0.31–2.66)	0.87	1.46 (0.47–4.54)	0.51
Hemorrhagic	0.74 (0.26–2.11)	0.58	1.14 (0.79–1.63)	0.47	0.88 (0.57–1.34)	0.56
Pneumonia	0.45 (0.04–5)	0.51	0.74 (0.35–1.56)	0.44	0.57 (0.22–1.44)	0.23
Pulmonary embolism	0.99 (0.99–1)	0.64	1.27 (0.25–6.24)	0.76	4.25 (0.85–21.2)	0.07
Return to operation room	1.76 (0.66–4.71)	0.25	1.18 (0.76–1.83)	0.44	1.08 (0.64–1.84)	0.75
Cardiac arrest	0.98 (0.98–1)	0.38	0.25 (0.06–1.03)	0.06	0.39 (0.07–1.98)	0.25
Urinary tract infection	0.95 (0.18–4.94)	0.95	1.37 (0.75–2.50)	0.29	0.88 (0.43–1.80)	0.73

*Pneumonia, sepsis, septic shock, superficial SSI, organ space SSI, urinary tract infection, and pneumonia.
AOR, adjusted odds ratio; BP, bowel preparation; PRI, progressive renal insufficiency; SSI, surgical site infection.

Mechanical BP alone did not have any significant associations with the outcomes of colon surgery patients. Our results show that MBP without oral antibiotics did not have significant associations with mortality, morbidity, or any of 18 postoperative complications including infectious complications. Although we found a higher rate of postoperative progressive renal insufficiency after MBP (0.6% vs 0.3%), the difference was not significant in multivariate analysis. Dehydration, electrolyte abnormality, prolonged ileus, and prolonged hospitalization have previously been reported as complications of mechanical BP in colorectal surgery.[11,13,24,25] This study reaffirms multiple earlier reports demonstrating the lack of benefit of MBP alone in colorectal surgery,[2,6,7,9] but also confirms a lack of harm.

Our results show OBP alone has no significant association with mortality, major morbidity, or postoperative complications in colon surgery. Although in our study the rates of superficial SSI, intra-abdominal infections, and anastomosis leakage were lower in patients who had OBP compared with patients without BPs (2.6% vs 8.2%, 3.4% vs 5.7%, and 3.4% vs 5.1%, respectively), the benefits of OBP in our study were not strong enough to significantly affect postoperative complications in multivariate analysis. Lewis26 previously reported that combined oral and systemic antibiotics are superior to systemic antibiotics alone in preventing SSIs in elective colon surgery.26 However, additional studies are needed to compare the benefits of OBP with the potential adverse

effects of OBP such as the emergence of resistant bacteria, C difficile seudomembranous colitis, and increasing health care-related costs.[27]

Study limitations

This study is a retrospective review and is subject to typical biases for retrospective studies such as selection bias. Data in this study were extracted from the NSQIP database, which collects data from more than 500 hospitals in the US, and there is a wide variation in hospital setting, hospital quality, surgical strategy, and surgeons' expertise that can confound the study. In addition, NSQIP does not provide any details regarding BPs (ie, techniques and amount of mechanical BP, type of drugs used for antibiotic BP, the exact time of BP before operation). Also, NSQIP does not collect information regarding preoperative prophylactic intravenous antibiotic treatment, contamination of abdominal cavity or surgical wound with bowel contents during operations, and hydrotherapy after mechanical BP. Also, coding errors in data collection may exist because of the use of discharge data in the NSQIP database.[28] The NSQIP database does not include some procedure-specific details such as the use of drains in surgery and prophylactic intravenous antibiotics, which may affect the risk for infection.[29,30] Despite these limitations, this study is one of the limited numbers of nationwide reports on associations between BP and postoperative complications in colorectal resection procedures using multivariate analysis and adjusting the results with multiple factors.

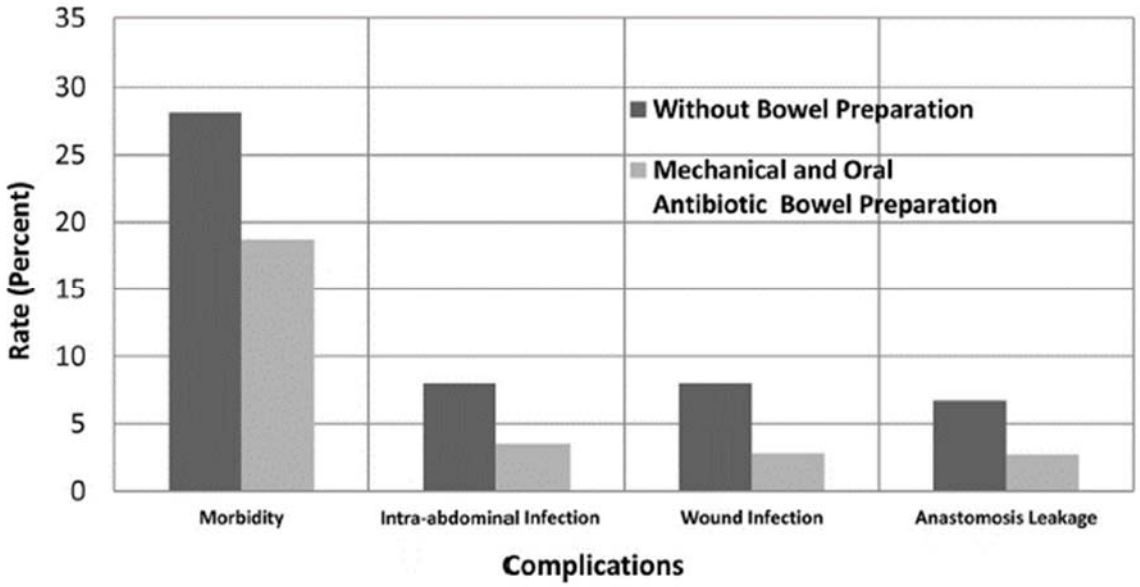

Figure 2. The rate of postoperative complications in patients who did not have any bowel preparation and patients who had mechanical and oral antibiotic bowel preparation in left side colon resections.

CONCLUSIONS

During 2012 to 2013, 72.4% of patients who underwent elective colorectal resection in the United States had mechanical BP with or without oral antibiotic BP. Our results show that a combination of OBP and MBP is associated with decreased postoperative complications of anastomosis leakage, superficial SSI, and intra-abdominal infections in left side colon resections. However, the benefit of a combination of OBP and MBP in right side colon resections is limited to the lower risk of superficial SSI. Mechanical bowel preparation alone and OBP alone do not have any significant associations with postoperative complications. This study did not demonstrate any adverse effect regarding BP in elective colon surgery. Further clinical trials are indicated to evaluate if using both mechanical and oral antibiotic BPs can improve outcomes.

Author Contributions

Study conception and design: Moghadamyeghaneh, Hanna, Carmichael, Mills, Pigazzi, Nguyen, Stamos
Acquisition of data: Moghadamyeghaneh
Analysis and interpretation of data: Moghadamyeghaneh
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Disclosure Information: Nothing to disclose.
Abstract presented at the American College of Surgeons 100th Annual Clinical Congress, San Francisco, CA, October 2014.

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