Risk Factors of Early Postoperative Bowel Obstruction for Patients Undergoing Selective Colorectal Surgeries

Shuguang Yang

Peking University People's Hospital

Zhidong Gao

Peking University People's Hospital

Huiying Zhao

Peking University People's Hospital

Youzhong An

Peking University People's Hospital

Jianghui Yang

Peking University People's Hospital

Hua Zhang

Peking University Third Hospital

Yudi Bao

Peking University People's Hospital

Yingjiang Ye (✉ yeyingjiang@pkuph.edu.cn)

Peking University People's Hospital

Research Article

Keywords: Risk-factors, Early postoperative bowel obstruction, Colorectal surgery

Posted Date: August 24th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-624962/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at BMC Gastroenterology on December 1st, 2021. See the published version at <https://doi.org/10.1186/s12876-021-02025-8>.

Abstract

Objective: Postoperative bowel obstruction was one of the most severe complications in patients received colorectal surgeries. The aim of this study was to explore risk factors of early postoperative obstruction and to construct a nomogram to predict the possibility of occurrence.

Methods: The records of 1437 patients who underwent selective colorectal surgery in Peking University People's Hospital from 2015 to 2020 was retrospectively collect. Risk factors of early postoperative bowel obstruction were identified by logistic regression analysis and a nomogram was then constructed. Bootstrap was applied to verify the stability of the model.

Results: COPD, hypothyroidism, probiotic indications, duration of antibiotics, and time to postoperative feeding were identified as independent risk factors and were put into a nomogram for predicting early postoperative bowel obstruction. The nomogram showed a robust discrimination, with area under the receiver operating characteristic curve was 0.894 and was well calibrated.

Conclusion: A nomogram including independent risk factors of COPD, hypothyroidism, probiotic indications, duration of antibiotics, and time to postoperative feeding were established to predict the risk of early postoperative bowel obstruction.

Introduction

Postoperative bowel obstruction, either mechanical or functional, was a common and severe complication which might affect the recovery of bowel function and lead to prolonged hospitalization and rising medical costs. Previous studies showed that postoperative bowel obstruction could even increase mortality and morbidity in patients following abdominal surgery[1, 2]. Postoperative bowel obstruction might be classified based on the time duration from the initial surgery. Early postoperative bowel obstruction was defined as occurring within the first 30 days after surgery[3]. Edna et al found that the incidence of postoperative small bowel obstruction after the colorectal was 9%[4]. The reason causing postoperative bowel obstruction was either mechanical obstruction from adhesions or paralytic ileus in abdominal surgery[5].

Previous studies found that cystotomy, lysis of adhesions, concomitant bowel surgery postoperative transfusion were independent risk factors for the development of small bowel obstruction after benign gynecologic surgery[6]. Several studies focused on the incidence and management of postoperative bowel obstruction. The risk factors of postoperative bowel obstruction after colorectal surgery have not been adequately documented. Our study aimed to explore the risk factors of postoperative bowel obstruction following colorectal surgery.

Materials And Methods

This was a retrospective nested case-control study which retrospectively enrolled patients who underwent colonic and/or rectal surgery from January 2015 to December 2020 at Peking University People's Hospital. Patients who were diagnosed as digestive tract perforation before surgery, patients with history of gastrointestinal surgery and patients who underwent enterostomy, as jejunostomy or ileostomy were excluded. Patients were divided into two groups according to whether clinical and radiological signs of bowel obstruction were identified or not.

Data Collection

Patients' demographic characteristics (age, sex, Body mass index[BMI]), underlying disease (history of smoking or alcohol, hypotension, coronary heart disease[CHD], arrhythmia, cerebral infarction, encephalorrhagia, hypothyroidism, diabetes mellitus, chronic obstructive pulmonary disease [COPD], renal inadequacy, hyperlipidemia, hepatic inadequacy, blood disease, preoperative chemotherapy, preoperative anemia, preoperative ileus), surgical details including American Society of Anesthesiologists [ASA] classification, bowel preparation, surgical site, surgical approach, excision method, operative time, antibiotic correlation (preoperative antibiotics, preoperative fortified antibiotics and postoperative fortified antibiotics), time to postoperative feeding, probiotic correlation (using probiotics and probiotic indication), postoperative albumin level, postoperative analgesia, time to extraction of gastric and drainage tube were recorded.

Early postoperative bowel obstruction was defined as the clinical presentation with abdominal distension or pain within 30 days after surgery[3]. The clinical diagnosis must be confirmed by the presence of dilated bowel loops with multiple fluid levels in the plain abdominal X-ray or computed tomography [CT] [7].

Statistical analysis

SPSS 26.0 (IBM) was used for all statistical analyses. Data were given as means with standard deviations or as medians with interquartile ranges (IQRs), as appropriate. The normality of data distributions was assessed, after which non-normally distributed data were compared via Mann-Whitney U tests and normally distributed data were compared via student's t tests, while categorical data were compared via χ^2 tests or Fisher's exact test. Univariate logistic regression analyses were performed based upon whether or not bowel obstruction. Variables that attained a $p < 0.05$ in this univariate model were included in a subsequent multivariate model in order to identify independent predictors of bowel obstruction. For this multivariate analysis, backward stepwise elimination was conducted such that only variables yielding a $p < 0.05$ were retained for the final model. Odds ratios (OR) and corresponding 95% confidence intervals (CI) were calculated for all variables and associated relationships. For all analysis, p value of less than 0.05 was considered to be statistically difference.

Logistic regression was used to screen the associated factors and establish the prediction model, and Nomogram was applied for convenience of clinical application. The performance of nomogram was

assessed by discrimination and calibration. The discrimination ability of model was quantified using area under the receiver operating characteristic curve (AUC). Bootstrap was applied to verify the stability of the model, and 1000 times of retractable extraction was adopted. The above analysis was completed by R software RMS package.

Results

Patient characteristics

A total of 1437 patients (mean age, 64.24 [range 19–93] years; 47.6% female) were enrolled. The incidence of postoperative bowel obstruction was 10.6%. The clinical characteristics of patients were showed in Table 1. There were no statistically significant differences in BMI, preoperative anemia, preoperative ileus, bowel preparation, location of colorectal resection, operative time, hypoproteinemia or time to extraction of gastric tube for patients underwent colorectal surgery.

Table 1
Patient characteristics and univariable analysis of the risk of postoperative bowel obstruction

Variables N(%)	No postoperative ileus n = 1284	Postoperative ileus n = 153	χ^2/t	P value
Female	615(47.90)	69(45.10)	0.429	0.512
Age	63.92 ± 13.16	66.97 ± 12.02	0.022	0.004
BMI	23.64 ± 3.55	23.09 ± 3.24	0.603	0.051
Right colectomy	436(33.96)	47(30.72)	0.642	0.423
Transverse colectomy	60(4.67)	11(7.19)	1.844	0.175
Left colectomy	124(9.66)	18(11.76)	0.682	0.409
Sigmoid colectomy	450(35.05)	54(35.29)	0.004	0.952
Rcctectomy	289(22.51)	34(22.22)	0.006	0.936
Malignant	1224(95.33)	148(96.73)	0.625	0.429
Hypertension	798(62.15)	91(59.48)	0.414	0.520
CAD	168(13.08)	24(15.69)	0.800	0.371
Arrhythmia	85(6.62)	11(7.19)	0.071	0.790
Cerebral infarction	106(8.26)	14(9.15)	0.143	0.705
Encephalorrhagia	8(0.62)	2(1.31)	0.201	0.654
Hypothyroidism	23(1.79)	8(5.23)	6.111	0.013
Diabetes mellitus	234(18.22)	31(20.26)	0.377	0.539
COPD	50(3.89)	15(9.80)	11.056	0.001
Renal inadequacy	33(2.57)	4(2.61)	0.000	1.000
Hyperlipidemia	258(20.09)	37(24.18)	1.401	0.236
Hepatic inadequacy	17(1.32)	3(1.96)	0.073	0.787
Blood disease	12(0.93)	1(0.65)	0.000	1.000
History of alcohol	169(13.16)	24(15.69)	0.749	0.387
History of smocking	218(16.98)	28(18.30)	0.169	0.681
Preoperative chemotherapy	52(4.05)	6(3.92)	0.006	0.939

*: Comparison between two groups,*group and*group..... The difference between groups was statistically significant (P < 0.01 or P < 0.05).

Variables N(%)	No postoperative ileus n = 1284	Postoperative ileus n = 153	χ^2 / t	P value
Preoperative anemia	565(44.00)	73(47.71)	0.762	0.383
Preoperative ileus	249(19.39)	33(21.57)	0.421	0.810
ASA I	145(11.29)	18(11.76)	7.556	0.047*
ASA II	937(72.98)	98(64.05)		
ASA III	192(14.95)	35(22.88)		
ASA IV	10(0.78)	2(1.31)		
Soapsuds enema for bowel preparation	133(10.36)	18(11.76)	0.288	0.592
Oral laxatives for bowel preparation	1178(91.74)	135(88.24)	2.135	0.144
Glycerin enema for bowel preparation	212(16.51)	22(14.38)	0.456	0.500
Oral antibiotics for bowel preparation	58(4.51)	4(2.61)	1.199	0.274
Laparotomy	644(50.16)	57(37.25)	9.107	0.003
Curative resection	1126(87.69)	132(86.27)	0.253	0.615
Operative time (Min)	208.17 ± 67.78	205.74 ± 68.67	0.133	0.678
Preoperative antibiotics	80(6.23)	17(11.11)	5.173	0.023
Preoperative fortified antibiotics	45(3.50)	12(7.84)	6.755	0.009
Postoperative fortified antibiotics	536(41.74)	76(49.67)	3.515	0.061
Duration of antibiotics (Day)	6.68 ± 3.62	11.92 ± 9.10	213.504	0.000
Time to postoperative feeding (Day)	5.48 ± 1.75	8.07 ± 4.46	222.496	0.000
Using probiotics	348(27.10)	54(35.29)	4.553	0.033
Probiotic indications	505(39.33)	150(98.04)	189.965	0.000
Postoperative analgesia	1214(94.55)	146(95.42)	0.207	0.649
Duration of analgesia	2.77 ± 0.98	2.99 ± 1.49	0.040	0.074

*: Comparison between two groups,*group and*group..... The difference between groups was statistically significant (P < 0.01 or P < 0.05).

Variables N(%)	No postoperative ileus n = 1284	Postoperative ileus n = 153	χ^2/t	P value
Hypoproteinemia	1067(89.10)	134(87.58)	2.001	0.157
Extraction of gastric tube (Day)	1.74 ± 1.48	3.04 ± 9.12	86.873	0.085
Extraction of drainage tube (Day)	8.77 ± 7.11	11.41 ± 5.24	5,618	0.000
*: Comparison between two groups,*group and*group..... The difference between groups was statistically significant (P < 0.01 or P < 0.05).				

Selected Factors For Model

The association between the occurrence of early postoperative obstruction and age, hypothyroidism, COPD, ASA classification, laparotomy, preoperative antibiotics, preoperative fortified antibiotics, duration of antibiotics, time of first postoperative feeding, using probiotics, probiotic indications and time to extraction of drainage were investigated by multivariable logistic regression analysis using a stepwise method. COPD (p = 0.046), hypothyroidism (p = 0.003), probiotic indications (p < 0.001), duration of antibiotics (p < 0.001) and time of first postoperative feeding (p < 0.001) were found as independent risk factors of postoperative bowel obstruction after adjusting logistic regression (Table 2).

Table 2
Risk factors of postoperative bowel obstruction in Logistic regress

	OR (95%CI)	Pvalue
COPD	Ref	0.046
No	2.56(1.02–1.05)	
Yes		
Hypothyroidism	Ref	0.003
No	4.92(1.71–14.19)	
Yes		
Probiotic indications	Ref	< 0.001
No	30.26(9.37–97.70)	
Yes		
Duration of antibiotics (Day)	1.10(1.05–1.15)	< 0.001
Time to postoperative feeding (Day)	1.27(1.16–1.39)	< 0.001

Predict Model For Early Postoperative Bowel Obstruction

On the basis of previous results, a nomogram that included five before-mentioned risk factors was constructed to predict postoperative bowel obstruction (Fig. 1). The value of each of these variables was given a score on the point scale axis. The area under the curve (AUC) was 0.894 (95% confidence interval 0.865–0.923) (Fig. 2) and the calibration curve was presented in Fig. 3.

Discussion

Postoperative bowel obstruction was a quite common complication after colorectal surgery[8]. Previous studies showed that risk factors of prolonged or early postoperative bowel obstruction for patients after colorectal surgery[9–11]. But few studies analyzed multiple risk factors for early postoperative bowel obstruction and no one previous study was found focusing on the prediction model of early postoperative bowel obstruction[12]. As far as we knew, our study was the very first to establish a nomogram to predict patient-specific factors for early postoperative bowel obstruction with high discriminative ability and excellent calibration. In this study, we identified COPD, hypothyroidism, probiotic indications, duration of antibiotics and time of first postoperative feeding as potential risk factors and created a statistical predictive model for early postoperative bowel obstruction.

Recent findings highlighted that gut microbiota might play an important role in shaping lung inflammation[13]. Both imbalance of gut microflora, which led to the release of intestinal endotoxin and translocation of intestinal flora, which led to the release of inflammatory mediators could directly or indirectly promote the beginning and development of COPD[14]. Several studies found that COPD was the only preoperative morbidity predictive of complications after colorectal cancer resection[15, 16]. A history of COPD was an independent risk factor of postoperative 30-day morbidity, mortality, and hospital duration of stay in patients underwent colectomy, small bowel resection and appendectomy[17]. In that study, COPD was also found as an independent predictor for early postoperative bowel obstruction in patients underwent colorectal surgery[18].

Patients with chronic constipation and abdominal distension should be considered with the diagnosis of hypothyroidism in 1969[19]. S. Goto et al[20] compared daily stool volume of rat between hypothyroidism group and sham operated group. They found[20] that hypothyroidism impaired colonic motility and function as frequently seen in rats. Another case report[21] reported that a patient got intestinal symptoms from hypothyroidism in which previous conventional examinations were negative. In our study, the incidence of early postoperative bowel obstruction was higher in patients with hypothyroidism. Hypothyroidism might impaired gut motility[22].

During recent years the impact of antibiotic agents on the intestinal microflora has been investigated in patients undergoing colorectal surgery[23]. Prophylactic antibiotics are effective in preventing surgical-wound infections[24]. Antibiotics impact the intestinal microflora depends on the agents' spectrum and concentration[25]. Antibiotics usually had significant additional effects on many tissues. The study

comparing the contractile responses of ileum smooth muscle to different agonists in adult guinea pigs indicated that antibiotics may impaired small bowel smooth muscle contractility, which was the implication for the long-term use of parenteral antibiotics in the postoperative period[26]. In our study, duration of antibiotics (11.92 ± 9.10 day) was longer in early postoperative bowel obstruction group (OR 1.10, 95%CI 1.05–1.15). According to the guideline of probiotics use[27], three most common clinical indications were prevention of antibiotic-related side effects, treatment of antibiotic-related side effects and irritable bowel syndrome. Our study indicated that patients with antibiotic-related side effects such as diarrhea and abdominal distension (also as probiotic indications), were potential victims of early postoperative bowel obstruction. But there was no difference between patients with and without using probiotics.

A meta-analysis[28] evaluating the effect on the early time of oral feeding after upper gastrointestinal surgery found that early postoperative oral feeding reduced the length of hospital stay and decreased relevant complications as anastomotic leak and incidence of nasogastric tube reinsertion. Sabrina Toledano et al[29] showed that early oral feeding reduced the time to first flatus and first ostomy output compared with traditional diet in the patients who had an ostomy creation, which may promote the recovery of bowel function. In our study, time to first postoperative feeding was an independent risk factor of early postoperative bowel obstruction.

Previous studies mechanical bowel preparation was routinely used to improve postoperative recovery of colon surgery[30]. But bowel cleaning with oral antibiotics can reduce the incidence of surgical site infection, anastomotic leakage and other morbidity compared with mechanical bowel preparation[31–35] for patients undergoing colorectal surgery. Recently, Koskenvuo et al recruited a multicenter, parallel, single blind trial to fund that oral antibiotics bowel preparation cannot reduce the occurrence of surgical site infection or overall morbidity after colonic surgery[36]. There was no significant difference in mechanical bowel preparation with or without oral antibiotics for early postoperative bowel obstruction.

Plasma albumin is involved in the transport of human of metabolites, maintenance of colloid osmotic pressure and other physiological function[37]. Plasma albumin value is performed to evaluate the postoperative nutritional status[38]. Another study showed no significant difference in postoperative day of flatus or postoperative day of intake between patients with albumin levels dropped below 3.5g/dl and patients with albumin greater or equal to 3.5g/dL[39]. Our study showed that hypoproteinemia may not be an independent risk factor of early postoperative bowel obstruction for patients after colorectal surgery.

Analgesia is becoming more acceptable by surgical patients. Opioids are the most commonly used for analgesia. Almost 93.6% patients choose opioids for analgesia in our study. But opioids have numerous side-effects such as breath inhibition, nausea, vomiting, ileus and urinary retention[40]. One study showed that intravenous acetaminophen helps to reduce opioids consumption, which reduced time to return of bowel function for patients undergoing colorectal surgery[41]. In our study, both analgesic protocol and

duration of analgesia were not the risk factors of early postoperative bowel obstruction for patients underwent colorectal surgery.

It is that the incidence of postoperative morbidity mortality increased in elderly patients[42], which elderly patients were more likely to present with later stage disease. ASA classification is associated with postoperative morbidity in the patients undergoing major abdominal cancer surgery[43]. ASA score predicts postoperative length of stay and complication risk[44]. Age and ASA classification may increase the incidence of early postoperative bowel obstruction after unifactor analysis but was not an independent factor for early postoperative bowel function after logistic regression analysis in this study.

We investigated multiple factors that may be associated with early postoperative bowel obstruction. But there were also some limitations, because the data was collected retrospectively. It was still unclear whether the predict model could be applied in all patients, because our data were collected from China. Nevertheless, we think our nomogram could help the postoperative management of patients undergoing colorectal surgery.

Conclusion

To our knowledge, this study presented that COPD, hypothyroidism, probiotic indications, duration of antibiotics and time of first postoperative feeding were the independent risk factors for early postoperative bowel obstruction after colorectal surgery. A nomogram based on the above key factors was established to predict the risk of early postoperative bowel obstruction, which might help improving postoperative management in patients.

Abbreviations

BMI

underlying disease

CHD

coronary heart disease

COPD

chronic obstructive pulmonary disease

ASA

American Society of Anesthesiologists

CT

computer tomography

OR

Odds ratios

CI

confidence intervals

AUC

area under the curve

Declarations

Ethics approval and consent to participate

The medical ethics committee of our college (Peking University People's Hospital) approved the retrospective study. As the study was retrospective, it did not affect the diagnosis and treatment of patients.

Consent for publication

Not applicable.

Availability of data and material

The datasets used are available from the corresponding author on reasonable request.

Competing interests

There were no conflicts of interest to declare.

Funding

This work was supported by Peking University People's Hospital Scientific Research Development Funds (RDL 2020-06)

Contributions

YSG and GZD designed the study, participated in the literature search, analysis of data, as well as manuscript writing. YJH participated in the literature search and data analysis and revised the manuscript. ZHY and BYD participated in the data analysis and revised the manuscript. YYJ have made contributions to the design of the work. ZH have made contributions to the acquisition, analysis of data. YSG is the first author. YYJ or GZD are corresponding authors, and responsible for ensuring that all listed authors have approved the manuscript before submission.

Acknowledgements

Thank you for all participants for accomplishing this study.

References

1. Muffly TM, Ridgeway B, Abbott S, Chmielewski L, Falcone T: Small bowel obstruction after hysterectomy to treat benign disease. Journal of minimally invasive gynecology 2012, 19(5):615–619.

2. Fevang BT, Fevang J, Stangeland L, Soreide O, Svanes K, Viste A: Complications and death after surgical treatment of small bowel obstruction: A 35-year institutional experience. *Ann Surg* 2000, 231(4):529–537.
3. Miller G, Boman J, Shrier I, Gordon PH: Etiology of small bowel obstruction. *Am J Surg* 2000, 180(1):33–36.
4. Edna TH, Bjerkeset T: Small bowel obstruction in patients previously operated on for colorectal cancer. *The European journal of surgery = Acta chirurgica* 1998, 164(8):587–592.
5. Pickleman J, Lee RM: The management of patients with suspected early postoperative small bowel obstruction. *Annals of surgery* 1989, 210(2):216–219.
6. Antosh DD, Grimes CL, Smith AL, Friedman S, McFadden BL, Crisp CC, Allen AM, Gutman RE, Rogers RG: A case-control study of risk factors for ileus and bowel obstruction following benign gynecologic surgery. *International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics* 2013, 122(2):108–111.
7. Wilson MS, Hawkswell J, McCloy RF: Natural history of adhesional small bowel obstruction: counting the cost. *Br J Surg* 1998, 85(9):1294–1298.
8. Matter I, Khalemsky L, Abrahamson J, Nash E, Sabo E, Eldar S: Does the index operation influence the course and outcome of adhesive intestinal obstruction? *The European journal of surgery = Acta chirurgica* 1997, 163(10):767–772.
9. Quiroga-Centeno AC, Jerez-Torra KA, Martin-Mojica PA, Castañeda-Alfonso SA, Castillo-Sánchez ME, Calvo-Corredor OF, Gómez-Ochoa SA: Risk Factors for Prolonged Postoperative Ileus in Colorectal Surgery: A Systematic Review and Meta-analysis. *World J Surg* 2020, 44(5):1612–1626.
10. Nakajima J, Sasaki A, Otsuka K, Obuchi T, Nishizuka S, Wakabayashi G: Risk factors for early postoperative small bowel obstruction after colectomy for colorectal cancer. *World J Surg* 2010, 34(5):1086–1090.
11. Wang XJ, Chi P, Lin HM, Lu XR, Huang Y, Xu ZB, Huang SH, Sun YW, Ye DX: Risk Factors for Early Postoperative Small Bowel Obstruction after Elective Colon Cancer Surgery: An Observational Study of 1,244 Consecutive Patients. *Dig Surg* 2018, 35(1):49–54.
12. Masoomi H, Kang CY, Chaudhry O, Pigazzi A, Mills S, Carmichael JC, Stamos MJ: Predictive factors of early bowel obstruction in colon and rectal surgery: data from the Nationwide Inpatient Sample, 2006–2008. *J Am Coll Surg* 2012, 214(5):831–837.
13. McAleer JP, Kolls JK: Contributions of the intestinal microbiome in lung immunity. *European Journal of Immunology* 2018, 48(1):39–49.
14. Kim HJ, Li H, Collins JJ, Ingber DE: Contributions of microbiome and mechanical deformation to intestinal bacterial overgrowth and inflammation in a human gut-on-a-chip. *Proceedings of the National Academy of Sciences of the United States of America* 2016, 113(1):E7-E15.
15. Leung AM, Gibbons RL, Vu HN: Predictors of length of stay following colorectal resection for neoplasms in 183 Veterans Affairs patients. *World J Surg* 2009, 33(10):2183–2188.

16. Lemmens VE, Janssen-Heijnen ML, Houterman S, Verheij KD, Martijn H, van de Poll-Franse L, Coebergh JW: Which comorbid conditions predict complications after surgery for colorectal cancer? *World J Surg* 2007, 31(1):192–199.
17. Fields AC, Divino CM: Surgical outcomes in patients with chronic obstructive pulmonary disease undergoing abdominal operations: An analysis of 331,425 patients. *Surgery* 2016, 159(4):1210–1216.
18. Millan M, Biondo S, Fraccalvieri D, Frago R, Golda T, Kreisler E: Risk factors for prolonged postoperative ileus after colorectal cancer surgery. *World J Surg* 2012, 36(1):179–185.
19. Cole P, Petrie JC, Bewsher PD: Intestinal obstruction and hypothyroidism. *Br Med J* 1969, 3(5671):655–656.
20. Goto S, Billmire DF, Grosfeld JL: Hypothyroidism impairs colonic motility and function. An experimental study in the rat. *European journal of pediatric surgery: official journal of Austrian Association of Pediatric Surgery [et al] = Zeitschrift fur Kinderchirurgie* 1992, 2(1):16–21.
21. Bassotti G, Pagliacci MC, Nicoletti I, Pelli MA, Morelli A: Intestinal pseudoobstruction secondary to hypothyroidism. Importance of small bowel manometry. *J Clin Gastroenterol* 1992, 14(1):56–58.
22. Hays MT: Thyroid hormone and the gut. *Endocrine research* 1988, 14(2–3):203–224.
23. Brismar B, Edlund C, Malmborg AS, Nord CE: Ecological impact of antimicrobial prophylaxis on intestinal microflora in patients undergoing colorectal surgery. *Scand J Infect Dis Suppl* 1990, 70:25–30.
24. Classen DC, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP: The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. *The New England journal of medicine* 1992, 326(5):281–286.
25. Nord CE: Studies on the ecological impact of antibiotics. *European Journal of Clinical Microbiology and Infectious Diseases* 1990, 9(7):517–518.
26. Ceran C, Karadas B, Kaya T, Arpacik M, Bagcivan I, Sarac B: Do antibiotics contribute to postoperative ileus? Contractile responses of ileum smooth muscle in Guinea pigs to long-term parenteral ceftriaxone and ampicillin. *ANZ J Surg* 2006, 76(11):1023–1026.
27. Draper K, Ley C, Parsonnet J: Probiotic guidelines and physician practice: a cross-sectional survey and overview of the literature. *Benef Microbes* 2017, 8(4):507–519.
28. Willcutts KF, Chung MC, Erenberg CL, Finn KL, Schirmer BD, Byham-Gray LD: Early Oral Feeding as Compared With Traditional Timing of Oral Feeding After Upper Gastrointestinal Surgery: A Systematic Review and Meta-analysis. *Ann Surg* 2016, 264(1):54–63.
29. Toledano S, Sackey J, Willcutts K, Parrott JS, Tomesko J, Al-Mazrou AM, Kiran RP, Brody RA: Exploring the Differences Between Early and Traditional Diet Advancement in Postoperative Feeding Outcomes in Patients With an Ileostomy or Colostomy. *Nutrition in clinical practice: official publication of the American Society for Parenteral and Enteral Nutrition* 2019, 34(4):631–638.
30. Wind J, Polle SW, Fung Kon Jin PHP, Dejong CHC, Von Meyenfeldt MF, Ubbink DT, Gouma DJ, Bemelman WA: Systematic review of enhanced recovery programmes in colonic surgery. *Acute Pain*

- 2006, 8(4):189–190.
31. Condon RE, Bartlett JG, Greenlee H, Schulte WJ, Ochi S, Abbe R, Caruana JA, Gordon HE, Horsley JS, Irvin G, III et al: Efficacy of Oral and Systemic Antibiotic Prophylaxis in Colorectal Operations. *Archives of Surgery* 1983, 118(4):496–502.
 32. Takesue Y, Yokoyama T, Akagi S, Ohge H, Murakami Y, Sakashita Y, Miyamoto K, Uemura K, Itaha H, Matsuura Y: A Brief Course of Colon Preparation with Oral Antibiotics. *Surgery Today* 2000, 30(2):112–116.
 33. Rollins K, Javanmard-Emamghissi H, Acheson A, Lobo D: The Role of Oral Antibiotic Preparation in Elective Colorectal Surgery: A Meta-analysis. *Annals of Surgery* 2018, 270:1.
 34. Fry DE: Colon preparation and surgical site infection. *The American Journal of Surgery* 2011, 202(2):225–232.
 35. Espin Basany E, Solís-Peña A, Pellino G, Kreisler E, Fracalvieri D, Muinelo-Lorenzo M, Maseda-Díaz O, García-González JM, Santamaría-Olabarrieta M, Codina-Cazador A et al: Preoperative oral antibiotics and surgical-site infections in colon surgery (ORALEV): a multicentre, single-blind, pragmatic, randomised controlled trial. *The Lancet Gastroenterology & Hepatology* 2020, 5(8):729–738.
 36. Koskenvuo L, Lehtonen T, Koskensalo S, Rasilainen S, Klintrup K, Ehrlich A, Pinta T, Scheinin T, Sallinen V: Mechanical and oral antibiotic bowel preparation versus no bowel preparation for elective colectomy (MOBILE): a multicentre, randomised, parallel, single-blinded trial. *The Lancet* 2019, 394(10201):840–848.
 37. Adams HA, Piepenbrock S, Hempelmann G: [Volume replacement solutions—pharmacology and clinical use]. *Anesthesiologie, Intensivmedizin, Notfallmedizin, Schmerztherapie: AINS* 1998, 33(1):2–17.
 38. Xiao-Bo Y, Qiang L, Xiong Q, Zheng R, Jian Z, Jian-Hua Z, Qian-Jun Z: Efficacy of early postoperative enteral nutrition in supporting patients after esophagectomy. *Minerva chirurgica* 2014, 69(1):37–46.
 39. Woods MS, Kelley H: Oncotic pressure, albumin and ileus: the effect of albumin replacement on postoperative ileus. *The American surgeon* 1993, 59(11):758–763.
 40. Kehlet H, Dahl JB: The value of "multimodal" or "balanced analgesia" in postoperative pain treatment. *Anesthesia and analgesia* 1993, 77(5):1048–1056.
 41. Aryaie AH, Lalezari S, Sergeant WK, Puckett Y, Juergens C, Ratermann C, Ogg C: Decreased opioid consumption and enhance recovery with the addition of IV Acetaminophen in colorectal patients: a prospective, multi-institutional, randomized, double-blinded, placebo-controlled study (DOCIVA study). *Surgical endoscopy* 2018, 32(8):3432–3438.
 42. Surgery for colorectal cancer in elderly patients: a systematic review. *Colorectal Cancer Collaborative Group. Lancet* 2000, 356(9234):968–974.
 43. Hightower CE, Riedel BJ, Feig BW, Morris GS, Ensor JE, Jr., Woodruff VD, Daley-Norman MD, Sun XG: A pilot study evaluating predictors of postoperative outcomes after major abdominal surgery: Physiological capacity compared with the ASA physical status classification system. *Br J Anaesth* 2010, 104(4):465–471.

44. Jacqueline R, Malviya S, Burke C, Reynolds P: An assessment of interrater reliability of the ASA physical status classification in pediatric surgical patients. Paediatric anaesthesia 2006, 16(9):928–931.

Figures

Figure 1

Nomogram for early postoperative bowel obstruction after colorectal surgery. The value of variable was given a score on the point scale axis. To estimate the probability of early postoperative bowel obstruction, a total score could be calculated by adding each and could be projected to the lower total point scale.

Figure 2

Receiver operating characteristic curve for the prediction model. Area under the curve was 0.894 (95% confidence interval 0.865-0.923).

Figure 3

Calibration of the nomogram for early postoperative bowel obstruction. The x-axis shows the predicted probability of early postoperative bowel obstruction, and the y-axis shows the observed probability of early postoperative bowel obstruction.