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ORIGINAL ARTICLE

Prevalence and predictors of surgical site infections after bowel resection for Crohn's disease: the role of dual-ring wound protector

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Abstract

Purpose Surgical site infections (SSIs) have become a leading cause of preventable morbidity and mortality in surgery. The aim was to evaluate the efficacy of a dual-ring wound protector to prevent the SSIs in Crohn's disease (CD) after bowel resection.

Methods This retrospective observational study included all CD patients undergoing bowel resection at the Inflammatory Bowel Disease Center between January 2015 and June 2018 at Sir Run Run Shaw Hospital. Risk factors of SSIs were evaluated by assessing preoperative clinical characteristics and perioperative treatments in univariate and multivariate analyses. Outcomes for CD patients with and without the wound protector were compared.

Results Three hundred forty-four CD patients were enrolled in this study, 121 (35.2%) patients had postoperative complications, of whom, 72 (20.9%) patients developed SSIs (12.8% patients with incisional SSI and 8.1% patients with organ/space SSI). There was a significant reduction in the incidence of incisional SSI in the wound protector group (8.1% vs 16.8%, $p < 0.05$). No significant differences were identified in organ/space SSI between groups with and without wound protector (6.3% vs 9.8%, $p = 0.232$). Incisional SSI correlated with preoperative albumin, C-reactive protein, white blood cell, age (≤ 16), penetrating disease behavior, surgical history, open surgery, stoma creation, estimated blood loss, infliximab, and wound protector ($p < 0.05$). Multivariate analysis identified the wound protector to be one of independent factors for preventing incisional SSIs (OR 0.357, 95% CI 0.161–0.793, $p < 0.05$).

Conclusion Among the CD patients with bowel resection, the use of a dual-ring wound protector during surgery significantly reduced the risk of incisional SSI.

Keywords Crohn's disease · Surgical site infection · Wound protector · Bowel resection

Introduction

Crohn's disease (CD) is a chronic inflammatory disease which can affect all segments of the gastrointestinal tract. As CD is characterized by the relapsing and remitting manner, it becomes a progressive disease which results in bowel damage and disability [1]. Despite improvements in medical therapy, approximately 80% of CD patients will experience surgical intervention at least once in the whole course of their disease resulting from complications associated with penetrating or structuring disease [2]. In addition, it is reported that around 70% of patients with CD require repeat surgery by 20 years owing to recurrence [3]. Furthermore, when compared to anti-TNF agents, the surgical treatment is sometimes considered the first strategy for the severely inflamed intestinal segment of CD patients with immunomodulator-refractory or steroid-refractory disease [4, 5].

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Approximately 10 to 37% of patients with CD suffer postoperative complications, especially the infectious complications after the intestinal resection [6], which is more common than other colorectal diseases [7, 8]. Among postoperative complications, surgical site infection (SSI) is thought to be the most common one [9]. The occurrence of SSI can lead to a significant financial burden to the healthcare system, patients' dissatisfaction, and prolonged hospitalizations [10]. The risk factors of SSI in CD patients include impaired nutritional status, immunosuppressive state, the presence of abscesses or intestinal fistula at the time of surgery, corticosteroid therapy, and surgical approach [6, 8, 9]. Thus, the methods to reduce SSI's incidence are really important from the medical and economic perspective.

Various methods have been proposed to prevent SSIs over the last decades, such as cleaning the skin, removing the hair, maintaining normothermia during surgery, and using antibiotics preoperatively for prophylaxis [11]. A wound protector is developed to be the physical barrier between the abdominal wound edges and the surgical work including viscera, gloves, and visceral contents [12]. The dual-ring wound protector consists of an inner ring and an outer ring with the plastic cylinder. The inner ring is put into the peritoneal cavity, and the other outer ring is put outside of the abdomen. Then, the plastic will be made to be taut circumferentially around the wound by rolling the outer ring over the plastic cylinder [13]. There are several studies revealing the role of a wound protector in preventing surgical site infection in abdominal surgery. Gheorghe et al. [14] found that SSIs were reduced in patients undergoing open abdominal surgery with wound-edge protection devices. In addition, plastic wound protectors were also proven to decrease SSIs in patients undergoing laparoscopic-assisted colectomy for colorectal cancer [15]. Moreover, the use of wound protectors in abdominal surgical procedures with clean-contaminated, contaminated, and dirty wound was recommended to reduce SSIs in the last WHO recommendations for surgical site infection prevention [16].

Given that the incidence of SSIs is higher in patients with Crohn's disease after surgery and the advantages of a wound protector in preventing SSIs are shown in other diseases, the design of this study was to evaluate the efficacy of a dual-ring wound protector in preventing SSIs after bowel resection in CD patients.

Materials and methods

Patients

Consecutive patients who underwent elective bowel resection for Crohn's disease were retrospectively analyzed at the Inflammatory Bowel Disease (IBD) Center of our hospital between January 2015 and June 2018. All the data of the CD patients undergoing bowel resection were collected from the patients' medical charts in our IBD database, which include medical histories, laboratory reports, information of surgery, and therapeutic procedures. Patients with incomplete laboratory data, emergent surgery, and stoma reversal purely were excluded. This study was approved by the ethics committee of our hospital.

Intervention

The dual-ring wound protector was started to be used during surgery in our hospital since 2017. The incidence of surgical site infections with a wound protector was compared between two cohorts of patients. Cohort A used the gauze for wound protection from January 2015 to December 2016 as shown in Fig. 1a. Cohort B had a dual-ring wound protector (Kangning Medical Co., China) during surgery (Fig. 1b, c) since January 2017. All surgical procedures were performed by one surgical team. Perioperative care and intraoperative treatment were similar according to the routine practice of the surgical team. These included hair removal with a clipper before surgery, utilization of povidone iodine solutions for skin disinfection, administration of surgical antibiotic prophylaxis within the 120 min before the incision, maintenance of adequate circulating volume, and incisional wound irrigation with povidone-iodine solution before closure. The operating surgeon made the decision to choose the open or laparoscopic approach, as well as the size of the wound protector according to the incision length.

Definition of outcomes

The primary outcome of this study was the incidence of incisional SSI which was defined by the Centers for Disease Control and Prevention (CDC) criteria [16]. The definition of the SSIs was described as "Any infection of the superficial or deep tissues or the organ/space affected by surgery, and which occurs within 30 days of surgery when no prosthesis has been implanted". SSIs could be classified into two kinds including incisional and organ/space SSI. Incisional SSIs were divided into superficial SSI which involved only the skin and subcutaneous tissues and deep SSI which meant infection of deeper soft tissues [17]. Secondary outcome included other postoperative complications based on the Clavien-Dindo classification, except SSIs, and the length of hospital stay. Clavien-Dindo Grades I and II were defined as mild complications, and Clavien-Dindo Grades III and IV were defined as major complications [18, 19].

Data collection

Baseline characteristics, intraoperative data, and laboratory data were collected from our computer database. The data of

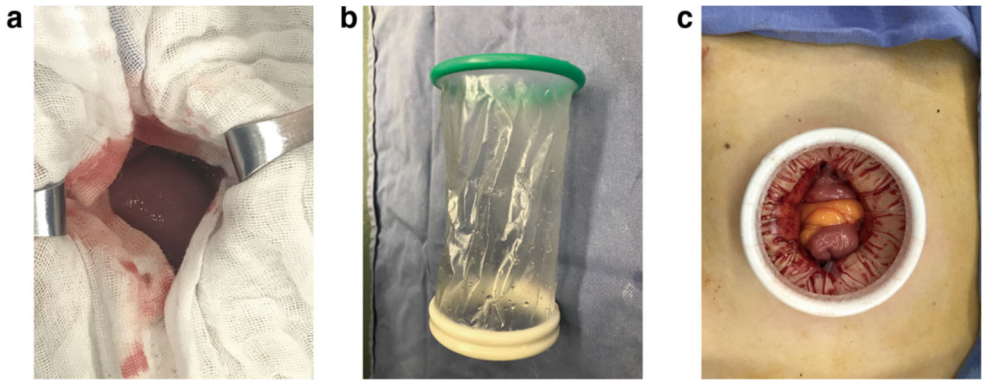

Fig. 1 The nonwound protector group had gauze that covered the edge of the skin incision during bowel resection (**a**). The wound protector group had a dual-ring wound protector (**b**), and the wound protector was placed during bowel resection in Crohn's disease (**c**)

baseline characteristics collected included age, sex, BMI, ASA grade, comorbidities, surgical indication, duration of disease before surgery, smoking habits, history of surgery, disease location, behavior according to the Montreal phenotype classification (inflammatory/failure of medical therapy, structuring, penetrating, and perianal disease) [20], and medical treatment before surgery. In detail, the duration of the anti-TNF therapy was more than 8 weeks and enteral nutrition was provided for over 4 weeks in CD patients before surgery enrolled in this study. Intraoperative data included operative time, surgical approach (open vs laparoscopy), stoma creation, estimated blood loss, and wound protection method. Laboratory data included preoperative hemoglobin (Hb), albumin (ALB), C-reactive protein (CRP), lymphocyte, erythrocyte sedimentation rate (ESR), white blood cell (WBC), red blood cell (RBC), platelet, and hematocrit.

Statistical analysis

All of the statistical analyses were conducted using SPSS 21.0 (SPSS, Inc., Chicago, IL). Continuous data was presented as the mean ± SE or median (range), whereas categorical data were presented as a number (%). The continuous variables were analyzed by the student t test or Mann-Whitney U test depending on the normality of the data distribution, and the categorical variables were analyzed by the Pearson $\chi 2$ test or the Fisher exact test, as appropriate. Significant associations ($p < 0.05$) on univariate analysis were used in a multivariate logistic regression analysis to verify independent predictors of incisional SSIs. Values of $p < 0.05$ were considered statistically significant.

Results

Study population and baseline characteristic

In all, 344 CD patients were enrolled in this study for the final analysis. The mean age of the patients was 36.5 ± 0.7 years old, and 224 (65.1%) were male. The mean disease duration before surgery in these patients was 52.0 ± 2.6 months. Fifteen (4.4%) patients had a smoke habit. Among the 344 included patients, 124 (36.0%) had ileum alone and 167 (48.5%) had ileocolonic involvement. In addition, 233 (68.0%) of CD patients suffering surgery were due to complications related to disease, 128 (37.2%) was due to penetrating disease, 36 (10.5%) was due to both structuring and penetrating diseases, and 19 (5.5%) was due to failure of medical therapy. Preoperatively, 50 (14.5%) patients used infliximab, 84 (24.4%) used 5-aminosalicylates, 67 (19.5%) used azathioprine, 16 (4.7%) used corticosteroids, 96 (27.9%) used enteral nutrition, and 16 (4.7%) used others. Patients' demographic details are shown in Table 1.

Operative data

A total of 160 (46.5%) patients used a dual-ring wound protector for prevention of surgical site infections. The mean duration of surgery for bowel resection was 191.0 ± 3.1 min, with an associated mean estimated blood loss of 76.1 ± 3.9 mL. One hundred eighty-eight (54.7%) patients received laparoscopic surgery. Seventy-one (20.6%) patients underwent conversion to open surgery. Two hundred eighteen (63.4%) patients received intestinal resection for the first time during the course of their disease. One hundred nine (31.7%) patients had the stoma creation during surgery. More details about operative information are shown in Table 1.

Postoperative morbidity and surgical site infections

Totally, 64.8% of CD patients undergoing bowel resection recovered uneventfully and 35.2% patients had postoperative complications. The incidence of postoperative complications between patients with the wound protector and without wound protector was 30.0% vs 39.7% ($p = 0.061$). As shown in Table 2, patients without the wound protector were at a significantly increased risk of mild complications (33.7% vs 20.0%, $p = 0.004$), of which, wound infection (16.8%) and early postoperative bowel obstruction (6.5%) were most common. In addition, the incidence of SSIs was significantly

Table 1 Baseline characteristics of all the patients

Characteristics	All (344)
Age*, year	36.5 ± 0.7
Men	224 (65.1)
BMI*, kg/m^2	18.8 ± 0.1
Comorbidities	
Diabetes mellitus	17 (4.9)
Hypertension	18 (5.2)
Preoperative hemoglobin*	118.2 ± 1.0
Preoperative albumin*	36.0 ± 0.3
Preoperative C-reactive protein*	15.9 ± 1.8
Preoperative erythrocyte sedimentation rate*	18.7 ± 0.9
Preoperative white blood cell*	6.25 ± 0.17
Preoperative red blood cell*	4.23 ± 0.03
Current smoking	15 (4.4)
Mean disease duration before surgery*, month	52.0 ± 2.6
Operative time* (min)	191.0 ± 3.1
First-time operated	218 (63.4)
Small bowel resection	141 (41.0)
Ileocolectomy	149 (43.3)
Colectomy	54 (15.7)
Laparoscopic surgery	188 (54.7)
Conversion	71 (20.6)
Stoma creation	109 (31.7)
Estimated blood loss*, mL	76.1 ± 3.9
Montreal classification	
Age, year	
A1 (≤ 16)	3 (0.9)
A2 (17–40)	228 (66.3)
A3 (>40)	113 (32.8)
Location	
L1 (ileal)	124 (36.0)
L2 (colonic)	37 (10.8)
L3 (ileocolonic)	167 (48.5)
L4 (upper gastrointestinal)	35 (10.2)
Behavior	
B1 (inflammatory/failure of medical therapy)	19 (5.5)
B2 (stricturing)	233 (68.0)
B3 (penetrating)	128 (37.2)
Perianal disease	98 (28.5)
Preoperative treatment	
Azathioprine	67 (19.5)
Infliximab	50 (14.5)
5-ASA	84 (24.4)
Corticosteroids	16 (4.7)
Enteral nutrition	96 (27.9)
Others	16 (4.7)

Values in parentheses are percentages unless indicated otherwise; *values are mean ± SE; *SSI*, surgical site infection

decreased in patients with the wound protector (14.4% vs 26.6%, $p = 0.005$). Totally, 44 (12.8%) cases had incisional SSI. Among the 44 included patients with incisional SSI, 20 (45.5%) had ileocolonic resection, 14 (31.8%) had terminal ileal resection, 8 (18.2%) had colonic resection, and 7 (15.9%) had upper gastrointestinal resection (Table 3). The incidence of incisional SSI was significantly lower in the wound protector group compared to the non-wound protector group (8.1% vs 16.8%, $p = 0.016$). However, there was no significant difference between these two groups in organ/space SSI (6.3% vs 9.8%, $p = 0.232$). The information of postoperative morbidity and surgical site infections is shown in Table 2.

Factors associated with incisional surgical site infection

In order to identify the risk factors for incisional SSI, the univariate and multivariate analyses were performed in our study. The types of procedures including small bowel resection, ileocolectomy, and colectomy did not affect incisional SSI in our study. As shown in Table 3, the univariate analysis indicated that the factors of preoperative albumin, preoperative CRP, preoperative WBC, age (≤ 16), penetrating disease, history of surgery, surgical approach, stoma creation, estimated blood loss, preoperative medical treatment (infliximab), and the wound protector were associated with the incisional SSI (all $p < 0.05$). Then, the multivariate analysis model was used to determine the risk factors associated with the incisional SSI independently, which revealed without the wound protector (OR = 0.357; 95% CI, 0.161–0.793; $p < 0.05$) as one of independent risk factors for incisional SSI. On the other hand, age less than 16 years old, repeated surgery, open surgery, and infliximab before surgery were also demonstrated to be the independent risk factors associated with incisional SSI as shown in Table 4 ($p < 0.05$).

Discussion

In the gastrointestinal surgery, SSIs are considered to be one of the most common postoperative complications [11, 21]. Various factors have been identified to be risk factors associated with SSIs. Meanwhile, multiple interventions have been introduced to eliminate SSIs substantially, like wound protectors. In the current study, we focused on the role of the dual-ring wound protector for SSI prevention in CD patients undergoing bowel resection. As a result, this study revealed that CD patients who received a wound protector had lower mild complications and a lower incidence of incisional SSI than CD patients without a wound protector. Furthermore, the wound protector was also demonstrated to be an independent protective factor for the incisional SSI.

Table 2 Comparison of postoperative complications for bowel resection in CD patients with and without wound protector

Characteristics	All ($n = 344$)	Wound protector (160)	No wound protector (18 4)	p value
Postoperative complications	121 (35.2)	48 (30.0)	73 (39.7)	0.061
Mild complications (Grades I and II)	94 (27.3)	32 (20.0)	62 (33.7)	0.004
Wound infection	44 (12.8)	13 (8.1)	31 (16.8)	–
Fever > 38.5 °C after surgery	16 (4.7)	8 (5.0)	8 (4.3)	–
Diarrhea	6 (1.7)	1 (0.6)	5 (2.7)	–
Early postoperative bowel obstruction	17 (4.9)	5 (3.1)	12 (6.5)	–
Postoperative blood transfusions > 2 U	6 (1.7)	3 (1.9)	3 (1.6)	–
Line sepsis	4 (1.2)	1 (0.6)	3 (1.6)	–
Hyperglycemia	1 (0.3)	1 (0.6)	0 (0)	–
Major complications (Grades III and IV)	61 (17.7)	26 (16.3)	35 (19.0)	0.502
Gastrointestinal bleeding	16 (4.7)	5 (3.1)	11 (6.0)	–
Anastomotic leakage	16 (4.7)	7 (4.4)	9 (4.9)	–
Abdominopelvic collection	5 (1.5)	3 (1.9)	2 (1.1)	–
Pleural effusion	3 (0.9)	1 (0.6)	2 (1.1)	–
Intra-abdominal abscess	7 (2.0)	1 (0.6)	6 (3.3)	–
Stoma complications	8 (2.3)	6 (3.8)	2 (1.1)	–
Septic shock	3 (0.9)	1 (0.6)	2 (1.1)	–
Sepsis	2 (0.6)	1 (0.6)	1 (0.5)	–
Kidney failure	1 (0.3)	1 (0.6)	0 (0)	–
Grade V	0 (0)	0 (0)	0 (0)	–
Postoperative stay*, days	11.1 ± 0.4	10.6 ± 0.5	11.5 ± 0.5	0.229
SSIs	72 (20.9)	23 (14.4)	49 (26.6)	0.005
Incisional SSI	44 (12.8)	13 (8.1)	31 (16.8)	0.016
Organ/space SSI	28 (8.1)	10 (6.3)	18 (9.8)	0.232

Values in parentheses are percentages unless indicated otherwise; *values are mean ± SE; *SSI*, surgical site infection

To the best of our knowledge, this is the first study to examine the possibility of a dual-ring wound protector to prevent SSIs in CD patients undergoing bowel resection. The possible methodology of wound protectors to reduce incisional SSI is their ability to cover the cut edges of the wound completely, and their firm and retractable nature of the dual-ring. In particular, this plastic barrier can have dramatic effects in preventing both endogenous and exogenous pathogens from imbedding themselves into the cut skin, fat, fascia, and peritoneum, thus resulting in a reducing incidence of incisional SSI [12]. The abundance and virulence of bacteria are considered to be risk factors in incisional SSI when they attach to the surgical site. Once more than 10^5 bacteria are present in one gram of tissue, the possibility of infection after the surgery can increase [22]. Mohan et al. [23] suggested that exposure of the skin and subcutaneous tissue to enteric organisms was decreased by 50% with wound protectors during gastrointestinal surgery. Horiuchi et al. [24] found that the patients with negative cultures at the incision margin had low incidence of SSIs, which resulted from the wound protector. Maintaining the wound temperature and humidity and preventing direct physical trauma from fixed retractors are considered to be another mechanism of reducing the frequency of incisional SSI by the impervious plastic barrier wound protector. Reid et al. [13] indicated that incisional SSI decreased significantly from 22.7 to 4.7% in elective open colorectal resectional surgery with the use of barrier wound protectors. In our study, we also found that CD patients with wound protectors suffered less mild complications which mostly included incisional SSI. There were significant differences in incisional SSI between the wound protector group and non-wound protector group in our study, and we also demonstrated that the wound protector could be an independent predictor for incisional SSI (OR = 0.357; 95% CI, 0.161–0.793; $p < 0.05$). What is more, the wound protectors could also provide a smooth and lubricated surface for our specimen to slide out more readily, especially during laparoscopic operation [25]. Thus, we recommended the use of a wound protector in CD patients.

The incidence of SSIs in CD surgery has been reported to be higher than that in other patients requiring abdominal surgery, with 18.0–26.7% of overall SSIs, 9.8–10.8% of deep/organ space SSI, and 9.0–12.0% of incisional SSI, which was consistent with our current findings [8, 9, 26]. Many reasons are considered to influence the SSIs in CD patients, which include poor nutritional status, high disease activity,

Table 3 Univariate analysis of risk factors associated with incisional SSI

Characteristics	Incisional SSI (44)	No incisional SSI (300)	*p* value
Age*, year	34.6 ± 1.8	36.8 ± 0.7	0.270
Men	26 (59.1)	198 (66.0)	0.369
BMI*, kg/m^2	18.4 ± 0.4	18.8 ± 0.1	0.299
Comorbidities			
Diabetes mellitus	3 (6.8)	14 (4.7)	0.808
Hypertension	2 (4.5)	16 (5.3)	0.827
Preoperative hemoglobin*	119.5 ± 3.1	118.0 ± 1.1	0.620
Preoperative albumin*	34.4 ± 0.8	36.2 ± 0.3	0.032
Preoperative C-reactive protein*	27.1 ± 9.2	14.3 ± 1.5	0.017
Preoperative erythrocyte sedimentation rate*	19.2 ± 2.6	18.6 ± 0.9	0.838
Preoperative white blood cell*	7.14 ± 0.56	6.11 ± 0.17	0.040
Preoperative red blood cell*	4.20 ± 0.09	4.24 ± 0.04	0.723
Current smoking	2 (4.5)	13 (4.3)	0.949
Mean disease duration before surgery*, month	65.1 ± 8.0	50.1 ± 2.8	0.056
Montreal classification			
Age, year			
A1 (≤ 16)	2 (4.5)	1 (0.3)	0.044
A2 (17–40)	30 (68.2)	198 (66.0)	0.485
A3 (> 40)	12 (27.3)	101 (33.7)	0.399
Location			
L1 (ileal)	14 (31.8)	110 (36.7)	0.532
L2 (colonic)	8 (18.2)	29 (9.7)	0.112
L3 (ileocolonic)	20 (45.5)	147 (49.0)	0.660
L4 (upper gastrointestinal)	7 (15.9)	28 (9.3)	0.204
Behavior			
B1 (inflammatory/failure of medical therapy)	1 (2.3)	18 (6.0)	0.511
B2 (stricturing)	24 (56.8)	209 (69.7)	0.088
B3 (penetrating)	25 (56.8)	103 (34.3)	0.004
Perianal disease	15 (34.1)	83 (27.7)	0.378
Operative time*, min	202.3 ± 9.4	189.4 ± 3.3	0.163
First-time operated	19 (43.2)	199 (66.3)	0.003
Small bowel resection	17 (38.6)	124 (41.3)	0.734
Ileocolectomy	20 (45.5)	129 (43.0)	0.759
Colectomy	7 (15.9)	47 (15.7)	0.967
Laparoscopic surgery	10 (22.7)	178 (59.3)	<0.001
Conversion	10 (22.7)	61 (20.3)	0.714
Stoma creation	23 (52.3)	86 (28.7)	0.002
Estimated blood loss*, mL	112.0 ± 15.5	70.8 ± 3.8	<0.001
Preoperative treatment			
Azathioprine	7 (15.9)	60 (20.0)	0.522
Infliximab	12 (27.3)	38 (12.7)	0.001
5-ASA	11 (25.0)	73 (24.3)	0.923
Corticosteroids	3 (6.8)	13 (4.3)	0.442
Enteral nutrition	10 (22.7)	86 (28.7)	0.412
Others	3 (6.8)	13 (4.3)	0.728
Wound protector	13 (29.5)	147 (49.0)	0.016

Values in parentheses are percentages unless indicated otherwise; *values are mean ± SE; *SSI*, surgical site infection

Table 4 Multivariate analysis of factors associated with incisional SSI

Characteristics	Multivariate		
	p value	OR	95% CI
Preoperative albumin	0.220	0.958	0.895–1.026
Preoperative C-reactive protein	0.256	1.005	0.996–1.014
Preoperative white blood cell	0.358	1.048	0.948–1.159
Montreal classification			
Age, year			
A1 (≤ 16)	0.014	28.218	1.960–406.196
Behavior			
B3 (penetrating)	0.333	1.456	0.681–3.116
First-time operated	0.021	0.411	0.193–0.876
Laparoscopic surgery	0.032	0.374	0.152–0.920
Stoma creation	0.397	1.419	0.631–3.193
Estimated blood loss	0.823	1.000	0.996–1.005
Preoperative treatment			
Infliximab	0.021	2.849	1.167–6.954
Wound protector	0.011	0.357	0.161–0.793

SSI, surgical site infection

severity of inflammation, and medical treatments before surgery [27]. In this study, we also found patients with lower albumin level and higher CRP level were in higher risk of SSIs. Furthermore, the pathogenesis of CD could be the impaired intestinal immune system, and the characteristic of CD patients undergoing surgery is a long history of various medical treatments which can alter their immunological response and impair host defense, such as immunological modulators, biologic agents, and corticosteroids. Thus, the immunological response to pathogens might be not strong enough to prevent SSIs. Recent studies have hinted that the risks of all postoperative complications were increased with preoperative steroids, and a meta-analysis also suggested that using steroid preoperatively (OR 1.74, 95% CI 1.11–2.71) could result in an increased risk of postoperative infections [28]. However, we did not find the same result in patients with steroid. It might be related with the last dose of steroid before surgery. Brouquet et al. [29] suggested that the anti-TNF therapy increased the risk of postoperative morbidity in CD patients requiring bowel resection. However, Uchino et al. [27] reported the administration of preoperative infliximab could reduce risk of incisional SSI in CD patients with penetrating disease in a cohort study. They implied that the potential deleterious effects of infliximab for SSIs might be associated with disease behavior (structuring or penetrating disease) and a randomized trial is necessary to be conducted for further confirmation. In this study, we found the incidence of incisional SSI was associated with the preoperative infliximab use, which was in accordance with some studies before. As far as we are concerned, the SSIs might be associated with inhibitory effect on the immune response with infliximab. What is more, the last dose of the infliximab before surgery also affected the conclusion, and in this study, patients exposed to infliximab within 8 weeks of surgery were included.

CD patients were always complicated with abscesses and/or fistulas, and they were considered to be at a relatively higher risk of developing organ/space SSI. Some studies reported that the anastomotic leaks after bowel resection in CD led to postoperative intra-abdominal abscesses and the incidence varied from 4 to 50% [30]. Serradori et al. [31] found that the combined use of steroids and anti-TNF-α therapy could result to increased risk of postoperative intra-abdominal infections. In our study, the dual-ring wound protector could not decrease the rate of organ/space SSI. However, it is reported that intra-abdominal active drainage could be used to prevent organ/space SSI development in CD patients [32]. The underlying mechanism and risk factors of organ/space SSI are different compared with that of incisional SSI; thus, other strategies to prevent them will be needed in the future.

Abscess formation, bowel obstruction, and the history of multiple surgeries can make surgery more challenging, which increases the possibility of SSIs [33]. Actually, the abdominal abscesses which occur frequently in CD patients might lead to contaminated or dirty/infected wounds. The incisional SSI was evaluated to be related with surgical wound classification [34]. In addition, stoma creation was usually needed in more complex CD patients. In these CD patients with stoma creation, the incidence of incision SSI was also increased significantly in our study (52.3% vs 28.7%, $p < 0.05$). Thus, more attention should be paid to pre-surgical optimization to reduce serious inflammation in CD and improve operative outcomes [34]. Some studies reported that half of the patients would undergo surgery within 10 years and a third of CD patients would need multiple surgeries [35]. The old wound resulting from multiple surgeries might be in the risk of infection due to its disability of tissue growth. The incidence of surgical site infection was increased in secondary operation, and various methods were needed to prevent SSIs including vacuum sealing drainage. Also, we found that patients at first surgery had less SSI in this study. The laparoscopic approach has also been reported to reduce the risks of SSIs when compared to open surgery in digestive surgery [36]. In our study, we also found laparoscopic surgery could be one of the independent factors to affect incisional SSI in CD patients undergoing bowel resection, which was consistent with previous reports in other conditions of the abdominal surgery [37].

The current study had several limitations. First, this study was a retrospective observational analysis, and the influence of residual confounding factors could not be fully excluded. Thus, a randomized clinical trial might be needed [11, 13]. Second, as this study was conducted by a single-center study, management strategies for CD only depended on our local experience. Additionally, SSIs might also be affected by the

surgeon and the entire operative team, and the conclusions of our current study needed multicenter prospective studies to verify. The surgical experience could also affect the postoperative complications, including SSIs. Last, the results of bacterial cultures from the incision margin were not analyzed in this study, which might confirm the mechanism of SSIs.

Conclusion

In summary, the patient-related and surgery-related factors should be optimized to prevent incisional SSI. The current study confirmed that a dual-ring wound protector for CD patients undergoing bowel resection had an almost 50% relative risk reduction in incisional SSI subsequently. Utilizing dual-ring wound protectors was also proven to be an independent protective factor for incisional SSI in CD. Thus, when feasible, surgeons are encouraged to use wound protectors in abdominal surgery for CD.

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Data availability The datasets generated during and/or analyzed during the current study are available from the first author or corresponding author on reasonable request.

Compliance with ethical standards

The institutional review board of Sir Run Run Shaw Hospital approved the project.

Conflict of interest The authors declare that they have no conflicts of interest.

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