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ORIGINAL ARTICLE

Risk factors for surgical site infection following colorectal resection: a multi-institutional study

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Abstract
Introduction Surgical site infection (SSI) is an infection occurring in an incisional wound within 30 days of surgery and significantly affects patients undergoing colorectal surgery. This study examined a multi-institutional dataset to determine risk factors for SSI following colorectal resection.
Methods Data on 386 patients who underwent colorectal resection in three institutions were accrued. Patients were identified using a prospective SSI database and hospital records. Data are presented as median (interquartile range), and logistic regression analysis was used to identify risk factors.
Results Patients (21.5 %) developed a postoperative SSI. The median time to the development of SSI was 7 days (5–10). Of all infections, 67.5 % were superficial, 22.9 % were deep and 9.6 % were organ space. In univariate analysis, an ASA grade of II (RR 0.6, CI 0.3–0.9, P=0.019), having an elective procedure (RR 0.4, CI 0.2–0.6, P<0.001), using a laparoscopic approach (RR 0.5, CI 0.3–0.9, P=0.019), having a daytime procedure (RR 0.3, CI 0.1–0.7, P=0.006) and having a clean/contaminated wound (RR 0.4, CI 0.2–0.7, P=0.001) were associated with reduced risk of SSI. In multivariate analysis, an ASA grade of IV (RR 3.9, CI 1.1–13.7, P=0.034), a procedure duration over 3 h (RR 4.3, CI 2.3–8.2, P<0.001) and undergoing a panproctocolectomy (RR 6.5, CI 1.0–40.9, P=0.044) were independent risk factors for SSI. Those who developed an SSI had a longer duration of inpatient stay (22 days [16–31] vs 15 days [10–26], P<0.001).
Conclusions Patients who develop an SSI have a longer duration of inpatient stay. Independent risk factors for SSI following colorectal resection include being ASA grade IV, having a procedure duration over 3 h, and undergoing a panproctocolectomy.

Keywords Surgical site infection · Colorectal surgery · Wound infection · Risk

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Introduction

A surgical site infection (SSI) is defined as infection occurring in an incisional wound within 30 days of the procedure or within 1 year if a prosthesis is implanted [1]. SSI is the third most frequent type of nosocomial infection and accounts for approximately 15–18 % of all hospital infections; however, the SSI rate is higher in those undergoing colorectal surgery [2]. The development of an SSI has a direct negative influence on patient outcome. Patients can expect to spend an additional 8.5 days in the hospital, require prolonged antibiotic therapy and vacuum-assisted wound closure therapy and are 60 % more likely to spend time in the ICU after surgery than are matched controls [3]. SSI exerts a significant economic toll where an estimated 325,000 SSIs in USA annually cost the US health system by approximately US$1.8 billion [4, 5]; this is also true in the case of colorectal surgery [2].

While colorectal resection is associated with a significant postoperative SSI rate [6], there has been a wide discrepancy in its reported incidence, ranging from 3 to 30 % [2, 7–13]. Given this high incidence of SSI, attempts have been made to identify and modify risks [2]. However, there has been no clear consensus on the associated risk factors contributing to SSI following colorectal surgery, which has limited the data's value to

surgeons involved in quality improvement programs hoping to address specific variables that could reduce this risk.

The current study is a retrospective analysis of a prospectively maintained, multi-institutional database to identify risk factors for the development of SSI following colorectal resection using specific diagnosis and surveillance criteria. The resultant incidences of SSI were determined, and multivariate analyses were conducted to assess independent risk factors for the development of SSI following colorectal resection.

Methods

A retrospective analysis of consecutive patients who underwent emergency and elective colorectal resection in three institutions over a 2-year period was performed (2007–2009). Patients were identified using an inpatient SSI Surveillance System database and hospital records. Data was recorded prospectively on each patient in the database, which was completed immediately postoperatively by the operating surgeon. Postoperative care was similar between the three institutions. The diagnosis of SSI in each case was by the surgeon or attending doctor. Infection was determined according to Centre for Disease Control and Prevention definitions of wound infection and was confirmed with positive wound cultures [5].

Subjects included in this study were those who underwent operations on the lower gastrointestinal tract, including subtotal colectomy, right/left hemicolectomy, anterior resection (AR), abdominoperineal resection (APR), panproctocolectomy and Hartman's procedure. Patients undergoing a secondary operation or reoperation were excluded from the study. Data obtained included age, sex, operation class (elective or emergency) and operation type, anesthesia, ASA grade and wound classification (clean, clean/contaminated, contaminated, and dirty). The diagnosis and classification of SSI (superficial incisional, deep incisional, or organ/space), the duration of procedure and the use of prophylactic antibiotics were recorded. In every case, prophylactic antibiotics were given within 60 min of the procedure and continued for 24 h postoperatively. The use of postoperative antibiotics in cases classified with dirty wounds was at the operating surgeon's discretion. Daytime surgery was defined as a procedure beginning between 8 am and 8 pm and nighttime surgery was a procedure performed beginning between 8 pm and 8 am. Routine postoperative care was provided to each patient, and each patient was followed up for a minimum of 30 days by a SSI/colorectal nurse specialist.

Unless otherwise stated, data is represented as median (interquartile range (IQR)) and N represents the number of patients included in the analysis. Differences in distribution of clinical data and the development of an SSI were evaluated using a two-sided Fisher's exact test for categorical variables and the Mann-Whitney *U* test for continuous variables. Multiple logistic regression analysis was performed to examine predictors of SSI. Following univariate analysis, the variables which were statistically significant were used in a multivariate analysis. Correlations were calculated using the Spearman rank correlation test, and $P<0.05$ was considered statistically significant. All calculations were done using SPSS version 12.0 (SPSS, Inc., Chicago, IL).

Results

Patient characteristics

Data was obtained and analysed on 386 patients who underwent colorectal resection. Table 1 compares patient demographics and incidence of SSI. A total of 83 SSIs were recorded (overall rate of 21.5 %). The median duration to diagnosis of SSI was 7 days (5–10). There were 56 superficial infections (67.5 % of all infections), 19 deep infections (22.9 %) and 8 organ space infections (9.6 %). There was no significant difference in age at the time of surgery and development of SSI (64 (56–75) vs 66 (58–76), $P=0.606$, Mann-Whitney *U* test). Twenty-three percent of men developed an SSI relative to 20 % of women ($P=0.453$, Fisher's exact test). An American Society of Anaesthesiologists (ASA) grade of

Table 1 Patient demographics

Characteristics	Total N (%)	SSI (−) (%)	SSI (+) (%)	*P* value[a]
Total	386 (100)	303 (78.5)	83 (21.5)	
Age, median (IQR) (years)	65 (56–76)	64 (56–75)	66 (58–76)	0.606
Gender:				
Male	222 (57.5)	171 (77.0 %)	51 (23.0 %)	0.453
Female	164 (42.5)	132 (80.4 %)	32 (19.5 %)	
ASA grade:				
Grade I	100 (25.9)	81 (81)	19 (19)	0.572
Grade II	216 (55.9)	179 (82.9)	37 (17.1)	0.024
Grade III	52 (13.5)	36 (69.2)	16 (30.8)	0.101
Grade IV	15 (3.9)	5 (33.3)	10 (66.7)	<0.001
Grade V	3 (0.8)	2 (66.7)	1 (33.3)	0.517

N number of patients, *IQR* interquartile range, *SSI* surgical site infection, *ASA* American Society of Anaesthesiologists

[a] All were assessed with the Fisher's exact test except age which was assessed with the Mann-Whitney *U* test

IV was associated with an increased incidence of SSI ($P<0.001$, Fisher's exact test).

Perioperative characteristics and the development of surgical site infection

The association of SSI with perioperative variables is summarised in Table 2. Those who underwent an emergency procedure relative to an elective procedure were at increased risk of postoperative SSI (17 vs 36 %, $P<0.001$, Fisher's exact test). Patients who underwent an open relative to a laparoscopic approach were more likely to develop an SSI (26 vs 16 %, $P=0.018$, Fisher's exact test). If the procedure was over 3 h long, the rate of SSI rose from 17 to 46 % ($P<0.001$, Fisher's exact test). Procedures carried out at night were associated with increased SSI relative procedures carried out during the day (43 vs 20 %, $P<0.001$, Fisher's exact test). Patients undergoing a panproctocolectomy relative to another resection were at increased risk of SSI ($P=0.021$, Mann-Whitney U test).

Table 2 Perioperative characteristics and development of surgical site infection

Characteristics	Total N (%)	SSI (−) (%)	SSI (+) (%)	*P* value[a]
Setting:				
Elective	298 (77.2)	247 (82.9)	51 (17.1)	<0.001
Emergency	88 (22.8)	56 (63.6)	32 (36.4)	
Approach:				
Open	221 (57.3)	164 (74.2)	57 (25.8)	0.018
Laparoscopic	165 (42.7)	139 (84.2)	26 (15.8)	
Duration:				
<3 h	321 (80.6)	267 (83.2)	54 (16.8)	<0.001
>3 h	67 (19.4)	36 (53.7)	29 (46.3)	
Time:				
Day	358 (92.7)	287 (80.2)	71 (19.8)	<0.001
Night	28 (7.3)	16 (57.1)	12 (42.9)	
Prophylactic antibiotics:				
Yes	384 (99.5)	301 (78.4)	83 (21.6)	0.458
No	2 (0.5)	2 (100)	0 (0)	
Procedure:				
Right hemicolectomy	84 (21.8)	61 (72.6)	23 (27.4)	0.093
Left hemicolectomy	19 (4.9)	18 (94.7)	1 (5.3)	0.058
Hartman's procedure	27 (7.0)	21 (77.8)	6 (22.2)	0.543
APR	26 (6.7)	20 (76.9)	6 (23.1)	0.501
Anterior resection	213 (55.2)	172 (80.8)	41 (19.2)	0.142
Total colectomy	4 (1)	4 (100)	0 (0)	0.378
Subtotal	7 (1.8)	5 (71.4)	2 (28.6)	0.465
Panproctocolectomy	6 (1.6)	2 (33.3)	4 (66.7)	0.021

N number of patients, *SSI* surgical site infection, *APR* abdominoperineal resection

[a] Assessed with the Fisher's exact test

Multiple logistic regression analysis

In a multiple logistic regression analysis, using univariate analysis, an ASA grade of II, having an elective procedure, having a laparoscopic procedure, undergoing the procedure during the day and having a clean/contaminated wound reduced the risk of SSI whilst ASA grade IV, having a procedure duration over 3 hours, having a contaminated or dirty wounds and having a panproctocolectomy were associated with an increased risk of SSI (Table 3). However, when those factors which were significant were examined together in a multivariate analysis only, ASA grade IV (RR 3.9, 95 % CI 1.1–13.7, $P=0.034$), procedures greater than 3 h (RR 4.3, 95 % CI 2.3–8.2, $P<0.001$) and having a panproctocolectomy relative to other resections (RR 6.5, 95 % CI 1.0–40.9, $P<0.044$) were independent risk factors for developing SSI (Table 4).

Table 3 Univariate analysis of preoperative patient characteristics and operative variables on the development of surgical site infection

Variable	RR	CI	*P* value
Age	1.003	0.985–1.020	0.773
Male vs female	1.264	0.769–2.077	0.356
ASA grade:			
Grade I	0.814	0.459–1.441	0.480
Grade II	0.557	0.341–0.909	0.019
Grade III	1.771	0.927–3.382	0.083
Grade IV	8.164	2.708–24.616	<0.001
Grade V	1.835	0.164–20.493	0.622
Elective vs emergency	0.353	0.208–0.600	<0.001
Laparoscopic vs open	0.538	0.321–0.902	0.019
>3 h vs <3 h	4.249	2.390–7.552	<0.001
Day vs night	0.330	0.149–0.728	0.006
Wound class:			
Clean	0.631	0.159–2.494	0.511
Clean/contaminated	0.392	0.230–0.669	0.001
Contaminated	1.954	1.016–3.759	0.045
Dirty/infected	2.933	1.292–6.659	0.010
Procedure:			
Right hemicolectomy	1.521	0.872–2.652	0.140
Left hemicolectomy	0.193	0.025–1.468	0.112
Hartman's procedure	1.046	0.408–2.683	0.925
APR	1.103	0.428–2.841	0.840
Anterior resection	0.743	0.457–1.210	0.233
Subtotal	1.472	0.280–7.725	0.648
Panproctocolectomy	7.620	1.371–42.359	0.020

$N=386$

ASA American Society of Anaesthesiologists, *RR* relative risk, *CI* confidence interval, *APR* abdominoperineal resection

Table 4 Multivariate analysis of preoperative patient characteristics and operative variables on the development of surgical site infection

Variable	RR	CI	*P* value
ASA grade:			
Grade II	0.659	0.374–1.161	0.149
Grade IV	3.896	1.107–13.705	0.034
Elective vs emergency	0.723	0.328–1.597	0.423
Laparoscopic vs open	0.901	0.472–1.719	0.751
>3 h vs <3 h	4.343	2.301–8.199	<0.001
Day vs Night	0.660	0.232–1.876	0.436
Wound class:			
Clean/contaminated	0.459	0.103–2.044	0.307
Contaminated	0.742	0.162–3.406	0.701
Dirty/infected	1.064	0.211–5.358	0.940
Panproctocolectomy vs other resections	6.546	1.047–40.905	0.044

Adjusted for all other variables in the table. *N*=386

ASA American Society of Anaesthesiologists, *RR* relative risk, *CI* confidence interval

Discussion

The current study has demonstrated in a large, modern, multi-institutional dataset that the rate of SSI following colorectal resection is 21.5 %. The median time to developing an SSI was 7 days, and 67.5 % were superficial. Having an ASA grade of IV, having a procedure duration over 3 h, and undergoing a panproctocolectomy were independent risk factors for the development of SSI, and those who developed an SSI had a longer duration of inpatient stay.

The incidence of SSI in patients undergoing colorectal surgery is 3.8 times higher than in patients undergoing general surgery [14]. Whilst the rates of reported SSI following colorectal resection are both high and variable from retrospective series, they are higher (21–45 %) from randomized controlled studies [6, 15], emphasizing the scope of the problem.

The rate of SSI was 10 % lower in those undergoing a laparoscopic approach, similar to other series [16]. However, in multivariate analysis, this benefit was not statistically significant. This is surprising given prior studies have shown that a laparoscopic approach is an independent positive factor for reducing the incidence of SSI [16–18]; this statistical disparity in the current study may reflect a smaller patient number or an increasing trend to perform complex and contaminated colorectal surgery laparoscopically rather than open as individual surgeons' laparoscopic experience grows. This may be the case in this study as over 40 % of cases were attempted laparoscopically, including complex and contaminated cases.

Prior series have found left-sided and rectal resections associated with increased risk of SSI [19]. The association between panproctocolectomy and SSI presented herein is unique. Factors not assessed which could account for this increased rate of SSI could be attributed to various factors. The majority of patients who underwent a panproctocolectomy had ulcerative colitis. Patients with ulcerative colitis can become malnourished, immunosuppressed and hypoalbuminaemic, all of which are risk factors for SSI [20, 21]. In addition, 50 % of patients who underwent a panproctocolectomy for ulcerative colitis underwent emergency surgery of which 25 % of the wounds were dirty or contaminated.

Procedures over 3 h in duration were also an independent risk factor for the development of SSI. Procedural duration has long been an accepted marker for the complexity of individual cases [22]. In addition, the duration of operation is a component of the National Nosocomial Infections Surveillance (NNIS) risk index for SSI [4]. Prolonged surgical duration is associated with longer wound exposure to pathogenic microorganisms and diminished efficacy of antimicrobial prophylaxis [23, 24].

This study is not without out its limitations. Additional risk factors for SSI following colorectal surgery such as diabetes mellitus [25], increased body mass index [26], subcutaneous fat or waste circumference [27] and associated diverting ostomy were not examined. However, recently, Balentine et al. have reported that increased abdominal circumference, a measure of central obesity, is a better predictor of short-term complications than body mass index in patients undergoing colorectal surgery. In addition, increased abdominal circumference independently predicted increased risk of superficial infections [28]. Data regarding the indication for emergency resection, proportionate source control, evidence of septic shock and duration of postoperative antibiotic use in cases classified as dirty were not recorded in our prospective database, and discerning these outcomes in all cases retrospectively was not possible. Concerning the association between diverting ostomy and SSI, Konishi et al. have demonstrated that ostomy creation in rectal but not colonic surgery is a risk factor for SSI [29]. This, these authors felt, was due in part to rectal tumour patients receiving neo-adjuvant radiotherapy.

Despite these limitations, this examination of a large, multi-institutional dataset demonstrates an acceptable rate of SSI in a modern colorectal population. An ASA grade of IV, having a procedure duration over 3 h and undergoing a panproctocolectomy are independent risk factors for the development of SSI. Whilst these factors cannot be modified perioperatively, their presence should emphasise the need to modulate other risk factors present and highlight patients to be observed closely. In particular, preventative factors that surgeons should implement include perioperative supplemental oxygen therapy [30] and maintenance of normothermia [31], in addition to

extremely tight glycaemic control in an effort to reduce the incidence of SSI following colorectal surgery.

Compliance with ethical standards

Conflicts of interest None to declare

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