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ORIGINAL CONTRIBUTION

Oral Antibiotics Bowel Preparation Without Mechanical Preparation For Minimally Invasive Colorectal Surgeries: Current Practice And Future Prospects

Short title: Bowel preparation for colorectal surgery

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ABSTRACT

BACKGROUND: The efficacy of preoperative oral antibiotics alone compared to mechanical bowel preparation and oral antibiotics in minimally invasive surgery is still a matter of ongoing debate.

OBJECTIVE: This study aimed to assess the trend of surgical site infection rates in parallel to the utilization of bowel preparation modality over time for minimally invasive surgery colorectal surgeries in the United States.

DESIGN: Retrospective analysis.

SETTINGS: The American College of Surgeons National Surgical Quality Improvement Program database.

PATIENTS: Adult patients who underwent elective colorectal surgery and reported bowel preparation modality.

MAIN OUTCOME MEASURES: The trends and compare surgical site infection rates for mutually exclusive groups according to the underlying disease (colorectal cancer, inflammatory bowel disease, and diverticular disease) who underwent bowel preparation using oral antibiotics or combined mechanical bowel preparation and oral antibiotics. Patients who had rectal surgery were analyzed separately.

RESULTS: A total of 30,939 patients were included. Of them, 12,417 (40%) had rectal resections. Over the seven-year study period, mechanical bowel preparation and oral antibiotics utilization has increased from 29.3% in 2012 to 64.0% in 2018; $p<0.0001$ at the expense of no preparation and mechanical bowel preparation alone. Similarly, oral antibiotics utilization has increased from 2.3% in 2012 to 5.5% in 2018; $p<0.0001$. For colon cancer patients, patients who had oral antibiotics alone had higher superficial surgical site infection rates compared to patients who had combined mechanical bowel preparation and oral antibiotics (1.9% vs. 1.1%; p=0.043). Superficial, deep and organ space surgical site infection rates were similar for all other comparative colon surgery groups (cancer, inflammatory bowel disease, and diverticular disease). Patients with rectal cancer who had oral antibiotics had higher rates of deep surgical site infection (0.9% vs. 0.1%; p=0.004). However, superficial, deep and organ space surgical site infection rates were similar for all other comparative rectal surgery groups.

LIMITATIONS: Retrospective nature of the analysis.

CONCLUSION: This study revealed widespread adoption of mechanical bowel preparation and oral antibiotics mechanical bowel preparation and oral antibiotics and increased adoption of oral antibiotics over the study period. Surgical site infection rates appear to be similar from a clinical relevance standpoint among most comparative groups, questioning systematic preoperative addition of mechanical bowel preparation to oral antibiotics alone in all patients for minimally invasive colorectal surgery. See **Video Abstract** at http://links.lww.com/DCR/B828 .

PREPARACIÓN INTESTINAL CON ANTIBIÓTICOS ORALES SIN PREPARACIÓN MECÁNICA EN CIRUGÍAS COLORRECTALES MÍNIMAMENTE INVASIVAS: PRÁCTICA ACTUAL Y PERSPECTIVAS FUTURAS

ANTECEDENTES: La eficacia de los antibióticos orales preoperatorios solos en comparación con la preparación intestinal mecánica mas antibióticos orales en la cirugía mínimamente invasiva es un tema de debate que todavía esta en curso.

OBJETIVO: Este estudio tuvo como objetivo evaluar la tendencia de las tasas de infección del sitio quirúrgico en relacion a la utilización de la modalidad de preparación intestinal a lo largo del tiempo en cirugías colorrectales mínimamente invasivas en los Estados Unidos.

DISEÑO: Análisis retrospectivo.

ENTORNO CLINICO: Base de datos del Programa Nacional de Mejoramiento de la Calidad Quirúrgica del Colegio Estadounidense de Cirujanos.

PACIENTES: Pacientes adultos sometidos a cirugía colorrectal electiva y reportados con modalidad de preparación intestinal.

PRINCIPALES MEDIDAS DE VALORACIÓN: Tendencias y comparacion de las tasas de infección del sitio quirúrgico para grupos mutuamente excluyentes según la enfermedad subyacente (cáncer colorrectal, enfermedad inflamatoria intestinal y enfermedad diverticular) que se sometieron a preparación intestinal usando antibióticos orales exclusivamente o preparación intestinal mecánica combinada con antibióticos orales. Los pacientes que se sometieron a cirugía rectal se analizaron por separado.

RESULTADOS: Se incluyeron un total de 30.939 pacientes. De ellos, 12.417 (40%) se sometieron a resecciones rectales. Durante el período de estudio de siete años, la preparación mecánica del intestino y la utilización de antibióticos orales aumentó del 29,3% en 2012 al 64,0% en 2018; p <0,0001 sobre la no preparación y de la preparación intestinal mecánica exclusivamente. De manera similar, la utilización de antibióticos orales ha aumentado del 2,3% en 2012 al 5,5% en 2018; p <0,0001. Para los pacientes con cáncer de colon, los pacientes que recibieron antibióticos orales solos tuvieron mayores tasas de infección superficial del sitio quirúrgico en comparación con los pacientes que recibieron una preparación intestinal mecánica combinada con antibióticos orales (1,9% frente a 1,1%; p = 0,043). Las tasas de infección superficial, profundo del sitio quirúrgico y de los compartimientos intraabdominales fueron similares para todos los demás grupos de cirugía de colon (cáncer, enfermedad inflamatoria intestinal y enfermedad diverticular). Los pacientes con cáncer de recto que recibieron antibióticos orales tuvieron tasas más altas de infección profunda del sitio quirúrgico (0,9% frente a 0,1%; p =

0,004). Sin embargo, las tasas de infección del sitio quirúrgico superficial, profundo y de los compartimientos intraabdominales fueron similares comparativamente para todos los demás grupos de cirugía rectal.

LIMITACIONES: Carácter retrospectivo del análisis.

CONCLUSIÓN: Este estudio reveló la adopción generalizada de preparación intestinal mecánica y antibióticos orales y una mayor aceptación de antibióticos orales durante el período de estudio. Las tasas de infección del sitio quirúrgico parecen ser similares desde un punto de vista de relevancia clínica entre la mayoría de los grupos comparados, lo que cuestiona la adición preoperatoria sistemática de preparación intestinal mecánica a antibióticos orales solos en todos los pacientes para cirugía colorrectal mínimamente invasiva. Consulte **Video Resumen** en http://links.lww.com/DCR/B828 . *(Traducción— Dr. Ingrid Melo)*

KEY WORDS: Bowel preparation; Colorectal surgery; Mechanical bowel preparation; Minimally invasive surgery; Preoperative oral antibiotic.

INTRODUCTION

In 2015, Scarborough et al. and Kiran et al. assessed the impact of different bowel preparation modalities on rates of surgical site infection (SSI) using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP). They evaluated patients undergoing colorectal surgery with[1] or without[2] diversion and found that combined mechanical bowel preparation and oral antibiotic administration (MOABP) reduced SSI rates compared to no preparation.[1,2] More recently, Klinger et al. utilized the same database to confirm these findings and concluded that MOABP resulted in a lower adjusted risk of SSI compared to oral antibiotic administration (OAB) alone.[3]

The recently published American Society of Colon and Rectal Surgeons Clinical Practice Guidelines recommends against OAB alone for elective colorectal surgery.[4] This position was challenged by a recent meta-analysis revealing no statistically significant differences in SSI rate when comparing OAB alone to combined MOABP.[5] Importantly, these findings were driven by randomized controlled trials (RCTs), which utilized an open approach to surgery and a low rate of rectal resection.[6–9] Interestingly, the MOBILE and ORALEV trials, which included a majority of laparoscopic cases (77%), revealed no statistically significant difference between MOABP or OAB alone versus no preparation, respectively.[10,11] However, this conclusion was criticized for being underpowered with an overrepresentation of patients undergoing a right-sided resection.[12] In addition, all of the aforementioned studies did not discriminate between baseline pathologies such as cancer, inflammatory bowel diseases (IBD), and diverticular disease. For these reasons, the direct comparison between MOABP versus OAB alone is still an ongoing matter of debate.[12] Furthermore, to date, there is no clear consensus about whether OAB administration is sufficient for patients undergoing minimally invasive colorectal surgery (MIS).[12]

Therefore, we aimed to assess the trend of SSI rates in parallel to the utilization of bowel preparation modality over time in the United States (U.S.). Furthermore, we aimed to compare SSI rates for patients undergoing elective minimally invasive colon or rectal surgery without ostomy creation who preoperatively had OAB versus MOABP. This focus on minimally invasive colon and rectal cases is of particular importance given the increasing, widespread utilization of MIS in the U.S.[13,14]

MATERIALS AND METHODS

Data source

This retrospective analysis utilized the ACS-NSQIP database, which represents a systematically audited and validated prospectively maintained national database. ACS-NSQIP started to report bowel preparation techniques in 2012 in the targeted colectomy files. Therefore, we included all adult (≥18 years) patients who underwent elective colorectal surgery and reported bowel preparation modality in the targeted files from 2012 to 2018. Patients who had systemic sepsis, concomitant stoma creation, SSI at the time of surgery, or American Society of Anesthesiologists (ASA) class V were excluded. Patients were divided into open (current procedure terminology (CPT) codes: 44140, 44145, 44160) and MIS procedures (CPT codes: 44204, 44205, 44207). Patients who had open surgeries were excluded. Patients who underwent MIS were subsequently divided into colonic (CPT codes: 44204, and 44205) and rectal (CPT codes: 44207) procedures. Subsequently, the International Classification of Diseases (ICD) codes were used to perform a subgroup analysis within each group according to the underlying disease into cancer (ICD codes: C18.x, 153.x, 154.x, C20, C21.8), inflammatory bowel diseases (ICD codes: 556.x, K51.xx, 555.x, K50.xx) and diverticular disease (ICD codes: 562.x).

Intervention and covariates

Within each disease category, patients who had preoperative OAB alone were compared to patients who had MOABP. Bowel preparations were defined as follows: patients in the OAB group must have taken oral antibiotics within 24 hours before surgery (erythromycin/neomycin and metronidazole). Patients who had prophylactic intravenous antibiotics at the time of surgery without preoperative oral antibiotics were not considered. Patients in the MOABP group must have completed oral bowel preparation before surgery (e.g., polyethylene glycol with or without electrolytes) in conjunction with OAB preparation, as defined above. Patients who had only enemas or suppositories were not considered.

Baseline demographics, anthropometrics including different serum values within 30 days of surgery (albumin, hematocrit, platelets), and perioperative variables were compared between patients who had OAB alone and patients who had combined MOABP.

Outcomes

First, utilization trends of each bowel preparation modality and SSI rates over the indexed study years were assessed for patients who underwent MIS.

The primary outcome, SSI, was divided into superficial, deep, and organ space infections. Superficial SSI was defined as an infection involving only skin or subcutaneous tissue of the surgical incision that occurred within 30 days after the primary surgery with at least one of the following criteria: purulent drainage from the surgical incision, organism isolated by culture from the fluid of the tissue of the superficial incision, the surgeon deliberately opened the superficial incision, or the physician or advanced practitioner confirmed the diagnosis. Deep incisional SSI was defined as an infection involving tissue beneath the skin layer, thus subcutaneous fat, fascia, or muscle layers. Organ space infection was established as an infection involving any part of the anatomy (organs or spaces) other than the incision, which was opened and manipulated during surgery.

Statistical analysis

The trend analysis was conducted using linear regression. The consecutive study years, modeled as a continuous variable, have been used as a covariate. The unstandardized β coefficients with their 95% confidence intervals have been used to assess the annual increase or decrease. Descriptive statistics have been reported as absolute percentages for categorical variables and median, interquartile ranges for the continuous variables. The differences between the two groups were assessed using the Chi-squared test or Fisher's exact test as appropriate for categorical variables and Wilcoxon rank-sum test for continuous variables. The binary logistic multivariable regression analysis has been used to adjust for the baseline confounders (thus the baseline differences between OAB and MOABP within each disease category). Baseline variables that had an alpha level < 0.1 in the univariate analysis were further included in the logistic regression. For all analyses, an alpha level < 0.05 was considered statistically significant, and all tests were two-tailed. All analyses were performed using the Statistical Package for Social Sciences (SPSS, Version 25; SPSS, Inc., Armonk, NY, U.S.A.).

RESULTS

Overall, 30,939 patients were identified. Of them, 18,522 (60%) patients underwent colon resections and 12,417 (40%) patients underwent rectal resections (Figure 1).

Trends of bowel preparation modality and SSI rates over time

Over the seven-year study period, MOABP utilization has increased from 29.3% in 2012 to 64.0% in 2018 with an annual increase of 6.6% per year; 95% CI 6.4% to 6.9%; p-value < 0.0001 at the expense of no preparation and MBP. Similarly, OAB utilization has increased from

2.3% in 2012 to 5.5% in 2018 with an annual slope of 0.5% per year, 95% CI 0.5% to 0.6%; p value < 0.0001 **(Figure 2).**

As MOABP increased over time, there was a concurrent increase in organ space infections. However, superficial and deep SSI decreased overtime with MOABP. There was no significant increase or decrease in superficial SSI or organ space infections when OAB alone was used. However, deep SSI rates decreased with OAB over time, as illustrated in Figure 3.

Colon surgery

Colon Cancer

Patients in the OAB group were older, had more advanced (stage 4) disease, and had lower hematocrit values preoperatively **(Table 1)**.

There was no difference in deep SSI or organ space infections between the two groups. However, patients who had OAB alone had higher superficial SSI rates compared to patients who had combined MOABP (1.9% vs. 1.1%; p-value 0.043). After adjusting for the baseline confounders, combined MOABP had lower odds of developing superficial SSI compared to OAB alone (adjusted OR 0.461; 95% CI 0.270 to 0.789) (Tables 1 and 2).

IBD

Most baseline characteristics were comparable between both groups. However, patients who had OAB alone were more likely to have bleeding disorders, transfusion before surgery, and chronic steroid use. There were no differences in SSI rates between the two groups **(Tables 1 and 2).**

Diverticular disease

Baseline risk factors were comparable between both groups except for higher body mass index, and more hypertension among OAB patients. There were no differences between both groups regarding SSI rates (Tables 1 and 2).

Rectal surgery

Rectal cancer

Patients who had OAB alone were more likely to have congestive heart failure, malnutrition, and more prolonged operations.

There were no differences in superficial SSI and organ space infection rates between both groups; however, patients who had only OAB had higher rates of deep SSI (0.9% vs. 0.1%; p-value 0.004) (Tables 3 and 4).

IBD

There were no differences in baseline factors except for age and BMI with patients underwent MOABP tended to be older and have a higher BMI. There were no differences in SSI rates.

Diverticular disease

There were no differences between both groups regarding baseline risk factors and SSI rates.

DISCUSSION

Based on a nationally representative sample, the adoption of combined MOABP increased significantly for MIS colorectal resections over the seven-year study period. This increase was not associated with a clinically relevant decrease in SSI rates overtime. On the contrary, the rates of organ space infections slightly increased with the use of MOABP. Moreover, there were no differences between OAB alone and combined MOABP regarding SSI rates among most comparative groups.

Mixing different baseline diseases might lead to inaccurate conclusions given important differences (immunosuppression, age, comorbidities).[15] Therefore, postoperative complication profiles, in particular regarding infectious complications, are expected to be different depending on the underlying disease. Mixing open and laparoscopic approaches may also lead to false conclusions if confounders like the length of incision, surgical duration, or postoperative recovery are not accounted for. However, despite these limitations, SSI rates in the present study were similar or even lower than what has been found by the MOBILE trial.[10] Most patients in the MOBILE trial were treated for colorectal cancer (about 78% of patients) and only a very low percentage of 2.5% underwent a low anterior resection. Although we found a similar superficial SSI rate (1% for combined preparation in MOBILE trial vs. 1.1% in the present ACS-NSQIP colon cancer cohort and 3% for no preparation in MOBILE trial vs. 1.9% in ACS-NSQIP) and lower rates of deep SSI (for MOABP 0.3% vs 2%) and organ space infection (for MOABP 2.1% vs 5%), which may be related, besides important differences in assessment, study design and potential underreporting, to the approach, given about 13% of patients in the MOBILE trial had open surgery.

Our analysis is based on a nationwide database that is audited with data being abstracted by trained data abstractors. We specifically analyzed and compared different patient populations to consider different pathophysiology and complication profiles. Moreover, we restricted our analysis to MIS alone to yield a more homogenous patient sample. Patients treated with OAB had more comorbidities, though SSI rates were not different between the groups. Although the superficial SSI rate was higher in cancer patients who had OAB alone and underwent colon surgery, it is questionable how clinically relevant the statistically significant difference between 1.9% and 1.1% is. Careful balancing of risks (dehydration, fluid homeostasis, patient satisfaction) and potential benefits of MBP is necessary, given the lesser impact of superficial incisional SSI, which can often be managed in an outpatient setting, on the patient.[16,17] This fact applies likewise to the rates of deep incisional SSI in rectal cancer patients (0.9% vs. 0.1%), where the incidence in both groups was very low. Nevertheless, the risk of underreporting of these complications in a National dataset has to be considered. Interestingly, in our analysis, cancer patients with higher co-morbidities tended to have only OAB, and despite this, they did not have a clinically meaningful increase in the SSI rates. Taken together, despite small differences in the rates of incisional SSI between the two preparation modalities in cancer patients, minor complications still represent an opportunity for targeted quality improvement and thus these findings need to be further evaluated.

Our trend analysis demonstrated that even in patients not receiving any bowel preparation, superficial SSI rates decreased over time. This may highlight improvements in perioperative care through enhanced recovery pathways and multidisciplinary care bundles.[18,19] However, in concert with the results of the MOBILE and ORALEV trials, our study suggests revising the concept of systematic mechanical bowel preparation for all colorectal operations.

While an empty colon for MIS resections may intuitively help to localize small tumors through palpation, it has been shown that MIS can be undertaken safely without MBP for elective colon surgery.[20] Indeed, preoperative tattooing eliminates the problem of localizing small tumors.[21] However, with the increasing trend towards the adoption of intracorporeal anastomosis,[22,23] the utility of OAB preparation alone will need to be further assessed.

The present analysis has limitations related to ACS-NSQIP that should be taken into account when interpreting the results. To the best of our knowledge, this is the first and largest study that addresses the question of the utility of OAB alone versus MOABP in unique mutually exclusive cohorts. While we chose not to implement propensity score matching due to the similarity of baseline confounders, the logistic regression analysis was used to account for residual confounders. However, quality of care, surgical settings, and adherence to SSI care bundles remain unknown confounders in ACS-NSQIP. Given these limitations, we believe an adequately powered multicenter randomized controlled trial is needed. However, the combined results of the present analysis, previous meta-analyses,[5,24] and the MOBILE and ORALEV trials,[10,11] the systematic addition of MBP before minimally invasive colorectal surgery might need to be questioned, despite the small yet statistically significant benefit in decreasing incisional SSI in patients undergoing MIS for colon or rectal cancer. This finding should be further evaluated given the limitations related to this retrospective large scale analysis.

CONCLUSION

This nationally representative sample revealed widespread adoption of MOABP and increasing use of OAB over the study period. Based on mutually exclusive comparative groups, OAB preparation alone appears to be comparable to combined MOABP from the perspective of clinical relevance and simplifies the preoperative preparation process in patients undergoing elective minimally invasive colorectal surgery without stomas. However, given the limitations related to this large-scale analysis, an adequately powered randomized controlled trial assessing the impact of OAB alone versus combined MOABP in elective MIS colorectal surgery without mixing different disease populations further represents an unmet need.

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LEGENDS

Table 1: Baseline characteristics for MIS colon surgeries according to the underlying disease. BMI: body mass index, ASA: American Society of Anesthesiologists, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, CHF: congestive heart failure, HTN: hypertension requiring medications, pRBCs: packed red blood cells, hrs: hours.

Table 2: SSI rates for MIS colon surgeries according to the underlying disease. Regression analysis after adjusting for the baseline confounders found that both MBP and antibiotic preparation is an independent preventive factor against the development of superficial surgical site infection for colon cancer patients. Adjusted OR: 0.461; 95% CI 0.270 to 0.789, p value 0.005. OAB alone was used as a reference.Adjusted for: dyspnea, disseminated cancer, preoperative hematocrit, currently on dialysis (pre-op), preoperative serum albumin, age, race, pathologic T stage.

Table 3: Baseline characteristics for MIS rectal surgeries according to the underlying disease. BMI: body mass index, ASA: American Society of Anesthesiologists, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, CHF: congestive heart failure, HTN: hypertension requiring medications, pRBCs: packed red blood cells, hrs: hours.

Table 4: SSI rates for patients underwent MIS rectal surgeries according to the underlying disease. Regression analysis using antibiotic as a reference: OR 0.164; 95% CI 0.032 to 0.855, p-value 0.032. Adjusted for CHF before surgery, > 10% loss of body weight in last 6 months, total operation time, and preoperative serum albumin.

Figure 1: Study flow diagram.

ASA: American Society of Anesthesiologists class, SSI: surgical site infection, PATOS: present at time of surgery, OAB: preoperative oral antibiotic preparation, MOABP; combined mechanical and oral antibiotic preparation, MIS: minimally invasive surgery, IBD: inflammatory bowel disease.

Figure 2: trends of the utilization of bowel preparation modality from 2012 to 2018 for patient underwent MIS colorectal surgery.

No preparation: -1.7% per year; 95% CI [-1.9% to -1.5%], p value < 0.0001,

OAB: 0.5% per year; 95% CI [0.5% to 0.6%], p value < 0.0001,

MBP: -5.5% per year, 95% CI [-5.7% to -5.3%], p value < 0.0001,

MOABP: 6.6% per year; 95% CI [6.4% to 6.9%], p value < 0.0001

Figure 3: Trends of SSI rates from 2012 to 2018 for patients who underwent elective colorectal MIS.A: Superficial SSI rates, B: Deep SSI rates, C: Organ Space SSI rates.

A. Superficial:

No preparation: -0.5% per year, 95% CI [-0.7% to -0.3%], p value < 0.0001,

OAB: -0.3% per year, 95% CI [-0.6% to 0.1%] p value 0.137.

MBP: -0.4% per year, 95% CI [-0.6% to -0.3%] p value < 0.0001,

MOABP: -0.1% per year, 95% CI [-0.2% to -0.046%], p value 0.003.

B. **Deep:**

no preparation: -0.0122% per year, 95% CI [-0.1% to 0.1%], p value: 0.733,

OAB: -0.2% per year, 95% CI [-0.3% to -0.1%], p value 0.005,

MBP: -0.0293% per year, 95% CI [-0.1% to 0.0212%], p value 0.256,

MOABP: -0.0459% per year, 95% CI [-0.1% to -0.0155%], p value 0.003.

C. **Organ/space: no preparation:** -0.024% per year; 95% CI [-0.2% to 0.2%], p value 0.808,

OAB: -0.1% per year; 95% CI [-0.5% to 0.2%], p value 0.451,

MBP: -0.034% per year; 95% CI [-0.2% to 0.1%], p value 0.671,

MOABP: 0.1% per year; 95% CI [0.04% to 0.3%], p value 0.006.

Table 1: Baseline characteristics for MIS colon surgeries according to the underlying disease.

Variables	Cancer		P-value	IBD		P-value	Diverticular		P-value
	OAB n= 1102	**MOABP n= 10264**		**OAB n= 353**	**MOABP n= 1711**		**OAB n= 403**	**MOABP n= 4689**	
Age	**70 (60 – 79)**	**68 (58 – 76)**	**0.002**	**33 (25 – 48)**	**37 (28 – 50)**	**0.005**	57 (49 – 67)	57 (48 – 65)	0.406
Sex; male	527 (47.8%)	4980 (48.5%)	0.660	145 (41.1%)	715 (41.8%)	0.805	192 (47.6%)	2228 (47.5%)	0.961
BMI	28 (24 – 31)	28 (24 – 32)	0.623	24 (21 – 29)	25 (21 – 29)	0.892	**30 (26 – 34)**	**29 (25 – 33)**	**0.006**
Race			**< 0.0001**			0.587			0.231
White	**763 (69.2%)**	**7615 (74.2%)**		302 (85.6%)	1455 (85.0%)		340 (84.4%)	4135 (88.2%)	
African American	**130 (11.8%)**	**1033 (10.1%)**		24 (6.8%)	107 (6.3%)		24 (6.0%)	244 (5.2%)	
Asian	**44 (4.0%)**	**542 (5.3%)**		2 (0.6%)	20 (1.2%)		7 (1.7%)	53 (1.1%)	
Others	**7 (0.6%)**	**140 (1.4%)**		0	4 (0.2%)		6 (1.5%)	46 (1.0%)	
Unknown	158 (14.3%)	934 (9.1%)		25 (7.1%)	125 (7.3%)		26 (6.5%)	211 (4.5%)	
ASA ≥ 3	659 (59.8%)	5882 (57.4%)	0.117	92 (26.1%)	483 (28.3%)	0.399	144 (35.7%)	1536 (32.8%)	0.229
DM	205 (18.6%)	1935 (18.9%)	0.840	5 (1.4%)	47 (2.7%)	0.190	44 (10.9%)	434 (9.3%)	0.282
Current smoker	118 (10.7%)	1105 (10.8%)	0.953	70 (19.8%)	326 (19.1%)	0.737	83 (20.6%)	841 (17.9%)	0.190
Dyspnea	105 (9.5%)	817 (8.0%)	0.076	8 (2.3%)	24 (1.4%)	0.236	11 (2.7%)	147 (3.1%)	0.765
COPD	56 (5.1%)	530 (5.2%)	0.907	3 (0.8%)	14 (0.8%)	>0.99	11 (2.7%)	114 (2.4%)	0.736
Functional status; dependent	23 (2.1%)	147 (1.4%)	0.111	**2 (0.6%)**	**0**	**0.029**	0	11 (0.2%)	0.399
Ascites	1 (0.1%)	8 (0.1%)	0.601	0	1 (0.1%)	>0.99	0	0	
CHF	10 (0.9%)	76 (0.7%)	0.581	0	1 (0.1%)	>0.99	0	9 (0.2%)	>0.99
HTN	623 (56.5%)	5547 (54.0%)	0.114	43 (12.2%)	252 (14.7%)	0.205	182 (45.2%)	1889 (40.3%)	0.057
Currently on hemodialysis	**0**	**39 (0.4%)**	**0.029**	0	1 (0.1%)	>0.99	0	8 (0.2%)	>0.99
Disseminated cancer	**77 (7.0%)**	**556 (5.4%)**	**0.037**	1 (0.3%)	4 (0.2%)	>0.99	3 (0.7%)	9 (0.2%)	0.06
Chronic steroid use	36 (3.3%)	315 (3.1%)	0.721	**237 (67.1%)**	**1035 (60.5%)**	**0.018**	11 (2.7%)	142 (3.0%)	0.879
Loss of weight; >10% / last 6 months	39 (3.5%)	281 (2.7%)	0.140	**28 (7.9%)**	**82 (4.8%)**	**0.023**	10 (2.5%)	90 (1.9%)	0.451
Bleeding disorder	29 (2.6%)	215 (2.1%)	0.257	**9 (2.5%)**	**13 (0.8%)**	**0.007**	4 (1.0%)	54 (1.2%)	>0.99
Transfusion ≥ 1pRBCs/ 72 hrs before surgery	5 (0.5%)	67 (0.7%)	0.550	**2 (0.6%)**	**0**	**0.029**	0	0	
Operative time	150 (116 - 196)	154 (116 – 204)	0.248	143 (105 – 188)	141 (110 – 190)	0.502	189 (140 – 238)	182 (141 – 239)	0.134
Preoperative Albumin	4 (3.6 – 4.3)	4 (3.7 – 4.3)	0.079	3.9 (3.6 – 4.2)	3.9 (3.6 – 4.2)	0.215	4.1 (3.7 – 4.3)	4.1 (3.8 – 4.4)	0.513
Preoperative hematocrit	**37 (33 – 41)**	**38 (33 – 42)**	**0.039**	39.4 (36 – 42)	40 (37 – 42)	0.251	41 (38 – 44)	41 (39 – 44)	0.631
Preoperative platelets	269 (215 - 324)	260 (212 – 321)	0.352	282 (229 – 363)	296 (242 – 367)	0.226	251 (214 – 295)	252 (212 – 302)	0.411
Chemotherapy within 90 days before the operation	39 (3.5%)	333 (3.2%)	0.718	4 (1.1%)	7 (0.4%)	0.215	3 (0.7%)	31 (0.7%)	0.537
T4			**0.030**						
yes	**146 (13.2%)**	**1102 (10.7%)**							
No	**875 (79.4%)**	**8466 (82.5%)**							
Unknown	**81 (7.4%)**	**696 (6.8%)**							

BMI: body mass index, ASA: American Society of Anesthesiologists, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, CHF: congestive heart failure, H.T.N.: hypertension requiring medications, pRBCs: packed red blood cells, hrs: hours.

Table 2: SSI rates for MIS colon surgeries according to the underlying disease

SSI	Cancer OAB n= 1102	Cancer MOABP n= 10264	P-value	IBD OAB n= 353	IBD MOABP n= 1711	P-value	Diverticular OAB n= 403	Diverticular MOABP n= 4689	P-value
Superficial	**21 (1.9%)**	**118 (1.1%)**	**0.043**	12 (3.4%)	32 (1.9%)	0.101	10 (2.5%)	92 (2.0%)	0.457
Deep	3 (0.3%)	17 (0.2%)	0.436	1 (0.3%)	5 (0.3%)	>0.99	1 (0.2%)	12 (0.3%)	>0.99
Organ/space	26 (2.4%)	212 (2.1%)	0.525	5 (1.4%)	51 (3.0%)	0.107	8 (2.0%)	92 (2.0%)	>0.99

Regression analysis after adjusting for the baseline confounders found that both MBP and antibiotic preparation is an independent preventive factor against the development of superficial surgical site infection for colon cancer patients.

Adjusted OR: 0.461; 95% CI 0.270 to 0.789, p value 0.005

OAB alone was used as a reference.

Adjusted for: dyspnea, disseminated cancer, preoperative hematocrit, currently on dialysis (pre-op), preoperative serum albumin, age, race, pathologic T stage.

Table 3: Baseline characteristics for MIS rectal surgeries according to the underlying disease.

	Cancer		P-value	IBD		P-value	Diverticular		P-value
Variables	**OAB n= 444**	**MOABP n= 5916**		**OAB n= 14**	**MOABP n= 78**		**OAB n= 488**	**MOABP n= 5477**	
Age	61 (52 – 70)	60 (51 – 69)	0.589	31 (26 – 45)	51 (30 – 59)	**0.04**	57 (49 – 64)	58 (50 – 66)	0.511
Sex; male	230 (51.8%)	3316 (56.1%)	0.083	6 (42.9%)	34 (43.6%)	>0.99	212 (43.4%)	2494 (45.5%)	0.373
BMI	27 (24 – 32)	28 (24 – 31)	0.116	21 (20 – 25)	26 (22 – 32)	**0.015**	28 (25 – 33)	29 (25 – 33)	0.812
Race			0.112			0.489			**0.033**
White	308 (69.4%)	4347 (73.5%)		12 (85.7%)	60 (76.9%)		416 (85.2%)	4820 (88.0%)	
African American	29 (6.5%)	383 (6.5%)		0	5 (6.4%)		20 (4.1%)	260 (4.7%)	
Asian	29 (6.5%)	383 (6.5%)		0	0		9 (1.8%)	36 (0.7%)	
Others	2 (0.5%)	50 (0.8%)		0	2 (2.6%)		2 (0.4%)	27 (0.5%)	
Unknown	76 (17.1%)	753 (12.7%)		2 (14.3%)	11 (14.1%)		41 (8.4%)	334 (6.1%)	
ASA ≥ 3	221 (49.8%)	2872 (48.6%)	0.625	4 (28.6%)	35 (44.9%)	0.380	153 (31.4%)	1860 (34.0%)	0.251
DM	64 (14.4%)	873 (14.8%)	0.844	0 (0.0%)	5 (6.4%)	>0.99	43 (8.8%)	498 (9.1%)	0.835
Current smoker	57 (12.8%)	805 (13.6%)	0.646	2 (14.3%)	14 (17.9%)	>0.99	77 (15.8%)	891 (16.3%)	0.778
Dyspnea	15 (3.4%)	245 (4.1%)	0.421	0 (0.0%)	2 (2.6%)	>0.99	27 (5.5%)	207 (3.8%)	0.07
COPD	9 (2.0%)	181 (3.1%)	0.249	0	1 (1.3%)	>0.99	17 (3.5%)	126 (2.3%)	0.122
Functional status; dependent	3 (0.7%)	46 (0.8%)	0.755	1 (7.1%)	0	0.152	1 (0.2%)	11 (0.2%)	0.113
Ascites	0	3 (0.1%)	>0.99	0	0		0	0	
CHF	4 (0.9%)	17 (0.3%)	0.054	0	0		0	7 (0.1%)	>0.99
HTN	173 (39.0%)	2495 (42.2%)	0.185	1 (7.1%)	28 (35.9%)	0.057	208 (42.6%)	2273 (41.5%)	0.630
Currently on hemodialysis	0	12 (0.2%)	>0.99	0	0		1 (0.2%)	15 (0.3%)	>0.99
Disseminated cancer	31 (7.0%)	412 (7.0%)	0.989	0	0		2 (0.4%)	14 (0.3%)	0.381
Chronic steroid use	7 (1.6%)	107 (1.8%)	0.854	10 (71.4%)	47 (60.3%)	0.555	14 (2.9%)	193 (3.5%)	0.436
Loss of weight; >10% / last 6 months	**22 (5.0%)**	**178 (3.0%)**	**0.035**	1 (7.1%)	2 (2.6%)	0.394	14 (2.9%)	107 (2.0%)	0.193
Bleeding disorder	9 (2.0%)	106 (1.8%)	0.710	0	1 (1.3%)	>0.99	6 (1.2%)	72 (1.3%)	>0.99
Transfusion ≥ 1pRBCs/ 72 hrs before surgery	1 (0.2%)	14 (0.2%)	>0.99	0	0		0	1 (0.0%)	>0.99
Operative time	**237 (172 – 307)**	**219 (165 – 290)**	**0.034**	227 (110 – 281)	217 (166 – 276)	0.672	193 (148 – 253)	184 (137 – 238)	0.003
Preoperative Albumin	4 (3.7 – 4.3)	4.1 (3.8 – 4.3)	0.071	3.5 (3.2 – 4.3)	4 (3.6 – 4..3)	0.146	**4 (3.6 – 4.3)**	**4.1 (3.8 – 4.4)**	**<0.0001**
Preoperative hematocrit	40 (36 – 42)	40 (37 – 43)	0.171	39 (35 – 41)	39 (35 – 43)	0.918	41 (38 – 44)	42 (39 – 44)	0.008
Preoperative platelets	239 (302 – 281)	238 (197 – 285)	0.831	330 (257 – 388)	296 (241 – 365)	0.715	253 (210 – 298)	253 (212 – 298)	0.949
Chemotherapy within 90 days before the operation	104 (23.4%)	1412 (23.9%)	0.649	0	0		4 (0.8%)	28 (0.5%)	0.301
T4			0.521						
yes	36 (8.1%)	394 (6.7%)							
No	374 (84.2%)	5064 (85.6%)							
Unknown	34 (7.7%)	458 (7.7%)							

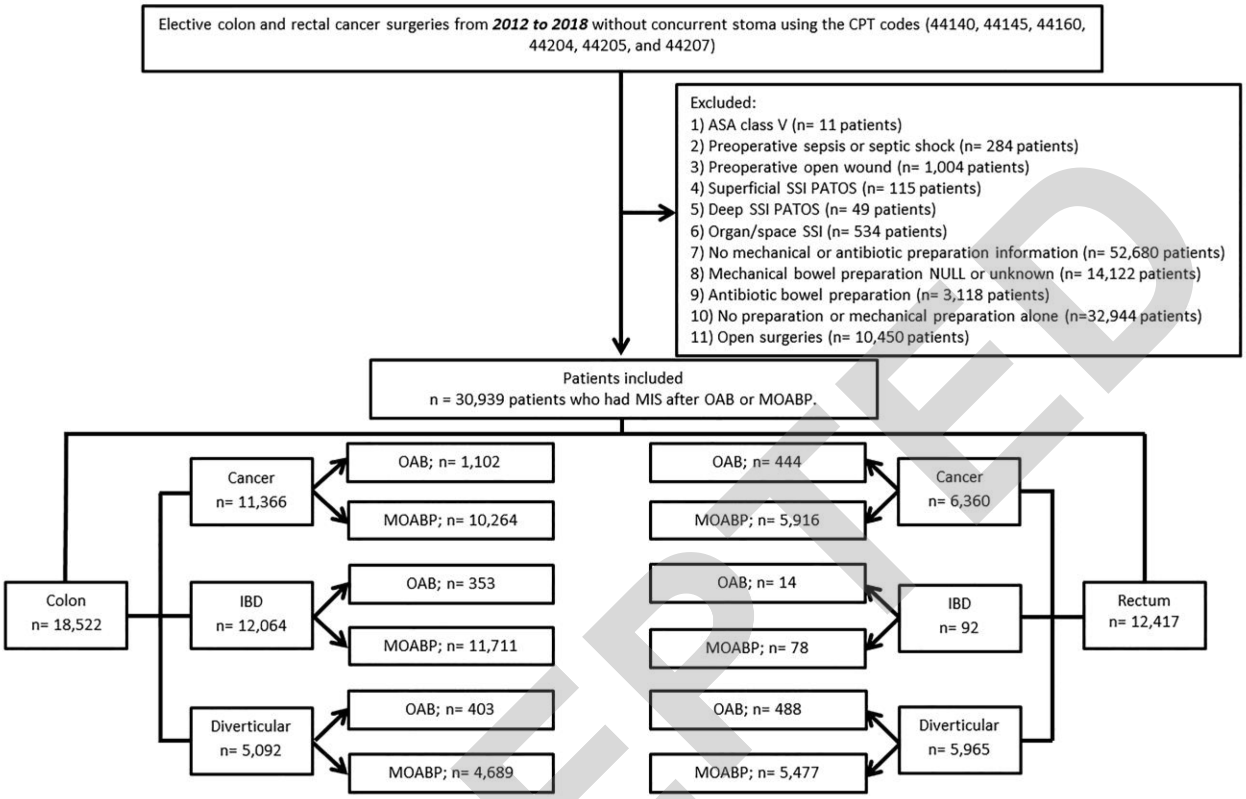
BMI: body mass index, ASA: American Society of Anesthesiologists, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, CHF: congestive heart failure, H.T.N.: hypertension requiring medications, pRBCs: packed red blood cells, hrs: hours.

Table 4: SSI rates for patients underwent MIS rectal surgeries according to the underlying disease

	Cancer		P-value	IBD		P-value	Diverticular		P-value
SSI	**OAB n= 444**	**MOABP n= 5916**		**OAB n= 14**	**MOABP n= 34**		**OAB n= 488**	**MOABP n= 5477**	
Superficial	8 (1.8%)	73 (1.2%)	0.273	2 (14.3%)	5 (6.4%)	0.288	12 (2.5%)	111 (2.0%)	0.505
Deep	**4 (0.9%)**	**6 (0.1%)**	**0.004**	0	0		2 (0.4%)	14 (0.3%)	0.381
Organ/space	24 (5.4%)	199 (3.4%)	0.035	0	2 (2.6%)	>0.99	15 (3.1%)	121 (2.2%)	0.207

Regression analysis using antibiotic as a reference: OR 0.164; 95% CI 0.032 to 0.855, p-value 0.032. Adjusted for CHF before surgery, > 10% loss of body weight in last 6 months, total operation time, and preoperative serum albumin.

Figure 1



Elective colon and rectal cancer surgeries from **2012 to 2018** without concurrent stoma using the CPT codes (44140, 44145, 44160, 44204, 44205, and 44207)
Excluded:
1) ASA class V (n= 11 patients)
2) Preoperative sepsis or septic shock (n= 284 patients)
3) Preoperative open wound (n= 1,004 patients)
4) Superficial SSI PATOS (n= 115 patients)
5) Deep SSI PATOS (n= 49 patients)
6) Organ/space SSI (n= 534 patients)
7) No mechanical or antibiotic preparation information (n= 52,680 patients)
8) Mechanical bowel preparation NULL or unknown (n= 14,122 patients)
9) Antibiotic bowel preparation (n= 3,118 patients)
10) No preparation or mechanical preparation alone (n=32,944 patients)
11) Open surgeries (n= 10,450 patients)
Patients included
n = 30,939 patients who had MIS after OAB or MOABP.
Colon
n= 18,522
Cancer
n= 11,366
OAB; n= 1,102
MOABP; n= 10,264
IBD
n= 12,064
OAB; n= 353
MOABP; n= 11,711
Diverticular
n= 5,092
OAB; n= 403
MOABP; n= 4,689
Rectum
n= 12,417
Cancer
n= 6,360
OAB; n= 444
MOABP; n= 5,916
IBD
n= 92
OAB; n= 14
MOABP; n= 78
Diverticular
n= 5,965
OAB; n= 488
MOABP; n= 5,477

Figure 2

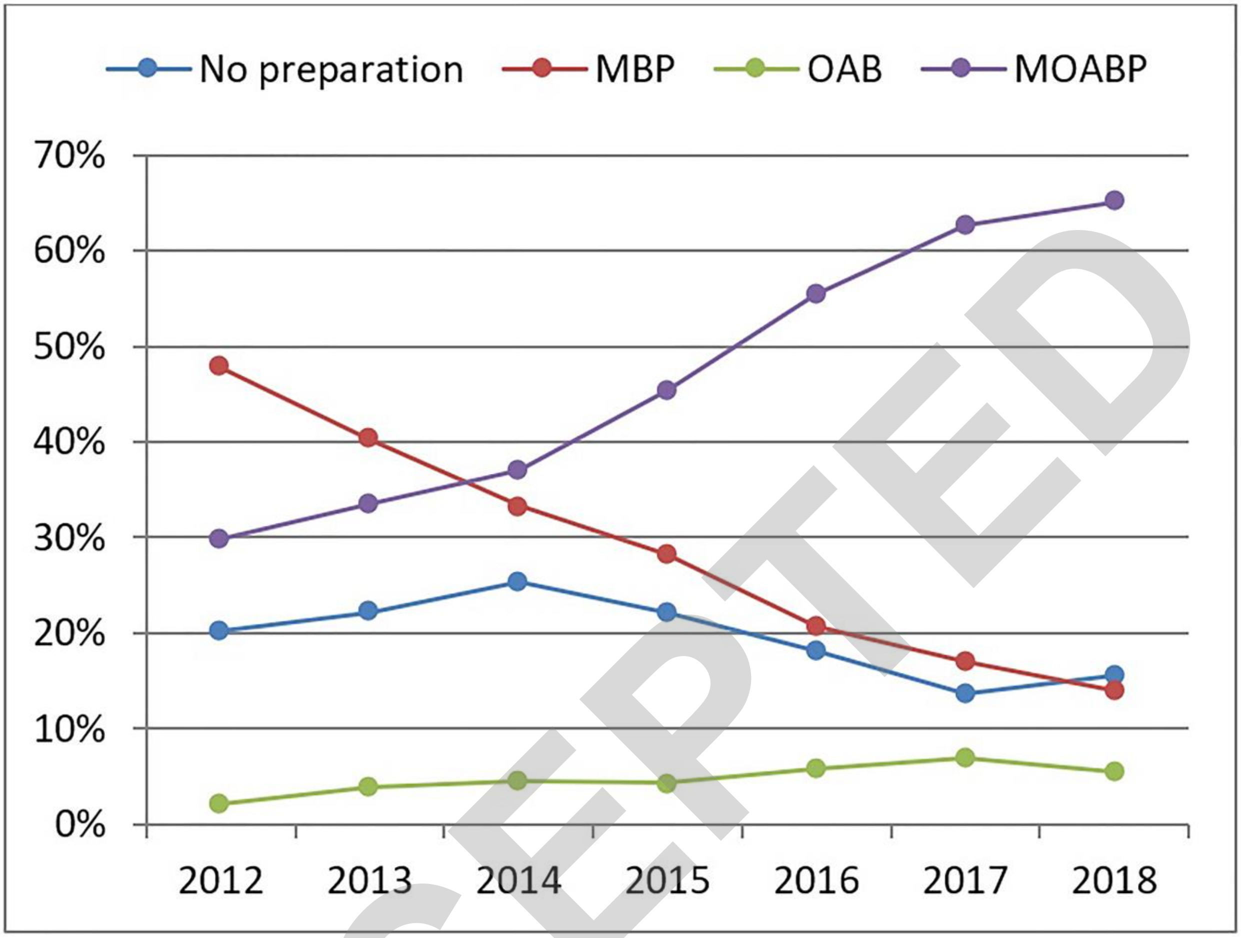
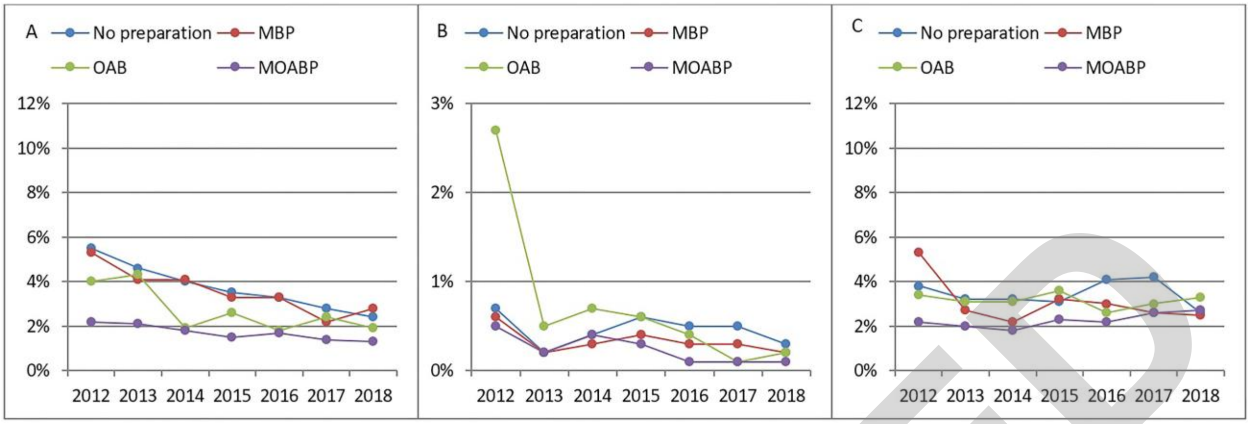

No preparation
MBP
OAB
MOABP
70%
60%
50%
40%
30%
20%
10%
0%
2012
2013
2014
2015
2016
2017
2018

Figure 3



A
No preparation
MBP
OAB
MOABP
12%
10%
8%
6%
4%
2%
0%
2012 2013 2014 2015 2016 2017 2018
B
No preparation
MBP
OAB
MOABP
3%
2%
1%
0%
2012 2013 2014 2015 2016 2017 2018
C
No preparation
MBP
OAB
MOABP
12%
10%
8%
6%
4%
2%
0%
2012 2013 2014 2015 2016 2017 2018