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Independent Predictors of Prolonged Postoperative Ileus Development

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Abstract

Background: Postoperative ileus has a significant impact on patient wellbeing, and with a 15% incidence in colectomy patients, costs US hospitals more than \$1.3 billion/year. While some causative mechanisms have been identified, little is known about what places patients at risk for ileus. We aimed to identify factors that independently influence the development of postoperative ileus.

Materials and Methods: Patients who underwent elective surgery between 2011–2012 were identified from the colectomy-specific American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database. Descriptive statistics were calculated and demographics, comorbidities, preoperative treatments, and operative characteristics were evaluated as risk factors using multivariate analyses.

Results: 9734 patients were included in this analysis; 1364 (14%) were found to have postoperative ileus. Patients who developed an ileus were more likely to develop any postoperative complication, to be readmitted, and require reoperation compared with patients without postoperative ileus. In addition, we identified thirteen independent risk factors for postoperative ileus.

Conclusions: Five modifiable risk factors for development of postoperative ileus were identified: smoking, weight loss, preoperative oral antibiotics, mechanical bowel preparation, and surgical approach. These identifications provide insight into possible targets for preoperative modification, which may lead to improvements in patients' quality of life and influence outcomes such as postoperative complications, readmission, and reoperation.

Keywords

Ileus; Risk Factors; Colectomy

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Authors' contributions: M.M., S.T., and G.K. designed the study. M.M. analyzed the data under the guidance of S.T. and G.K. All authors contributed to the interpretation of the results, particularly S.T. and G.K. with their clinical viewpoints. M.M. had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors reviewed and approved the final manuscript.

Introduction

Regarded as inevitable by some authors,[1] postoperative ileus (POI) is a period of gastrointestinal inactivity after an abdominal surgery, characterized by nausea, vomiting, and delayed passage of flatus and stool.[2] It contributes to patient discomfort and prolonged recovery times, which leads to increased hospital costs.[3] Despite much interest in reducing POI rates, postoperative patients continue to experience POI at significant rates and incur side effects associated with POI. In fact, the incidence of POI in patients undergoing colectomy is between 10% and 15%.[4–7] The mean length of hospital stay for patients with POI is 11.5 vs. 5.5 days for patients without POI.[8] Incremental costs associated with POI after abdominal surgery have been found to be \$9,417, costing hospitals more than \$1.3 billion per year in the United States.[8]

The causes of POI development are multifactorial. Several studies have identified contributing factors including spinal-intestinal autonomic reflexes, opioid administration, electrolyte imbalances, and inflammatory responses.[9–14] While these studies looked at POI as an outcome, identifying predictors of POI was not the focus. Knowledge about these risk factors can lead to better preoperative risk factor management, more informed surgical treatment decisions, earlier postoperative detection, and improved treatment.

We sought to characterize preoperative and intraoperative risk factors for ileus in patients undergoing both open and laparoscopic colectomies. Our definition of ileus is that used by the NSQIP: any nasogastric tube use or NPO status on POD#4 or later. The study aims were to characterize colectomy patients with and without POI, and to identify risk factors for POI development. We hypothesized factors that increase local or systemic inflammation (ex. open surgical approach or obesity) would be associated with POI development.

Methods

Data Source

This was a retrospective study of patients included in the American College of Surgeons National Surgery Quality Improvement Program (ACS-NSQIP) colectomy-specific participant use data file.[15] This database is an observational cohort study of 16,981 cases from 121 participating sites between 2011–2012. It comprises up to 240 variables; we analyzed 27 preoperative and intraoperative factors, controlled for 19 complications, and included 4 outcome metrics.

Exclusion criteria included patients who underwent procedures defined by the ACS-NSQIP as non-elective, those who died within 30 days, those with missing data, and those with operation times of less than 30 minutes. The remaining patients were included in the analysis. This study was deemed exempt by the University of Wisconsin-Madison Health Sciences Institutional Review Board.

Patients

Risk factor and outcome variables were defined by the NSQIP data user guide,[16] and were chosen based on clinical experience and literature review. Preoperative factors included age

(with >90 coded as 90), gender, race, body mass index (BMI), surgical indication, American Society of Anesthesiologists (ASA) physical status class, functional status, smoking status, steroid use, chemotherapy use, oral antibiotic use, use of mechanical bowel preparation, chronic obstructive pulmonary disease (COPD), dyspnea, congestive heart failure (CHF), hypertension (HTN), diabetes, dialysis use, ascites, weight loss, wound infection, bleeding disorder, and sepsis. Intraoperative factors included wound class, operation time, and surgical approach. The primary outcome variable of interest was the presence of postoperative ileus, defined by the NSQIP as a nasogastric tube or NPO on POD#4 or later.

Statistical Analysis

Descriptive analyses were performed to characterize the patients' demographic and other preoperative factors. Numerical data was categorized using clinically significant boundaries (e.g. BMI categories) when appropriate, while quartile cutoffs were utilized for variables without widely accepted clinical categories. Chi-squared analyses were used to compare categorical data between groups. Continuous variables were compared using Mann-Whitney U tests for two group variables, and Kruskal-Wallis tests for variables with more than two groups.

The multivariate model for prediction of ileus risk used binary logistic regression. The presence of complications was included in the regression to control for their interdependence. These complications included NSQIP-defined superficial wound infection, deep surgical site infection, organ space surgical site infection, wound dehiscence, pneumonia, failure to wean, re-intubation, pulmonary embolism, renal insufficiency, renal failure, urinary tract infection (UTI), cerebrovascular accident (CVA), cardiac arrest, myocardial infarction (MI), postoperative bleeding requiring a transfusion, deep vein thrombosis (DVT), sepsis, septic shock, and anastomotic leak.

Propensity scores were calculated using a logistic regression of all preoperative variables, and added to the multivariate model to adjust for non-random assignment of treatment where appropriate. All analyses were performed with SPSS version 22 (IBM, 2013). A p -value < 0.05 was considered significant for the purposes of this study.

Results

As demonstrated in Figure 1, the study population consisted of 9734 patients after exclusion criteria were applied. There were a total of 1364 (14.0%) cases of POI. Demographic and preoperative factors of the study population and the corresponding rates of POI are shown in Table 1. Not surprisingly, multiple medical comorbidities were found to be associated with POI. Patients who underwent operation for volvulus were most likely to develop POI while those undergoing an operation for diverticular disease were least likely (24.4% vs 11%).

As expected, the development of postoperative ileus carried important implications for the postoperative recovery. In particular, patients with only POI had a longer length of stay, increased readmission rates, and higher rate of reoperation than those without any complications (Figure 2, $p < 0.001$ for each). Interestingly, patients with both POI plus non-POI complications had a longer length of stay ($p < 0.001$), increased reoperation rates

($p<0.001$), but decreased readmission rates ($p=0.003$) compared to those with only non-POI complications. Overall, POI was significantly associated with the development of other postoperative complications (Table 2).

The intent was to use this dataset to examine factors that might correlate with a high risk for the developing a postoperative ileus. Therefore, a multivariable analysis was performed. 13 factors that were independent risk factors for POI development were identified (Table 3). The strongest risk factors were ($p<0.001$) included age > 73 , male gender, BMI 25–30 and 30+, surgical indications of Crohn's disease or volvulus, lack of oral antibiotics, preoperative chemotherapy treatment, sepsis, open surgical approach, and long operation times.

The correlation between lack of preoperative bowel preparation and oral antibiotics with the development of a postoperative ileus was particularly interesting. Therefore, a propensity score analysis was performed to control for differences between patients who were likely to undergo a bowel preparation. Using this adjusted analysis, an additional multivariable analysis was performed to examine factors that predict prolonged ileus. Once this propensity score was applied, the only factors that remained predictive of ileus formation were the diagnosis of Crohn's disease and volvulus, not receiving a preoperative bowel preparation, preoperative smoking, the presence of ascites, preoperative sepsis, and a prolonged operative time (Table 4).

Finally, we asked what complications were associated with lack of mechanical bowel preparation using this propensity score analysis. Interestingly, when controlled for the differences between patients who receive mechanical bowel preparation and those who do not, there was an increase in postoperative urinary tract infection in patients who received a preoperative mechanical bowel preparation (OR 1.50, 95% CI 1.13–2.00).

Discussion

We aimed to characterize perioperative risk factors for POI development. Using univariate and multivariate analyses on 9734 patients from the NSQIP database, we were able to identify 13 independent risk factors for POI. Furthermore, a lack of mechanical bowel preparation was found to be an independent predictor of POI even after controlling for non-randomization of assignment. [REMOVED REDUNDANCY AND SIMPLIFIED]

Before comparisons to other studies are made, the lack of a standardized definition of POI should be noted. For example, while Goldstein *et al* and Iyer *et al* used subjective criteria based on flexible ICD-9-CM coding, Ay *et al*, Chapuis *et al*, and Kronberg *et al* used objective temporal cutoffs for normal vs. prolonged POI.[1, 4, 6–8, 17] POI definitions are outlined in Table 5. [REMOVED NSQIP DEFINITION] This difference may limit direct comparison between studies.

Despite differences in definitions of POI noted above, rates of POI development in our study group are in line with similar investigations. Our rate (14.0%) was identical to that found by Chapuis *et al*, and similar to rates found by Iyer *et al*, Kronberg *et al*, and Svatek *et al* (15.3%, 10.2%, and 15.2%, respectively).[4–7] Salvador *et al* identified a higher rate of POI

(25%), but had a small patient group (40 subjects) and utilized a less objective definition for POI including any mention of ileus in the medical record.[18]

Our database included 30-day postoperative data, so outcomes were comprehensively characterized. Lengths of stay (median 11 days with POI vs. 5 days) were similar to those described by Iyer *et al* (10 vs. 6 days), but shorter than those found by Salvador *et al* (16 vs. 7 days), most likely due to their higher rate of POI and slightly older (median age = 64) population.[7, 18] We also investigated non-POI complications, which has not been included in similar studies. Not surprisingly, non-POI complication rates were significantly higher in those with POI than those without. This can likely be attributed to complication interdependence. However, it is not clear if POI acts as a cause or is a sequela of other complications. Further evaluation of the temporal relationship of multiple complications in these patients is an area of interest for future studies.

This is one of the few investigations focused on identifying independent risk factors of POI. Chapuis *et al* performed the most similar study to ours in that they used a large retrospective database for risk factor analysis. Both studies found that male sex and long operative times were associated with POI development. We found older age to be associated, but they did not. These and other differences may be a consequence of using data from a single surgical unit vs. our multi-institutional data, or from the inclusion of alternative variables. Specifically, Chapuis *et al* had access to more intraoperative data points, but they were not able to assess as many preoperative variables as were included in this study. The NSQIP database also provided the advantage of having a larger study group than most other POI investigations. Ay *et al*, Chapuis *et al*, Iyer *et al*, Kronberg *et al*, Salvador *et al*, and Svatek *et al* had populations of 103, 2400, 17876, 413, 40, and 283, respectively.[4–7, 17, 18] Granted, this was a retrospective analysis, but the data was collected by trained surgical clinical reviewers and predictive power was high. Between the unique set of well-defined variables and the large sample size, the colectomy-specific NSQIP database provided for a high-quality analysis.

Perhaps the most interesting result in our analysis was the protective relationship between mechanical bowel preparation and POI development. The benefit of preoperative bowel preparation is a topic with significant disagreement in the literature.[19, 20] As a result, there is no standardization for treatment assignment, which may lead to a strong bias towards healthier patients getting preparation, and thus, a lower incidence of POI. Because this was a retrospective review, there was no randomization of treatment assignment. However, after controlling for this non-randomization with a propensity score, the association was confirmed. While the odds ratio was statistically significant, we do not feel compelled to recommend a modification in preoperative care protocols [REMOVED REDUNDANCY] based on this data. This is also in part due to finding bowel preparation to be a risk factor for acquiring urinary tract infections after investigating all other complications as individual outcomes. Morris *et al* used the same 2011–2012 NSQIP colectomy database to investigate mechanical and oral antibiotic bowel preparations, focusing on surgical site infections, LOS, and readmissions.[21] They showed that a combination mechanical and oral antibiotic preparation was associated with a decrease in overall complications and shortened LOS. It should also be noted that MBP alone did not

have equivalent outcome improvements. These results are in line with ours, however, as no differentiation was made in our analysis between MBP alone or in combination with oral antibiotic administration.

In addition to the limitation in characterizing POI due to variable POI definitions, there was an inability to mitigate institutional characteristics and practices between the 121 sites participating in the NSQIP database. These factors include institution type, and surgical team patient volume, and trends in perioperative care protocol. However, this is not remediable given the intentional exclusion of data regarding institution detail [SIMPLIFIED].

Lastly, the NSQIP database does not currently include data on narcotic, prokinetic, or other medications that affect bowel motility. These may be important factors due to their potentially large positive or negative influence on outcomes, but we were unable to include them in our analysis. [REMOVED NONESSENTIAL DISCUSSION]

Despite these limitations, we believe this study outlines important risk factors for the development of POI. These are highlighted in Table 3 and include increasing age, male gender, obesity, no mechanical bowel preparation and no oral antibiotics, smoking, and an open operative approach. The high power of the study combined with high significance of multivariate analysis makes it clear that outcome improvements can be realized by revising current perioperative care. To confirm findings and aid clinical implementation of guidelines, we recommend prospective investigation of these risk factors and formation of a predictive model for POI development. Such a model was generated by Kronberg *et al*, but the power of the model might be improved by using a larger population, as only three factors were found to be independently predictive.[6]

The findings in this study could lead to an adoption of an enhanced recovery after surgery (ERAS) protocol in high-risk patient populations. One might hypothesize that the lack of an enhanced recovery protocol leads to dehydration in high-risk patient populations, which increases the development of a postoperative ileus.[22, 23] Of course, we cannot know from our dataset if an ERAS protocol is in place or if these patients were managed on such protocols. However, use of these protocols in the elderly and the obese patients is not widespread but is known to be safe.[24, 25]

This study is one of the first to explore the colectomy-specific NSQIP database, and the first to use it for investigating POI development risk factors. Large, patient level, aggregate databases like the ACS-NSQIP allow for widespread access to uncover associations with statistical analysis. This is vital for quality improvement, as hospitals look to develop personalized medicine from the current health information explosion. The modifiable risk factors we identified may be targeted for further investigation into preoperative modification in an effort to improve POI rates and thereby prevent patient discomfort, extended hospital stays, and increased hospital costs.

Conclusion

We used univariate and multivariate analyses to identify 13 independent risk factors for ileus, five of which are modifiable (smoking, weight loss, mechanical bowel preparation, preoperative oral antibiotic treatment, and surgical approach). These associations provide insight into possible targets for preoperative modification in patients with POI risk factors, who may then benefit from modified preoperative treatment such as oral antibiotic courses or mechanical bowel preparation. In addition, this knowledge may lead to targeted preoperative teaching, heightened postoperative surveillance, and more rapid treatment of POI.

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Disclosure

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The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

References

1. Artinyan A, Nunoo-Mensah JW, Balasubramaniam S, Gauderman J, Essani R, Gonzalez-Ruiz C, et al. Prolonged postoperative ileus-definition, risk factors, and predictors after surgery. *World journal of surgery*. 2008;32(7):1495–500. doi: 10.1007/s00268-008-9491-2. [PubMed: 18305994]
2. Kehlet H Postoperative ileus—an update on preventive techniques. *Nature clinical practice Gastroenterology & hepatology*. 2008;5(10):552–8. doi: 10.1038/ncpgasthep1230.
3. Moss G, Regal ME, Lichtig L. Reducing postoperative pain, narcotics, and length of hospitalization. *Surgery*. 1986;99(2):206–10. [PubMed: 2868530]
4. Chapuis PH, Bokey L, Keshava A, Rickard MJ, Stewart P, Young CJ, et al. Risk factors for prolonged ileus after resection of colorectal cancer: an observational study of 2400 consecutive patients. *Annals of surgery*. 2013;257(5):909–15. doi: 10.1097/SLA.0b013e318268a693. [PubMed: 23579542]
5. Svatek RS, Fisher MB, Williams MB, Matin SF, Kamat AM, Grossman HB, et al. Age and body mass index are independent risk factors for the development of postoperative paralytic ileus after radical cystectomy. *Urology*. 2010;76(6):1419–24. doi: 10.1016/j.urology.2010.02.053. [PubMed: 20472264]
6. Kronberg U, Kiran RP, Soliman MS, Hammel JP, Galway U, Coffey JC, et al. A characterization of factors determining postoperative ileus after laparoscopic colectomy enables the generation of a novel predictive score. *Annals of surgery*. 2011;253(1):78–81. doi: 10.1097/SLA.0b013e3181fcb83e. [PubMed: 21233608]
7. Iyer S, Saunders WB, Stemkowski S. Economic burden of postoperative ileus associated with colectomy in the United States. *Journal of managed care pharmacy : JMCP*. 2009;15(6):485–94. [PubMed: 19610681]
8. Goldstein JL, Matuszewski KA, Delaney CP, Senagore A, Chiao EF, Shah M, et al. Inpatient economic burden of postoperative ileus associated with abdominal surgery in the United States. *P and T*. 2007;32(2):82.

9. Quah HM, Samad A, Neathey AJ, Hay DJ, Maw A. Does gum chewing reduce postoperative ileus following open colectomy for left-sided colon and rectal cancer? A prospective randomized controlled trial. *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland*. 2006;8(1):64–70. doi: 10.1111/j.1463-1318.2005.00884.x. [PubMed: 16519641]
10. Carroll J, Alavi K. Pathogenesis and management of postoperative ileus. *Clinics in colon and rectal surgery*. 2009;22(1):47–50. doi: 10.1055/s-0029-1202886. [PubMed: 20119556]
11. Behm B, Stollman N. Postoperative ileus: etiologies and interventions. *Clinical gastroenterology and hepatology : the official clinical practice journal of the American Gastroenterological Association*. 2003;1(2):71–80. doi: 10.1053/cgh.2003.50012. [PubMed: 15017498]
12. Livingston EH, Passaro EP Jr., Postoperative ileus. *Digestive diseases and sciences*. 1990;35(1):121–32. [PubMed: 2403907]
13. Hiranyakas A, Bashankaev B, Seo CJ, Khaikin M, Wexner SD. Epidemiology, pathophysiology and medical management of postoperative ileus in the elderly. *Drugs & aging*. 2011;28(2):107–18. doi: 10.2165/11586170-000000000-00000. [PubMed: 21275436]
14. Schuster R, Grewal N, Greaney GC, Waxman K. Gum chewing reduces ileus after elective open sigmoid colectomy. *Archives of surgery*. 2006;141(2):174–6. doi: 10.1001/archsurg.141.2.174. [PubMed: 16490895]
15. Dahlke AR, Merkow RP, Chung JW, Kinnier CV, Cohen ME, Sohn MW, et al. Comparison of postoperative complication risk prediction approaches based on factors known preoperatively to surgeons versus patients. *Surgery*. 2014;156(1):39–45. doi: 10.1016/j.surg.2014.03.002. [PubMed: 24890570]
16. American College of Surgeon National Surgical Quality Improvement Program. ACS-NSQIP user guide for the 2011 Participant Data Use File: http://site.acsnsqip.org/wp-content/uploads/2012/03/2011-User-Guide_Final.pdf; [9 13, 2015].
17. Ay AA, Kutun S, Ulucanlar H, Tarcin O, Demir A, Cetin A. Risk factors for postoperative ileus. *Journal of the Korean Surgical Society*. 2011;81(4):242–9. doi: 10.4174/jkss.2011.81.4.242. [PubMed: 22111079]
18. Salvador CG, Sikirica M, Evans A, Pizzi L, Goldfarb N. Clinical and Economic Outcomes of Prolonged Postoperative Ileus in Patients Undergoing Hysterectomy and Hemicolectomy. *P&T*. 2005;30(10):590–95.
19. Raynor MC, Pruthi RS. Postoperative Ileus: time for an evidence-based consensus. *European urology*. 2013;64(4):598–9. doi: 10.1016/j.eururo.2012.12.025. [PubMed: 23290302]
20. Slim K, Vicaut E, Launay-Savary MV, Contant C, Chipponi J. Updated systematic review and meta-analysis of randomized clinical trials on the role of mechanical bowel preparation before colorectal surgery. *Annals of surgery*. 2009;249(2):203–9. doi: 10.1097/SLA.0b013e318193425a. [PubMed: 19212171]
21. Morris MS, Graham LA, Chu DI, Cannon JA, Hawn MT. Oral Antibiotic Bowel Preparation Significantly Reduces Surgical Site Infection Rates and Readmission Rates in Elective Colorectal Surgery. *Annals of surgery*. 2015. doi: 10.1097/SLA.0000000000001125.
22. Lovely JK, Maxson PM, Jacob AK, Cima RR, Horlocker TT, Hebl JR, et al. Case-matched series of enhanced versus standard recovery pathway in minimally invasive colorectal surgery. *Br J Surg*. 2011;99(1):120–6. Epub 2011/09/29. doi: 10.1002/bjs.7692. [PubMed: 21948187]
23. Nygren J, Soop M, Thorell A, Hausel J, Ljungqvist O. An enhanced-recovery protocol improves outcome after colorectal resection already during the first year: a single-center experience in 168 consecutive patients. *Dis Colon Rectum*. 2009;52(5):978–85. Epub 2009/06/09. doi: 10.1007/DCR.0b013e31819f1416 00003453–200905000-00018 [pii]. PubMed PMID: 19502866. [PubMed: 19502866]
24. Bagnall NM, Malietzis G, Kennedy RH, Athanasiou T, Faiz O, Darzi A. A systematic review of enhanced recovery care after colorectal surgery in elderly patients. *Colorectal Dis*. 2014;16(12):947–56. doi: 10.1111/codi.12718. [PubMed: 25039965]
25. Boulind CE, Yeo M, Burkill C, Witt A, James E, Ewings P, et al. Factors predicting deviation from an enhanced recovery programme and delayed discharge after laparoscopic colorectal surgery. *Colorectal Dis*. 2011;14(3):e103–10. Epub 2011/11/19. doi: 10.1111/j.1463-1318.2011.02799.x.

Figure 1.
Exclusions made from NSQIP database.

Figure 2.

Length of stay (LOS) in patients with both POI plus non-POI complications, with only POI, with only non-POI complications, and those without any complications.

Table 1.

Univariate Analysis of Demographics, Preoperative Factors, and Intraoperative Characteristics

Variable	n	POI (%)	P-value
Age (median=62)			
<53	2687	12.4	
53–62	2643	13.7	
63–73	2304	12.8	
74+	2100	17.9	<0.001
Gender			
Female	5025	12.3	
Male	4709	15.9	<0.001
Race			
White	7588	14.2	
Black	772	15.9	
Hispanic	438	12.8	
Asian	301	7.6	
Other	45	6.7	0.008
BMI			
Underweight	265	13.2	
Normal weight	3027	12.7	
Overweight	3183	14.4	
Obese	3259	14.5	0.049
Diagnosis			
Cancer	5006	13.2	
Diverticular	2360	11.0	
Bleeding	58	19.0	
Crohn's Disease	578	17.1	
Volvulus	131	24.4	
Ulcerative Colitis	195	15.4	
Other	1389	18.9	<0.001
Steroids—Chronic			
Present	659	18.0	
Absent	9050	13.7	0.001
Chemotherapy			
Present	521	22.8	
Absent	9184	13.5	<0.001
Bowel Prep			
Present	6596	12.2	
Absent	3138	17.8	<0.001
Oral Antibiotics			
Present	2712	10.7	
Absent	7022	15.3	<0.001

Variable	n	POI (%)	P-value
Smoke			
Present	1743	16.1	
Absent	7991	13.6	0.006
COPD			
Present	414	18.8	
Absent	9320	13.8	0.004
Dyspnea			
Present	613	18.8	
Absent	9088	13.7	0.001
CHF			
Present	60	23.3	
Absent	9674	14.0	0.037
Hypertension			
Present	4515	14.8	
Absent	5219	13.3	0.033
Diabetes			
Present	923	14.7	
Absent	8413	13.9	0.574
Dialysis			
Present	37	21.6	
Absent	9697	14.0	0.182
Ascites			
Present	73	37.0	
Absent	9661	13.8	0.001
Weight Loss			
Present	482	19.5	
Absent	9252	13.7	<0.001
Wound Infection			
Present	171	26.3	
Absent	9563	13.8	<0.001
Bleeding Disorder			
Present	362	18.0	
Absent	9372	13.9	0.028
Transfusion			
Present	216	21.3	
Absent	9518	13.8	0.002
Sepsis			
Present	363	29.5	
Absent	9371	13.4	<0.001
Wound Class			
Clean	88	17.0	
Clean/Contaminated	7707	13.1	

Variable	n	POI (%)	P-value
Contaminated	1185	16.5	
Dirty/Infected	754	19.1	<0.001
ASA Class			
I	274	9.9	
II	4877	11.4	
III, IV, V	4583	17.1	<0.001
Functional Status			
Independent	9514	13.8	
Partially Dep.	165	24.8	
Totally Dep.	35	25.7	<0.001
Approach			
Open	4048	21.9	
Laparoscopic	3425	10.0	
HALS	2261	9.3	<0.001
Operation Time (min)			
<117	2444	11.3	
118–159	2412	13.6	
160–220	2449	13.1	
221+	2429	18.2	<0.001

*Data is incomplete for some variables—some may not sum to 9734. Significant P-values are bolded. Some categories do not include all 9734 cases due to unknown values. ASA indicates American Society of Anesthesiologists; HALS, Hand-Assisted Laparoscopic Surgery.

Table 2.

Univariate Analysis of POI Rates in Patients with Other Postoperative Complications

	n	POI (%)	P
<i>Any Other Complication</i>	2413	26.4	
<i>No Complications</i>	7321	9.9	<0.001
Superficial SSI	674	20.8	
No Superficial SSI	9060	13.5	<0.001
Deep SSI	120	32.5	
No Deep SSI	9614	13.8	<0.001
Organ Space SSI	423	33.1	
No Organ Space SSI	9311	13.1	<0.001
Dehiscence	99	38.4	
No Dehiscence	9635	13.8	<0.001
Pneumonia	147	41.5	
No Pneumonia	9587	13.6	<0.001
Reintubation	112	32.1	
No Reintubation	9622	13.8	<0.001
Pulmonary Embolism	57	22.8	
No Pulmonary Embolism	9677	14.0	0.055
Failure to Wean	103	42.7	
No Failure to Wean	9631	13.7	<0.001
Renal Insufficiency	53	41.5	
No Renal Insufficiency	9681	13.9	<0.001
Renal Failure	31	32.3	
No Renal Failure	9703	14.0	0.003
UTI	302	24.5	
No UTI	9432	13.7	<0.001
CVA	14	14.3	
No CVA	9720	14.0	0.977
Cardiac Arrest	19	31.6	
No Cardiac Arrest	9715	14.0	0.027
MI	42	31.0	
No MI	9692	13.9	0.002
Bleed Requiring Transfusion	875	28.8	
No Bleed Requiring Transfusion	8859	12.6	<0.001
DVT	136	35.3	
No DVT	9598	13.7	<0.001
Systemic Sepsis	357	34.5	
No Systemic Sepsis	9377	13.2	<0.001
Septic Shock	93	50.5	
No Septic Shock	9641	13.7	<0.001
Anastomotic Leak	335	33.7	

	n	POI (%)	P
No Anastomotic Leak	9399	13.3	<0.001

P-values calculated in comparison to patients not developing corresponding complication shown in associated row. SSI indicates surgical site infection; UTI, urinary tract infection; CVA, cerebrovascular accident; MI, myocardial infarction; DVT, deep vein thrombosis. Significant *P*-values are bolded.

Table 3.

Multivariate Analysis of Demographics, Preoperative Comorbidities, and Intraoperative Characteristics and Their Effect on POI development

Parameter	Logistic Regression			<i>P</i> -value
	OR	95% CI		
Age^a				
53–63	1.26	1.05	1.50	0.013
64–73	1.30	1.06	1.58	0.010
74+	1.95	1.58	2.42	<0.001
Male Gender	1.41	1.24	1.60	<0.001
Asian Race^b	0.57	0.36	0.89	0.014
BMI^c				
Overweight	1.25	1.07	1.47	0.006
Obese	1.32	1.12	1.56	0.001
Diagnosis^d				
Crohn's	1.51	1.11	2.06	0.009
Volvulus	2.16	1.38	3.36	0.001
No Bowel Prep	1.15	1.01	1.32	0.036
No Oral Antibiotics	1.29	1.10	1.50	0.001
Smoking	1.20	1.02	1.41	0.027
Chemotherapy	1.53	1.21	1.94	<0.001
Ascites	1.86	1.07	3.22	0.027
Sepsis	1.74	1.32	2.29	<0.001
Open Approach^e	2.04	1.77	2.36	<0.001
OpTime^f				
118–159	1.35	1.12	1.62	0.001
160–220	1.26	1.05	1.52	0.015
221+	1.63	1.36	1.96	<0.001

References for indicated parameters are:

^a <53 yrs,

^b white,

^c normal,

^d cancer,

^e Laparoscopic,

^f <117 min. Pre-op factors not significant include diabetes, dyspnea, functional status, ventilator, COPD, CHF, hypertension, renal failure, dialysis, preoperative wound infection, chronic steroid use, preoperative weight loss, bleeding disorder, preoperative bleed requiring transfusion, wound class, and ASA Class. The complications included in the analysis were superficial wound infection, deep surgical site infection, organ space surgical site infection, dehiscence, pneumonia, failure to wean, reintubation, pulmonary embolism, renal insufficiency, renal failure, UTI, CVA, cardiac arrest, MI, bleed requiring transfusion, DVT, sepsis, septic shock, and anastomotic leak.

Table 4.

Propensity Score Adjusted Multivariate Analysis of Demographics, Preoperative Comorbidities, and Intraoperative Characteristics and Their Effect on POI Development

Parameter	Logistic Regression		
	OR	95%	CI
Diagnosis^a			
Crohn's	1.84	1.24	2.74
Volvulus	2.26	1.44	3.54
No Bowel Prep	1.16	1.01	1.33
Smoking	1.22	1.03	1.43
Ascites	3.75	1.30	10.86
Sepsis	9.80	1.02	93.95
OpTime^b			
118–159	1.35	1.12	1.62
160–220	1.26	1.04	1.52
221+	1.63	1.35	1.95

References for indicated parameters are:

^a cancer,

^b <117 min. Pre-op factors not significant include age, gender, race, BMI, oral antibiotics, chemotherapy, diabetes, dyspnea, functional status, ventilator, COPD, CHF, hypertension, renal failure, dialysis, preoperative wound infection, chronic steroid use, preoperative weight loss, bleeding disorder, preoperative bleed requiring transfusion, wound class, surgical approach, and ASA Class. The complications included in the analysis were superficial wound infection, deep surgical site infection, organ space surgical site infection, dehiscence, pneumonia, failure to wean, reintubation, pulmonary embolism, renal insufficiency, renal failure, UTI, CVA, cardiac arrest, MI, bleed requiring transfusion, DVT, sepsis, septic shock, and anastomotic leak.

Table 5.

Definitions of POI in Similar Studies

Study	POI Definition
Murphy <i>et al</i>	Nasogastric tube or NPO on POD#4 or later
Goldstein <i>et al</i> [8]	ICD-9 diagnostic codes 560.1 and/or 997.4
Iyer <i>et al</i> [7]	ICD-9 diagnostic codes 560.1
Salvador <i>et al</i> [18]	“Documentation of POI in the medical record, confirmation through radiological tests, or delayed return of gastrointestinal function”
Ay <i>et al</i> [17]	Dysmotility later than 3 days after surgery
Chapuis <i>et al</i> [4]	Dysmotility later than 3 days after surgery
Kronberg <i>et al</i> [6]	Dysmotility later than 4 days after surgery, or placement of nasogastric tube after starting oral diet.
Svatek <i>et al</i> [5]	Dysmotility later than 6 days after surgery