ORIGINAL ARTICLE

https://doi.org/10.1590/1806-9282.20211174

An international multi-institutional analysis of operative morbidity in patients undergoing elective diverticulitis surgery

Yuksel Altinel[1,2,3]*, Paul Cavallaro[1], Rocco Ricciardi[1], Volkan Ozben[4], Ersin Ozturk[5], Ron Bleday[6], Members of the Turkish Diverticulitis Study Group Collaborative**, Erman Aytac[4], Liliana Bordeianou[1]

SUMMARY

OBJECTIVE: We investigated surgical complications of elective surgery for diverticulitis in international multi-institution to identify a prediction model for potential opportunities of quality improvement.

METHODS: We identified 1225 patients who underwent elective surgery for diverticulitis between January 2010 and January 2018. The data were obtained from the National Surgical Quality Improvement Program and the Turkish Diverticulitis Study Group Collaborative, retrospectively.

RESULTS: We observed that the presence of chronic obstructive pulmonary disease (OR: 3.2, 95%CI 1.8–5.9, p<0.001) or abscess at the time of surgery (OR: 1.4, 95%CI 1.2–1.7, p£0.001) is associated with a higher rate of minor complications, while comorbidities such as dyspnea (OR: 2.8, 95%CI 1.6–4.9, p£0.001) and preoperative sepsis (OR: 4.1, 95%CI 2.3–7.3, p£0.001) are associated with major complications. The centers had similar findings in minor and major complications (OR: 0.8, 95%CI 0.5–1.4, p=0.395). The major independent predictors for complications were malnutrition (low albumin) (OR: 0.5, 95%CI 0.4–0.6, p<0.001) and the American Society of Anesthesiology score (OR: 1.7, 95%CI 1.2–2.4, p=0.002).

CONCLUSION: Regarding the major and minor complications of diverticulitis of elective surgery, the malnutrition and higher American Society of Anesthesiology score showed higher impact among the quality improvement initiatives.

KEYWORDS: Diverticulitis. Complications. Surgery.

INTRODUCTION

The treatment of diverticulitis with elective sigmoidectomy is controversial. Approximately 20% of patients with episodes of diverticulitis enhance recurrences following conservative treatment[1]. Elective resection was recommended for the patients with the second attack of diverticulitis that was considered approximately 60% risk for post-surgical complications[2]. However, prophylactic elective resection for diverticulitis does not assure to decrease postoperative complications[3-5]. Based on the 2006 American Society of Colon and Rectal Surgeons guidelines, the indications for elective resection have been advised as a tailored approach following recurrences and complaints[6,7]. It is equally unclear what happens to patients with diverticulitis who underwent elective surgery, for example, in Western Europe or the United States[8,9]. Similarly, trends in surgical procedures offered and other nuances required to manage the outcomes of diverticulitis in the European and U.S. literature[10,11]. This study is underway to characterize the surgical course of patients who underwent elective surgery based on international multi-institutional data. Our primary goal was to assess the predictive factors that specifically lead to minor and major complications of elective surgery for diverticulitis in order to identify potential targets that may benefit from national efforts toward surgical quality improvement.

METHODS

We queried the database between January 1, 2010, and January 30, 2018. We only included patients who had elective laparoscopic and open surgery for diverticulitis during follow-up. We excluded patients under 18 years old, patients undergoing emergency surgery, and those who underwent a colectomy

[1]Massachusetts General Hospital, Colorectal Surgery Center, Department of Surgery – Boston (MA), United States.
[2]Harvard Medical School, Master in Science Clinical Investigation Program – Boston (MA), United States.
[3] University of Health Sciences, Bagcilar Training and Research Hospital, Department of General Surgery – Istanbul, Turkey.
[4]Acibadem University Atakent Hospital, Department of Surgery – Istanbul, Turkey.
[5]Medicana Bursa University Hospital, Department of Surgery – Bursa, Turkey.
[6]Brigham and Women's Hospital – Boston (MA), United States.
*Corresponding author: dryukselaltinel@gmail.com
**All contributing members of the Turkish Diverticulitis Study Group Collaborative are credited in Chart 1.
Conflicts of interest: the authors declare there is no conflicts of interest. Funding: none.
Received on January 09, 2022. Accepted on February 11, 2022.

Chart 1. The Turkish Diverticulitis Study Group Collaborative

Uludag University, Bursa, Region of Marmara	Tuncay Yilmazlar MD, Orcid:0000-0003-1924-0795, tunyil@uludag.edu.tr
	Ozgen Isik MD, Orcid:0000-0002-9541-5035, ozgen006@yahoo.com
Medicana Bursa University Hospital Department of Surgery, Region of Marmara	Baris Gulcu MD, Orcid:0000-0002-4808-1538, drbarisgulcu@gmail.com
	Ersoy Taspinar, Orcid:0000-0002-6663-0190
Acibadem University Maslak Hospital Department of Surgery, Region of Marmara	Ismail Ahmet Bilgin MD, Orcid:0000-0002-2073-842X, isahbilgin@hotmail.com
Acibadem University Atakent Hospital Department of Surgery, Region of Marmara	Cansu de Muijnck MD, Orcid:0000-0003-0161-5851, cansudemuijnck@gmail.com
Cukurova University Hospital Department of Surgery, South Central Anatolia	Ahmet Rencuzogullari MD, Orcid:0000-0002-5993-9536, rencuzdr@gmail.com
Sultan Abdulhamid Han Research and Training Hospital Department of Surgery, Region of Marmara	İlker Sucullu MD, Orcid:0000-0003-3906-6827, suculluilker@yahoo.com
	Ahmet Ziya Balta MD, Orcid:0000-0002-4143-4169, ahmetzbalta@yahoo.com
Bulent Ecevit University Hospital Department of Surgery, Black Sea region	Fatma Ayça Gultekin MD, Orcid:0000-0002-4148-5871, faycagultekin@yahoo.com
	Ramazan Kozan MD, Orcid:0000-0002-3835-8759
Koç University Hospital, Region of Marmara	Emre Balik MD, Orcid:0000-0001-5751-1133, ebalik@ku.edu.tr
	Emre Ozoran MD, Orcid:0000-0002-9371-6811, eozoran@kuh.ku.edu.tr
American Hospital Department of Surgery, Region of Marmara	Dursun Bugra MD, Orcid:0003-0316-6818, dursunbugra@yahoo.com
	Serkan Zenger MD, Orcid:0000-0003-2860-7413, serkanzen@hotmail.com
Gazi University Hospital Department of Surgery, West Anatolia	Sezai Leventoglu MD, Orcid:0000-0003-0680-0589, sezaileventoglu@hotmail.com
	Saygin Altiner MD, Orcid:0000-0001-6118-9984, sygn0607@gmail.com
Marmara University Hospital Department of Surgery, Region of Marmara	Wafi Attaallah MD, Orcid:0000-0002-3179-4144, drwafi2003@yahoo.com
Izmir Dokuz Eylul University Hospital Department of Surgery, Eagan Region	Aras Emre Canda MD, Orcid:0000-0002-8257-5881, emre.canda@deu.edu.tr

with an underlying diagnosis of colorectal cancer or inflammatory bowel disease (e.g., Crohn's disease and ulcerative colitis). Turkish data were collected by Turkish Collaborative Group. American patients were collected by the National Surgical Quality Improvement Program (NSQIP) database. Approval was obtained from the Partners Institutional Review Board and Partners Colorectal Collaborative for this study.

Clinical characteristics such as body mass index (BMI, kg/m^2), albumin (mg/dL), white blood cell count (10^9/L), sodium (mmEq/L), creatine (mg/dL), platelet (10^3/mm^3), international normalized ratio (INR), aspartate aminotransferase (AST, U/L), alanine aminotransferase (ALT, U/L), and blood urea nitrogen (BUN, mg/dL) were dichotomized based on data review.

The demographic characteristics of patients included age (<59.4 or >59.4 years), gender, and race (i.e., Caucasian, Hispanic, African American, and Asian). The clinical characteristics of patients included smoking status, dyspnea, functional health status, comorbidities (i.e., hypertension, diabetes mellitus, chronic obstructive pulmonary disease [COPD], ventilator dependence, history of myocardial infarction, and bleeding disorder history), steroid immunosuppression, American Society of Anesthesiology (ASA) classification, Charlson comorbidity index (CCI), episode times, previous drainage catheter placement (i.e., interventional radiology [IR]), and laboratory values. Treatment factors included indication for surgery, and operative factors included wound classification, operative approach, concurrent procedures (i.e., small bowel resection, bladder or vagina repair, hysterectomy, or oophorectomy), stoma creation, duration of surgery, length of stay, and the identification of general and colorectal surgeon. Outcomes assessed included minor complications such as superficial surgical-site infection (SSI), postoperative ileus, wound disruption, postoperative urinary tract infection, and prolonged nasogastric use and major complications such as anastomosis leak, deep organ space, SSIs, sepsis, pneumonia, embolism, acute renal failure, myocardial infarction, cardiovascular arrest, cerebrovascular accident, intubation, readmission, reoperation, and mortality. We identified sigmoid colectomy as a segmental resection and low anterior resection (LAR) as an extended resection[12-14].

Statistical analysis

Descriptive statistics were reported as percentages for categorical variables and as mean±standard deviation for continuous variables. Univariate analysis comparing patients with minor and major outcomes was performed using the chi-square test for categorical variables and t-test for continuous variables. Multivariable logistic regression was used to determine variables predictive of minor and major outcomes to control potential confounders. The receiver operating characteristic curve (ROC curve), sensitivity, and specificity were calculated. We used bootstrapping to generate 95% confidence interval (95%CI) of the sensitivity and specificity. A significance level was set at p<0.05. All analyses were performed using R software version 3.4.2.

RESULTS

Demographics and operative characteristics

We identified the major and minor complications based on the combined data of 219 Turkish and 1006 American patients who underwent elective colonic resections for diverticulitis. During the follow-up period, 1225 patients underwent elective surgery for diverticulitis. We identified 132 (10.8%) patients who had major complications. The majority (1182 patients, 96.5%) who underwent surgery had minor complications. Of these, 553 (45.1%) were male, and the average age was 59.4 years (Tables 1 and 2).

The patients with major complications were older (58.93 vs. 63.26 years, p<0.001) who are having lower albumin (4.02 vs. 3.53 mg/dL, p<0.001) and higher ASA classification (0.4 vs. 3.8%, p<0.001).

The patients with minor complications also appeared more likely to be taken to the operating room with higher recurrent episodes (>3 attacks; 16.3 vs. 37.9%, p=0.006).

The patients with major complications have been performed more likely with open surgeries (52.2 vs. 28.8%, p<0.001) and extended resection such as LAR (69.4 vs. 51.5%, p<0.001).

Minor complications mainly were seen after LAR (37.2 vs. 68.5%, p<0.001). The mean length of hospital stay was shorter (10.58 vs. 6.32 days, p<0.001).

Prediction model and performance

On univariate regression analysis, we noted that functional health status, hypertension, ASA score (3–4), advanced age (>59.4 years), persistently elevated white blood cell count (>8.25 × 10^9/L), a higher CCI (>2.08), low albumin levels (>3.97 mg/dL), diabetes mellitus, preoperative sepsis, dyspnea, sodium (>139 mmEq/L), BUN (>14.3 mg/dL), INR (>1.09), reason of surgery (fistula), abscess at the admission, recurrent episode (>3), procedure (laparoscopic), stoma, anastomosis, operative approach (LAR), wound classification (either contaminated or dirty) were associated with major complications (Table 3).

We performed a model for major outcomes in multivariable analysis, such as a higher ASA score (OR: 1.46, 95%CI 1.00–2.12, p=0.048), higher CCI (OR: 1.14, 95%CI 1.00–1.30, p=0.040), and malnutrition (low albumin) (OR: 0.57, 95%CI 0.41–0.80, p=0.001).

The area under the curve (AUC) was 0.690 (95%CI 0.600–0.740), sensitivity was 0.990 (95%CI 0.980–1), and specificity was 0.080 (95%CI 0.030–0.170).

On univariate regression analysis, we noted that functional health status, diabetes mellitus, congestive heart failure (CHF), persistently elevated white blood cell count (>8.25 × 10^9/L), a higher CCI (>2.08), low albumin levels (>3.97 mg/dL), dyspnea, creatine (>0.89 mg/dL), reason of surgery (fistula), abscess at the admission, abscess at the time of surgery, recurrent episode (>3), antibiotic preparation, procedure (laparoscopic), stoma, and anastomosis were associated with minor complications.

We generated a model for minor outcomes in multivariable analysis, such as lower creatine levels (OR: 0.62, 95%CI 0.39–0.91, p=0.033), lack of antibiotic preparation (OR: 0.38, 95%CI 0.19–0.78, p=0.008), and laparoscopic procedure (OR: 2.34, 95%CI 1.12–4.90, p=0.024).

The AUC was 0.700 (95%CI 0.660–0.720), sensitivity was 0.050 (95%CI 0.000–0.100), specificity was 1 (95%CI 1–1). Our model was pretty good at detecting the true negatives but fails in detecting the true positives.

DISCUSSION

This is the first large-scale study comparing clinical characteristics and operative factors for major and minor complications of patients who underwent elective colonic resection for diverticulitis in the international multi-institutional setting. The postoperative major and minor outcomes have been described previously in various distinctive case series, such as infectious or complicated complications[15-17]. Until present, it has been unclear whether the severity of diverticulitis phenotype of patients or the effect of operative management has an impact either alone or combined among the major and minor complications for elective surgery internationally.

The predictive features of complications specific to elective resection for diverticulitis might be inconstant with the studies by Bolkenstein[17], Holmer[18], and Moghadamyeghaneh[19]. It may be challenging to predict before surgery as an underlying cause of the diverticulitis itself. It appears that the recurrent episodes of diverticulitis (>3) did not have an impact on the patients' risk for major and minor complications in our cohort, regardless of its nature of severity. This is controversial but eventually established by additional literature that verified the first episode of complicated diverticulitis or subsequent

Table 1. Demographics and clinical characteristics.

	Major NONE	Major YES	p	Minor NONE	Minor YES	p
	n=1093	n=132		n=43	n=1182	
Demographics						
Age (59.40±12.50)	58.93±12.34	63.26±13.16	**<0.001**	62.53±12.44	59.28±12.49	0.094
Gender (male) (553, 45.1%)	491 (44.9%)	62 (47%)	0.723	17 (39.5%)	536 (45.3%)	0.551
Race						
Asian (6, 0.5%)	6 (0.5%)	0 (0%)	0.783	0 (0.0%)	6 (0.5%)	0.974
African American (27, 2.2%)	25 (2.3%)	2 (1.5%)		1 (2.3%)	26 (2.2%)	
White (1163, 94.9%)	1036 (94.8%)	127 (96.2%)		41 (95.3%)	1122 (94.9%)	
Hispanic (27, 2.2%)	25 (2.3%)	2 (1.5%)	0.462	0 (0.0%)	27 (2.3%)	0.509
Comorbidities						
Diabetes mellitus			**<0.001**			**<0.001**
DM Type 1 (42, 3.4%)	29 (2.7%)	13 (9.8%)		7 (16.3%)	35 (3.0%)	
DM Type 2 (59, 4.8%)	50 (4.6%)	9 (6.8%)		3 (7.0%)	56 (4.7%)	
BMI (28.56±6.13)	28.57±6	28.45±7.17	0.832	27.90±5.54	28.59±6.15	0.472
Smoking (240, 19.6%)	209 (19.1%)	31 (23.5%)	0.282	12 (27.9%)	228 (19.3%)	0.229
ETOH (69, 5.6%)	63 (5.8%)	6 (4.5%)	0.709	5 (11.6%)	64 (5.4%)	0.162
Dyspnea						
At rest (18, 1.5%)	12 (1.1%)	6 (4.5%)	**<0.001**	2 (4.7%)	16 (1.4%)	0.172
Moderate exertion (62, 5.1%)	49 (4.5%)	13 (9.8%)		3 (7.0%)	59 (5%)	
Functional health status						
Independent (1166, 95.2%)	1054 (96.4%)	112 (84.8%)	**<0.001**	36 (83.7%)	1130 (95.6%)	**0.001**
Partially dependent (33, 2.7%)	19 (1.7%)	14 (10.6%)		5 (11.6%)	28 (2.4%)	
Totally dependent (26, 2.1%)	20 (1.8%)	6 (4.5%)		2 (4.7%)	24 (2.0%)	
Ventilator-dependent (18, 1.5%)	13 (1.2%)	5 (3.8%)	**0.05**	0 (0.0%)	18 (1.5%)	0.865
COPD (46, 3.8%)	37 (3.4%)	9 (6.8%)	0.086	3 (7.0%)	43 (3.6%)	0.470
CHF (18, 1.5%)	9 (0.8%)	9 (6.8%)	**<0.001**	1 (2.3%)	17 (1.4%)	1
Hypertension (539, 44%)	469 (42.9%)	70 (53%)	**0.034**	22 (51.2%)	517 (43.7%)	0.420
Open wound (40, 3.3%)	27 (2.5%)	13 (9.8%)	**<0.001**	2 (4.7%)	38 (3.2%)	0.933
Steroid (57, 4.7%)	46 (4.2%)	11 (8.3%)	0.057	3 (7.0%)	54 (4.6%)	0.713
Bleeding disorders (26, 2.1%)	20 (1.8%)	6 (4.5%)	0.085	0 (0.0%)	26 (2.2%)	0.657
Preoperative sepsis						
Sepsis (37, 3%)	23 (2.1%)	14 (10.6%)	**<0.001**	2 (4.7%)	35 (3.0%)	0.729
Septic shock (5, 0.4%)	2 (0.2%)	3 (2.3%)		0 (0.0%)	5 (0.4%)	
SIRS (20, 1.6%)	18 (1.6%)	2 (1.5%)		0 (0.0%)	20 (1.7%)	

BMI: body mass index (kg/m^2); COPD: chronic obstructive pulmonary disease: ETOH: ethyl alcohol; CHF: congestive heart failure; SIRS: Systemic inflammatory response syndrome. Normally distributed data were recorded as mean±standard deviation. Bold values denote statistical significance at the p<0.05 level.

Table 2. Preoperative characteristics and intraoperative findings.

	Major NONE	Major YES	p	Minor NONE	Minor YES	p
	n=1093	n=132		n=43	n=1182	
Operative approach (laparoscopic) (598, 48.8%)	560 (51.2%)	38 (28.8%)	<0.001	17 (39.5%)	581 (49.2%)	0.278
Procedure (LAR) (826, 67.4%)	758 (69.4%)	68 (51.5%)	<0.001	16 (37.2%)	810 (68.5%)	<0.001
Concurrent procedures						
Intestine (12, 1%)	10 (0.9%)	2 (1.5%)	0.122	0 (0.0%)	12 (1%)	0.452
Uro-gynecological (182, 14.9%)	155 (14.2%)	27 (20.5%)		4 (9.3%)	178 (15.1%)	
Stoma						
None (1011, 82.5%)	922 (84.4%)	89 (67.4%)	<0.001	25 (58.1%)	986 (83.4%)	<0.001
Ileostomy (85, 6.9%)	72 (6.6%)	13 (9.8%)		5 (11.6%)	80 (6.8%)	
Colostomy (129, 10.5%)	99 (9.1%)	30 (22.7%)		13 (30.2%)	116 (9.8%)	
Splenic flexura taken down (870, 71%)	780 (71.4%)	90 (68.2%)	0.510	28 (65.1%)	842 (71.2%)	0.485
Anastomosis						
None (141, 11.5%)	41 (18.7%)	31 (23.5%)	<0.001	14 (32.6%)	127 (10.7%)	<0.001
End to end (680, 55.5%)	612 (56%)	68 (51.5%)		20 (46.5%)	660 (55.8%)	
End to side (354, 28.9%)	325 (29.7%)	29 (22%)		4 (9.3%)	350 (29.6%)	
Side to side (50, 4.1%)	46 (4.2%)	4 (3%)		5 (11.6%)	45 (3.8%)	
Wound class						
Clean (89, 7.3%)	81 (7.4%)	8 (6.1%)	<0.001	4 (9.3%)	85 (7.2%)	0.925
Contaminated (645, 52.7%)	596 (54.5%)	49 (37.1%)		22 (51.2%)	623 (52.7%)	
Dirty (228, 18.6%)	209 (19.1%)	19 (14.4%)		7 (16.3%)	221 (18.7%)	
Infected (263, 21.5%)	207 (18.9%)	56 (42.4%)		10 (23.3%)	253 (21.4%)	
Surgeon (colorectal) (901, 73.6%)	808 (73.9%)	93 (70.5%)	0.454	27 (62.8%)	874 (73.9%)	0.146
Surgical duration (min)	160.39±68.82	159.88±73.79	0.937	170.84±72.18	159.95±69.23	0.312
Hospital stay (days)	5.72±4.17	12.64±10.55	<0.001	10.58±7.31	6.32±5.54	<0.001
Laboratory						
Na (139.01±3.30)	139.10±3.24	138.29±3.68	0.008	138.47±3.22	139.03±3.30	0.271
BUN (14.13±7.36)	13.90±7.03	16.04±9.48	0.002	15.85±8.75	14.07±7.30	0.118
AST (25.76±20.40)	25.85±20.04	25.05±23.28	0.672	28.05±21.84	25.68±20.35	0.455
ALT (29.97±24.42)	30.92±24.66	22.13±20.91	<0.001	30.28±23.92	29.96±24.45	0.932
ALB (3.970±.68)	4.02±0.64	3.53±0.85	<0.001	3.54±0.80	3.99±0.67	<0.001
CRE (0.89±0.48)	0.89±0.48	0.90±0.51	0.712	1.24±1.72	0.88±0.36	<0.001
WBC (8.25±3.24)	8.11±3.01	9.45±4.57	<0.001	9.83±4.87	8.19±3.16	0.001
PLT (269.70±87.12)	268.65±84.69	278.32±105.07	0.229	284.26±86.16	269.17±87.14	0.265
INR (1.090±.22)	1.09±0.22	1.15±0.22	0.004	1.14±0.18	1.09±0.22	0.184
Mech bowel prep (646, 52.7%)	587 (53.7%)	59 (44.7%)	0.062	19 (44.2%)	627 (53%)	0.323
Antibiotic prep (311, 25.4%)	278 (25.4%)	33 (25%)	0.998	21 (48.8%)	290 (24.5%)	0.001
Chemotherapy (19, 1.6%)	13 (1.2%)	6 (4.5%)	0.010	3 (7%)	16 (1.4%)	0.021

Continue...

Table 2. Continuation.

	Major NONE	Major YES	p	Minor NONE	Minor YES	p
	n=1093	n=132		n=43	n=1182	
Reason for surgery						
Recurrent episode (700, 57.1%)	655 (59.9%)	45 (34.1%)	<0.001	13 (30.2%)	687 (58.1%)	0.001
Abscess (284, 23.2%)	227 (20.8%)	57 (43.2%)		18 (41.9%)	266 (22.5%)	
Fistula (241, 19.7%)	211 (19.3%)	30 (22.7%)		12 (27.9%)	229 (19.4%)	
Admission for abscess (197, 16.1%)	152 (13.9%)	116 (11.5%)	<0.001	17 (39.5%)	180 (15.2%)	<0.001
Recurrent episode (>3 episode) 455 (37.1)	427 (39.1%)	28 (21.2%)	<0.001	7 (16.3%)	448 (37.9%)	0.006
Abscess						
None (930, 75.9%)	859 (78.6%)	71 (53.8%)	<0.001	23 (53.5%)	907 (76.7%)	<0.001
Present at time of surgery (195, 15.9%)	152 (13.9%)	43 (32.6%)		18 (41.9%)	177 (15%)	
Prior IR drainage (100, 8.2%)	82 (7.5%)	18 (13.6%)		2 (4.7%)	98 (8.3%)	
ASA classification						
I (118, 9.6%)	108 (9.9%)	10 (7.6%)	<0.001	8 (18.6%)	110 (9.3%)	0.087
II (758, 61.9%)	701 (64.1%)	57 (43.2%)		20 (46.5%)	738 (62.4%)	
III (340, 27.8%)	280 (25.6%)	60 (45.5%)		15 (34.9%)	325 (27.5%)	
IV (9, 0.7%)	4 (0.4%)	5 (3.8%)		0 (0.0%)	9 (0.8%)	
CCI (2.08±1.83)	1.98±1.74	2.95±2.25	<0.001	2.72±1.94	2.06±1.82	0.019

Na: sodium; WBC (10^9/L): white blood count; BUN: blood urea nitrogen; AST: aspartate aminotransferase; ALT: alanine aminotransferase; CRE: creatinine; ALB (mg/dL): albumin; PLT: platelet; INR: international normalized ratio; CCI: Charlson comorbidity index; ASA: American Society of Anesthesiology classification. Normally distributed data were recorded as mean±standard deviation. Bold values denote statistical significance at the p<0.05 level.

attacks for ultimate complications[10,11]. Regarding the postoperative adverse outcomes such as morbidity and mortality, we reported that most of our findings among the impact of anastomotic leakage (3.3%) as a major complication (10%) and postoperative ileus (90.4%) and superficial SSI (15.2%) as minor complications (96%), which Moghadamyeghaneh et al.[19], Bordeianou et al.[20], and Bolkenstein et al.[21] correlated the findings of surgical management for diverticulitis. Consistently, major complications following elective diverticulitis surgery had reported with higher ASA score, which is associated with the adverse outcomes on postoperative morbidity and mortality rates following colorectal surgeries such as Hall's study[12].

We reported that higher CCI might express the increasing load of comorbidities in patients with major complications who underwent elective diverticulitis surgery. The possible consequences of the correlation of higher CCI and ASA scores, including malnutrition in diverticulitis patients, previously showed various adverse outcomes in colorectal surgeries[12,19-21]. Regarding our findings, such as malnutrition or hypoalbuminemia, these could be achieved by a supplementary assessment targeting all preoperative patients[21,22]. Significantly, the principles of nutritional support for diverticulitis are a potential intervention that may improve surgical outcomes similar to the study by Van de Wall[23]. We should optimize the preoperative nutritional management as an initial strategy to generate supplementary therapy collectively due to the nutritional risk of diverticular disease similar to the study by Giorgetti[22].

We found factors such as the presence of abscess at admission, presence of anastomosis, ASA score >2, and malnutrition have close association with minor and major complications that are consistent with some studies comparing the selection and outcomes of laparoscopic surgery in the elective or emergent/urgent situations[13,18,24,25].

Unfortunately, despite an increase in laparoscopy, these patients had more minor complications regarding possible higher numbers of laparoscopic procedures and promptly chosen options for elective colon resections similar to the studies by Holmer[18] and Khan[24]. As previously mentioned, prior antibiotic preparation might prevent SSI. Even though they seem to have collaborated with mechanical bowel preparation[13,25],

Table 3. Unadjusted covariates.

	OR	95% confidence interval	p
Major complications			
Age	1.028	1.013–1.044	<0.001
Diabetes mellitus	0.133	0.083–0.212	<0.001
Open wound	4.313	2.167–8.583	<0.001
Dyspnea	0.500	0.187–1.332	0.165
Functional health status	0.106	0.0874–0.129	<0.001
Ventilator-dependent	3.270	1.147–9.324	0.026
Hypertension	1.502	1.045–2.157	0.027
CHF	8.813	3.433–22.619	<0.001
Preoperative sepsis	0.107	0.088–0.130	<0.001
Albumin	0.403	0.316–0.512	<0.001
Na	0.937	0.892–9.845	0.009
BUN	1.034	1.012–1.056	0.001
WBC	1.11	1.059–1.165	<0.001
ALT	0.981	0.971–0.990	<0.001
INR	2.378	1.291–4.381	0.005
Reason surgery	2.069	1.271–3.369	0.003
Chemotherapy	3.956	1.477–10.591	0.006
Admission abscess	3.202	2.149–4.77	<0.001
Recurrent episode	0.419	0.271–0.648	<0.001
ASA class	0.092	0.048–0.176	<0.001
CCI	1.266	1.164–1.376	<0.001
Abscess	1.908	1.499–2.428	<0.001
Wound class	1.662	1.368–2.02	<0.001
Operative approach	1.583	1.015–2.468	<0.001
Stoma	0.096	0.077–0.119	<0.001
Anastomosis	0.611	0.466–0.799	<0.001
Procedure	0.469	0.326–0.676	<0.001
Hospital stay	0.841	0.565–1.251	0.394
Minor complications			
Diabetes mellitus	2.562	2.493–2.634	<0.001
Functional health status	2.635	2.608–2.663	<0.001
CRE	0.584	0.409–0.834	0.003
Albumin	2.172	1.493–3.159	<0.001
WBC	0.890	0.828–0.956	0.001
Reason surgery	0.361	0.162–0.802	0.012
Admission abscess	0.274	0.146–0.516	<0.001
Recurrent episode	3.138	1.385–7.111	0.006
Antibiotic prep	0.340	0.184–0.628	<0.001
Abscess	0.249	0.131–0.471	<0.001
Anastomosis	3.637	1.790–7.391	<0.001
Procedure	3.674	1.956–6.901	<0.001
CCI	0.852	0.744–0.975	0.020
Hospital stay	0.931	0.902–0.961	<0.001
Stoma	0.226	0.112–0.454	<0.001
Chemotherapy	0.182	0.051–0.653	0.008

it was performed even in most of our patients. For example, it appears that our cohort was offered more stomas and laparoscopic approach. Studies by Holmer[18] and Agresta[25] might reflect current strategies on how to handle a patient with a residual abscess, which seem to advocate for a diversion over a primary anastomosis.

Our model appeared to have moderate to high accuracy in predicting overall major and minor complications following elective surgery of diverticulitis. Considering the accuracy of our prediction model, Al-Khamis et al.[14], Bolkenstein et al.[17], and Bordeianou et al.[20] more likely reported the management of the patients' frailty based on the serious adverse outcomes.

The limitations of this study were as follows: (1) nested regression models to generate some imputations for the missing values less than 30% of laboratory results, (2) retrospective analysis including measurement and recall biases, and (3) without stepwise or any other machine learning models. However, this is the first and largest study to identify a prediction model for the minor and major postoperative complications in early settings for elective diverticulitis surgery.

CONCLUSIONS

The preoperative management of nutrition, comorbidities, and invasive interventions might be a helpful clinical tool to better identify the postoperative care for the major and minor outcomes, priorly. In addition, the prediction of postoperative outcomes when accounting for patient comorbidities and patient acuity might add value to the current challenges to improve the quality of care.

ACKNOWLEDGMENTS

We are thankful to members of the Partners Colorectal Surgery Collaboratives.

AUTHORS' CONTRIBUTIONS

YA: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft. **PC:** Data curation, Investigation, Writing – review & editing. **RR:** Data curation, Writing – review & editing. **RB:** Data curation, Writing – review & editing. **LB:** Investigation, Methodology, Project administration, Writing – review & editing. **VO:** Visualization, Data curation. **EO:** Visualization, Data curation. **EA:** Investigation, Methodology, Writing – review & editing.

REFERENCES

1. Peppas G, Bliziotis LA, Oikonomaki D, Falagas ME. Outcomes after medical and surgical treatment of diverticulitis: a systematic review of the available evidence. J Gastroenterol Hepatol. 2007;22(9):1360-8. https://doi.org/10.1111/j.1440-1746.2007.05118.x
2. Kohler L, Sauerland S, Neugebauer E. Diagnosis and treatment of diverticular disease: results of a consensus development conference. The Scientific Committee of the European Association for Endoscopic Surgery. Surg Endosc. 1999;13(4):430-6. https://doi.org/10.1007/s004649901007
3. Anaya DA, Flum DR. Risk of emergency colectomy and colostomy in patients with diverticular disease. Arch Surg. 2005;140(7):681-5. https://doi.org/10.1001/archsurg.140.7.681
4. Moreno AM, Wille-Jørgensen P. Long-term outcome in 445 patients after diagnosis of diverticular disease. Colorectal Dis. 2007;9(5):464-8. https://doi.org/10.1111/j.1463-1318.2006.01173.x
5. Regenbogen SE, Hardiman KM, Hendren S, Morris AM. Surgery for diverticulitis in the 21st century: a systematic review. JAMA Surg. 2014;149(3):292-303. https://doi.org/10.1001/jamasurg.2013.5477
6. Rafferty J, Shellito P, Hyman NH, Buie WD, Standards Committee of American Society of Colon and Rectal Surgeons. Practice parameters for sigmoid diverticulitis. Dis Colon Rectum. 2006;49(7): 939-44. https://doi.org/10.1007/s10350-006-0578-2
7. van de Wall BJM, Stam MAW, Draaisma WA, Stellato R, Bemelman WA, Boermeester MA, et al., DIRECT trial collaborators. Surgery versus conservative management for recurrent and ongoing left-sided diverticulitis (DIRECT trial): an open-label, multicentre, randomised controlled trial. Lancet Gastroenterol Hepatol. 2017;2(1):13-22. https://doi.org/10.1016/S2468-1253(16)30109-1
8. Papageorge CM, Kennedy GD, Carchman EH. National trends in short-term outcomes following non-emergent surgery for diverticular disease. J Gastrointest Surg. 2016;20(7):1376-87. https://doi.org/10.1007/s11605-016-3150-y
9. Ricciardi R, Baxter NN, Read TE, Marcello PW, Hall J, Roberts PL. Is the decline in the surgical treatment for diverticulitis associated with an increase in complicated diverticulitis? Dis Colon Rectum. 2009;52(9):1558-63. https://doi.org/10.1007/DCR.0b013e3181a90a5b
10. Khan A, Hawkins AT. Challenging surgical dogma: controversies in diverticulitis. Surg Clin North Am. 2021;101(6):967-80. https://doi.org/10.1016/j.suc.2021.05.024
11. Altinel Y, Hacim NA, Tokocin M, Meric S, Akbas A. How can we manage the therapeutic approach of acute diverticulitis regarding the number of attacks? Turk J Colorectal Dis. 2021;31(1):49-56. https://doi.org/10.4274/tjcd.galenos.020.2020-5-2
12. Hall BL, Hamilton BH, Richards K, Bilimoria KY, Cohen ME, Ko CY. Does surgical quality improve in the American College of Surgeons National Surgical Quality Improvement Program: an evaluation of all participating hospitals. Ann Surg. 2009;250(3):363-76. https://doi.org/10.1097/SLA.0b013e3181b4148f
13. Altinel Y, Cavallaro PM, Ricciardi R, Rubin MS, Bleday R, Ahmed F, et al. Can we predict surgically complex diverticulitis in elective cases? Dis Colon Rectum. 2020;63(5):646-54. https://doi.org/10.1097/DCR.0000000000001600
14. Al-Khamis A, Warner C, Park J, Marecik S, Davis N, Mellgren A, et al. Modified frailty index predicts early outcomes after colorectal surgery: an ACS-NSQIP study. Colorectal Dis. 2019;21(10):1192-205. https://doi.org/10.1111/codi.14725
15. Kulaylat AS, Hollenbeak CS, Stewart DB Sr. Increased postoperative morbidity associated with prolonged laparoscopic colorectal resections is not increased by resident involvement. Dis Colon Rectum. 2018;61(5):579-85. https://doi.org/10.1097/DCR.0000000000000934
16. Onur MR, Akpinar E, Karaosmanoglu AD, Isayev C, Karcaaltincaba M. Diverticulitis: a comprehensive review with usual and unusual complications. Insights Imaging. 2017;8(1):19-27. https://doi.org/10.1007/s13244-016-0532-3
17. Bolkenstein HE, van de Wall BJ, Consten EC, van der Palen J, Broeders IA, Draaisma WA. Development and validation of a diagnostic prediction model distinguishing complicated from uncomplicated diverticulitis. Scand J Gastroenterol. 2018;53(10-11):1291-7. https://doi.org/10.1080/00365521.2018.1517188
18. Holmer C, Kreis ME. Management of complications following emergency and elective surgery for diverticulitis. Visc Med. 2015;31(2):118-23. https://doi.org/10.1159/000377696
19. Moghadamyeghaneh Z, Carmichael JC, Smith BR, Mills S, Pigazzi A, Nguyen NT. A comparison of outcomes of emergent, urgent, and elective surgical treatment of diverticulitis. Am J Surg. 2015;210(5):838-45. https://doi.org/10.1016/j.amjsurg.2015.04.010
20. Bordeianou L, Cauley CE, Patel R, Bleday R, Mahmood S, Kennedy K, et al. Prospective creation and validation of the PREVENTT (Prediction and Enaction of Prevention Treatments Trigger) Scale for Surgical Site Infections (SSIs) in patients with diverticulitis. Ann Surg. 2019;270(6):1124-30. https://doi.org/10.1097/SLA.0000000000002859
21. Bolkenstein HE, Consten ECJ, van der Palen J, van de Wall BJM, Broeders IAMJ, Bemelman WA, et al. Long-term outcome of surgery versus conservative management for recurrent and ongoing complaints after an episode of diverticulitis: 5-year follow-up results of a multicenter randomized controlled trial (DIRECT-Trial). Ann Surg. 2019;269(4):612-20. https://doi.org/10.1097/SLA.0000000000003033
22. Giorgetti G, Fabiocchi F, Brandimarte G, Tursi A. Acute diverticulitis is at significant risk of malnutrition: an analysis of hospitalized patients in a medicine department. J Gastrointestin Liver Dis. 2019;28(suppl. 4):53-6. https://doi.org/10.15403/jgld-561
23. Van de Wall BJM, Stam MAW, Draaisma WA, Stellato R, Bemelman WA, Boermeester MA, et.al. Surgery versus conservative management for recurrent and ongoing left-sided diverticulitis (DIRECT trial): an open-label, multicentre, randomised controlled trial. Lancet Gastroenterol Hepatol. 2017;2(1):13-22. https://doi.org/10.1016/S2468-1253(16)30109-1
24. Khan RMA, Hajibandeh S, Hajibandeh S. Early elective versus delayed elective surgery in acute recurrent diverticulitis: a systematic review and meta-analysis. Int J Surg. 2017;46:92-101. https://doi.org/10.1016/j.ijsu.2017.08.583
25. Agresta F, Ciardo LF, Mazzarolo G, Michelet I, Orsi G, Trentin G, et al. Peritonitis: laparoscopic approach. World J Emerg Surg. 2006;1(1):9. https://doi.org/10.1186/1749-7922-1-9