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ORIGINAL ARTICLE

Right colon, left colon, and rectal surgeries are not similar for surgical site infection development. Analysis of 277 elective and urgent colorectal resections

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Abstract
Purpose Surgical site infections (SSIs) are the most common infections in colorectal surgery. Although some studies suggest that rectal surgery differs from colon surgery for SSI incidence and risk factors, the National Nosocomial Infection Surveillance system categorizes all colorectal surgeries into only one group. The aim of this study was to determine incidence, characteristics, and risk factors of SSIs according to the subclassification of colorectal surgery into right colon surgery (RCS), left colon surgery (LCS), and rectum surgery (RS).
Methods From November 2005 to July 2009, all patients requiring colorectal resectioning were enrolled into our program. The outcome of interest was an SSI diagnosis. Univariate and multivariate analyses were performed to determine SSI predictors in each group.
Results Two hundred seventy-seven consecutive colorectal resections were analyzed. SSI rates were 8% in RCS, 18.4% in LCS, and 17.6% in RS. LCS and RS showed significantly higher SSI incidences (p=0.022) and greater rates of organ/space infections compared to RCS (p=0.029). Predictors of SSI were steroid use among RCS, age greater than 70 years, multiple comorbidities, steroid use, non-neoplastic colonic disease, urgent operation, ostomy creation, postoperative intensive care among LCS, preoperative chemoradiation, heart disease, and prolonged operation among RS patients. On multivariate analysis, the coupled LCS and RS groups showed an increased risk for SSI compared to RCS (OR, 2.57).
Conclusions SSI incidences, characteristics, and risk factors seem to be different among RCS, LCS, and RS. A tailored SSI surveillance program should be applied for each of the three groups, leading to a more competent SSI recognition and reduction of SSI incidence and related costs.

Keywords Colon surgery · Rectal surgery · Surgical site infection · Hospital infection · Wound infection

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Introduction

Surgical site infection (SSI) is the most common nosocomial infection among surgical patients, accounting for up to 40% of all health care-associated infections in the surgical population [1, 2]. SSIs lead to increased perioperative morbidity and mortality and contribute to rising health care cost [3, 4].

Active SSI surveillance is known to reduce SSI incidence by surveillance-induced infection control efforts [5, 6]. A successful SSI surveillance program includes standardized definitions of infection and effective surveillance procedures in order to stratify the surgical operations according to specific SSI rates and risk factors, allowing ensuing clinical interventions [7].

In colorectal resective surgery, despite that postoperative SSIs have been widely studied, there are still some inconclusive results. First, there is still a great discrepancy in the reported incidence of SSI, with rates ranging from 3% to 30% in literature [8–13]. Second, colorectal surgery has always been categorized by the National Nosocomial Infection Surveillance (NNIS) system [6] into only one group, without discrimination between colon and rectal surgery, while more recent studies have shown that SSI rates and risk factors might be different in these two surgeries [7, 14].

If rectal surgery differs from colon surgery because of greater bacterial contamination, more frequent need for ostomies, longer operations, and possible neoadjuvant treatments in oncological patients, equally the surgery performed on the left colon might be considered different from surgery performed on the right colon [13, 15]. In the clinical practice, left colon resections are considered to be more frequently associated with urgent setting and contaminated intra-abdominal conditions compared to right colon surgery. Furthermore, in left colon resections as well as in rectal resections, it is expected to have a greater bacterial contamination because of the increasing bacterial density from ileocecal valve to the anal verge [16]. Anyhow, this topic related to the subclassification of colorectal surgery into right colon, left colon, and rectum surgery for SSI risk has never been specifically and patently analyzed.

In order to verify the differences between right colon, left colon, and rectal resective surgeries concerning postoperative SSI, we started a prospective program of SSI surveillance in our surgical department. The aim of our study were: (1) to determine the incidence and the characteristics of SSIs after colorectal surgery, according to the three surgical sites of surgery and (2) to identify the risk factors for SSI in these three groups.

Methods

Patients

Between November 2005 and July 2009, all patients requiring colorectal resectioning at the Department of General Surgery, University of Milano-Bicocca, San Gerardo Hospital, Monza, Italy were enrolled into our surveillance program of SSIs. All the operations were performed via laparotomy for both urgent and elective pathologies. All patients undergoing nonresective colorectal surgery (e.g., stoma creation, colostomy) and patients whose skin and subcutaneous tissues were left to heal secondarily were excluded from the study.

All patients provided written informed consent before entry into the study.

Preparation to operation and surgical procedures

The surgical procedures were classified into “right colon surgery” (RCS), “left colon surgery” (LCS), and “rectum surgery” (RS) and the data were collected separately. RCS was defined as a resective procedure performed on the right part of the colon (from the cecum to the colon transversum within the insertion of the middle colic artery). LCS comprised all the resective procedures involving the left part of the colon, from the colon transversum (down the insertion of the middle colic artery) to the rectosigmoid junction but not involving the rectum. RS was defined as a resective procedure involving at least one of the portions of the rectum below the rectosigmoid junction.

All patients undergoing elective colorectal resections had preoperative bowel preparation with polyethylene glycol solution the day before surgery and preoperative shaving with electric clippers 1 h before the operation. All elective and urgent patients received intravenous prophylactic antibiotics, consisting of metronidazole 500 mg and piperacillin 2 g. Antibiotic administration was started 30 min before incision, it was repeated in operations lasting more than 3 h and then discontinued within 24 h after the operation. Patients requiring surgical colorectal resectioning for urgent pathologies with bowel perforation, intra-abdominal abscess, or contaminated/dirty conditions of the abdominal cavity, underwent antibiotic therapy with different kinds of drugs for at least 7 days.

In all operations, preoperative skin antisepsis was obtained using povidone iodine solution, and traditional reusable surgical gowns, drapes, and gloving were used. A ring drape was used as a wound edge protector in all the operations.

The performed bowel anastomoses were classified as manual anastomosis, end-to-end stapler anastomosis, biofragmentable anastomotic ring, and coloanal anastomosis. Manual bowel anastomosis consisted in continuous, double layers (inner layer with traditional absorbable braided suture, outer layer with traditional nonabsorbable monofilament suture), side-to-side, or end-to-end, hand-sewn suture. End-to-end stapler anastomosis was performed by using a circular stapling device (Autosuture™, Covidien) while the biofragmentable anastomotic ring (Valtrac®-BAR) was used to perform end-to-end colonic anastomosis after segmental left colectomy. Coloanal anastomosis was defined as a straight hand-sewn suture (with traditional absorbable braided suture) between the colon stump and the anus. Abdominal incisions were closed primarily in all cases using a traditional absorbable polyglycol acid braided suture for the peritoneum, the fascia, and the subcutaneous tissue. The skin was sutured using stainless-steel staples.

All operations were performed by one of five equipped surgeons with experience in colorectal surgery. In our institution, a preoperative screening for methicillin-resistant *Staphylococcus aureus* (MRSA) and other multi-resistant germs was not carried out.

Surveillance methods and definition of SSI

The attending physicians observed the patients' surgical wounds for SSI incidence every day until their discharge. After discharge, all patients were followed up at least until postoperative day 30. The patients were telephoned by a physician and, in case of SSI suspicion, they were checked in the outpatient clinic.

The diagnosis of SSI was made after discussion among the attending physicians, basing on the definitions described in the guidelines of the Center for Disease Control and Prevention [5]. SSIs were classified into superficial incisional, deep incisional, and organ/space infections. Criteria for superficial incisional SSI were an infection that occurred at the incision site within 30 days after the operation, involving the skin and the subcutaneous tissue above the fascial layer. Deep incisional SSI was defined as an infection that occurred at the incision site within 30 days after surgery, involving the skin, the subcutaneous tissue, and the fascial layer without extension below the peritoneal layer into the abdominal cavity. Organ/space SSI was defined as an infection that occurred inside the abdominal cavity, involving intra-abdominal organs and spaces, within 30 days after the operation. An anastomotic leak was not considered as an SSI. Because there were a few cases of deep incisional infections, we grouped superficial and deep incisional infections together. Infections involving both organ/space and incisional site (superficial or deep) were categorized as organ/space infections.

Analyzed factors for SSIs

The following patients' data were prospectively collected and analyzed as risk factors for SSI on univariate analysis. The preoperative patient-related factors were age, evaluated as a continuous and categorical variable (≤70 years, >70 years); gender; history of diabetes mellitus (DM); heart disease; chronic obstructive pulmonary disease (COPD); history of "multiple comorbidities" (defined as history of at least two comorbidities between DM, heart disease, COPD, arterial hypertension, chronic liver disease, chronic renal disease, cerebrovascular accident history); preoperative steroid use, body mass index (BMI) in kilogram per square meter evaluated as categorical variable (≤25, >25); American Society of Anesthesiology (ASA) score evaluated as categorical variable (<3, ≥3); preoperative serum albumin evaluated as categorical variable (<3, ≥3 g/dL); preoperative hemoglobin evaluated as categorical variable (<12, ≥12 g/dL); colorectal pathological diagnosis; tumor stage (according to Dukes's classification [17]); neoadjuvant chemoradiotherapy; and preoperative hospital stay evaluated as a categorical variable (<2 days, ≥2 days).

Regarding intraoperative and postoperative factors, we analyzed the following: need of urgent operation, type of colorectal resection, type of anastomosis, additional surgical procedure (including additional resection of other organs than colon–rectum, hernia repair, extensive lysis of bowel adhesions), ostomy creation (with sub-classification into ileostomy and colostomy), duration of operation ("prolonged operation" was defined as an operation lasting more than the 75th percentile of the examined procedures), need of postoperative intensive care, need of perioperative transfusion of packed red blood cells (PRBC), surgical wound class evaluated as a categorical variable consisting of clean–contaminated class (class 2) and contaminated and dirty classes (classes 3 and 4) [18], NNIS risk index score [6] (composed of the following: ASA score of 3, 4, 5; wound classification of contaminated or dirty–infected; duration of operation longer than 3 h).

SSIs were analyzed for postoperative onset day, site of infection (incisional or organ/space), duration of SSI, and bacterial cultures.

Statistical analysis

This study evaluated incidence, characteristics and risk factors of postoperative SSIs in patients with RCS, LCS, or RS, in order to identify the presence of possible differences between the three groups.

Data were summarized as frequencies and proportions for categorical variables or as median and interquartile range (iqr) for continuous variables, and differences between groups were evaluated by the chi-square test, Fisher's exact test (in the presence of a cell's frequency less than 5) and Mantel–Haenszel test (for trend) for categorical data while for continuous data by Wilcoxon test or the Kruskal–Wallis test.

A logistic multivariate model was built when the event's number allowed as correction and the relative odds ratio (OR) and 95% confidence intervals (CI 95%) were calculated. Statistically, significance was set at <0.05. All the analyses were performed using the R 2.0.1 software.

Results

Analyzed population

During the study period, a total of 277 consecutive colorectal resections were performed for different colorectal pathologies and all patients completed the follow-up.

One hundred patients underwent RCS, 103 patients LCS, and 74 patients RS. An urgent operation was required for 33 patients (11.9%).

Within the RCS group, the patients showed a median age of 69 years (iqr, 59–76) and 53% were male. The most frequent procedure was right colectomy (81%) followed by ileocecal resection (11%) and other colectomies of the right colon (8%). The colorectal pathological diagnosis was cancer in 77% of the patients, inflammatory bowel disease (IBD) in 6%, colon infarction in 3%, and other colonic pathologies in 14%.

Patients who underwent LCS showed a median age of 67 years (iqr, 58–76) and 56.3% were male. The surgical procedures were left colectomy in 53.4% of the patients, segmental left colectomy in 43.7% and total colectomy in 2.9%. The indication for colonic resections was cancer in 62.2% of the patients, diverticular disease in 25.3%, colon infarction in 1.9%, IBD in 0.9% and other colonic pathologies in 9.7%.

Within the RS group, patients had a median age of 70 years (iqr, 62–77) and 56.8% were male. The surgical procedures were upper rectal resection in 35.1% of the patients, low anterior resection in 29.7%, abdominoperineal resection in 17.6%, Hartmann's procedure in 13.5%, and total proctocolectomy in 4.1%. According to disease classification, there were 85.1% of the patients with cancer, 4.1% with IBD, 2.7% with diverticular disease, and 8.1% patients with other rectal pathologies.

SSI incidence and SSI characteristics

The cumulative SSI incidence in the whole population was 14.4% (40/277). SSI occurred in eight patients (8%) of the RCS group, in 19 patients (18.4%) of the LCS group, and 13 patients (17.6%) of the RS group, without a significant difference among the three groups (p=0.071, chi-square test, Table 1). As a matter of fact, the SSI incidences in LCS and RS groups were not different (18.4% vs 17.6%, p=0.881, chi-square test). Both LCS and RS group, whether analyzed singularly or coupled, showed significantly higher SSI incidence compared to the RCS group (Table 2). Moreover, the SSI incidence in patients undergoing colon resections (RCS and LCS) was not different from SSI incidence in patients undergoing RS, respectively, 13.3% vs 17.6% (p=0.371, chi-square test, Table 2).

Table 1 Association between the site of surgery (RCS, LCS and RS) and development of SSI (n=277 patients)

Site of surgery	Number	SSI (%)	P[a]
RCS	100	8 (8.0)	
LCS	103	19 (18.4)	0.071
RS	74	13 (17.6)	

[a] Chi-square test

Table 2 Association between the site of surgery (RCS, LCS and RS) and development of SSI (n=277 patients)

Site of surgery	Number	SSI %	P[a]
LCS	103	19 (18.4)	0.881
RS	74	13 (17.6)	
RCS	100	8 (8.0)	0.028
LCS	103	19 (18.4)	
RCS	100	8 (8.0)	0.049
RS	74	13 (17.6)	
RCS	100	8 (8.0)	0.022
LCS+RS	177	32 (18.1)	
RCS+LCS	203	27 (13.3)	0.371
RS	74	13 (17.6)	

[a] Chi-square test

Considering the site of infection, the analysis showed that incisional infections occurred in 31 patients (77.5% among all SSIs) and organ/space infections in nine patients (22.5% among all SSIs). There was no significant difference between the three groups for the infection site (p=0.230, Fisher's exact test, Table 3). If coupled, LCS and RS patients showed a higher rate of organ/space infection compared to RCS patients (31.6% in LCS and 23.1% in RS vs 0% in RCS group, p=0.029, Fisher's exact test).

The median SSI onset was 7 days (iqr, 5–10) after the operation, the median SSI duration was 14 days (iqr, 8–24) and the median postoperative hospital stay for SSI patients was 20 days (iqr, 13–26), without significant differences between the three groups (see Table 3 for detailed data). Patients with SSI had a significantly longer median postoperative hospital stay than patients without SSI (p<0.001, Wilcoxon test), respectively, 20 days (iqr, 13–26) vs 10 days (iqr, 9–14); median overall postoperative hospital stay was 11 days (iqr, 9–15).

The majority of SSIs (n=37, 92.5% among all SSIs) were detected before hospital discharge (Table 3). SSIs causative pathogens identified from the cultures were coliforms, *Staphylococci*, anaerobes, and *Pseudomonas*, without a significant difference between the three groups. Multi-resistant bacteria such as MRSA, extended spectrum beta-lactamases-producing *Escherichia coli* and *Enterococcus faecium* were identified in 11%, 12%, and 22% of the cultures, respectively.

Predictors of SSI

On univariate analysis, the clinical preoperative factors showing a possible association with SSI development for the entire cohort of patients were preoperative steroid use, preoperative hospital stay longer than 2 days, and presence

Table 3 Characteristics of SSIs in the three groups (RCS, LCS, and RS)

Variable	All (*n*=277)		RCS (*n*=100)		LCS (*n*=103)		RS (*n*=74)		*P*
	Number	% (iqr)	Number	% (iqr)	Number	% (iqr)	Number	% (iqr)	
Site of SSI									
Incisional	31	77.5	8	100	13	68.4	10	76.9	0.230[a]
Organ/space	9	22.5	0	0	6	31.6	3	23.1	
Median day of SSI presentation	7	(5, 10)	7	(6, 9)	6	(4, 9)	8	(5, 10)	0.233[b]
Median SSI duration (days)	14	(8, 24)	17	(14, 20)	13	(7, 24)	13	(8, 24)	0.685[b]
Median postoperative hospital stay in SSI patients	20	(13, 26)	17	(11, 28)	20	(12, 25)	19	(14, 23)	0.916[b]
Post-discharge SSIs	3	7.5	2	25	1	5.3	0	0.0	0.125[c]

[a] Fishers's exact test

[b] Kruskal–Wallis test

[c] Wilcoxon test

of multiple comorbidities (Table 4). Preoperative levels of serum albumin and hemoglobin were not predictors of SSI development (p=1.000 and p=0.388, respectively). RCS group showed only preoperative steroid use as risk factor for SSI, while for LCS groups an age greater than 70 years, the presence of multiple comorbidities, preoperative steroid use, and non-neoplastic colonic disease were predictors of SSI development. Preoperative chemoradiation and history of heart disease resulted to be SSI risk factors in RS group.

Among the analyzed surgical and perioperative factors, the following were predictors of SSI in the whole population: ostomy creation, prolonged operation, postoperative need of intensive care, and NNIS risk index score (Table 5). Urgent operation resulted to be a possible risk factor for SSI only in LCS group. The subclassification of the surgical operation in each group, the type of anastomosis, the accomplishment of additional surgical procedures, the need of PRBC transfusion and the surgical wound class were not predictors of SSI on univariate analysis.

In the multivariate model, only the parameter "multiple comorbidities" remained statistically significant in the estimate of the OR of the risk of SSI for the coupled LCS and RS groups than RCS group (OR, 2.57; CI 95%, 1.13, 5.84).

Discussion

The reported SSI incidence after colorectal surgery shows a remarkable heterogeneity in literature, due to variability of surveillance methods and type of investigated surgical procedures [19]. In the present study, we reported a cumulative SSI incidence of 14.4% after colorectal surgical resection even including post-discharge infections. Two recent studies with comparable surveillance programs on elective colorectal surgery showed an SSI incidence of 12.8% and 26%, respectively [7, 8].

Albeit the large amount of studies about SSI after colorectal resection, only few reports have analyzed postoperative SSIs with regard to the resected tract of the large bowel (colon or rectum) [14, 20]. Konishi [7] showed that the incidence of incisional SSI is higher in elective rectal surgery than in elective colonic surgery and that the risk factors for incisional SSI are different between these two surgical procedures. Our study demonstrated that the subclassification of colorectal surgery into colon and rectal surgery, in relation to postoperative SSI, is unaccomplished and that it could be furthermore detailed, dividing the colon surgery into right colon and left colon resective surgery. As a matter of fact, our findings showed an SSI incidence respectively of 8%, 18.4%, and 17.6% in RCS, LCS, and RS. Among the three colorectal groups, there was no significant difference for SSI incidence (p=0.071). Nevertheless, the analysis of groups by two showed that the incidence of SSI was similar between LCS and RS patients (18.4% and 17.6%, respectively). Furthermore, both LCS and RS patients had a significantly higher SSI incidence compared to the RCS group (8%). In contrast with Konishi's [7] results, we demonstrated that the patients who underwent colonic resections (RCS plus LCS) did not differ from the patients who underwent RS for SSI incidence (13.3% vs 17.6%, p=0.371). Hence, the subclassification of colorectal surgery into three groups as proposed in our study seems to be more appropriate for the setting of an SSI surveillance program.

A possible explanation of the dissimilar SSI incidences among the three groups of patients could be the variation in microbial flora in the different colorectal segments [21]. Considering that the bacterial residents increase in quantity from the right colon to the rectum, with variations of the

Table 4 Patient characteristics and univariate analysis of SSI risk factors

Variable	RCS+LCS+RS (*n*=277)			RCS (*n*=100)			LCS (*n*=103)			RS (*n*=74)		
	Number	SSI %	*P*[a]	Number	SSI %	*P*[a]	Number	SSI %	*P*[a]	Number	SSI %	*P*[a]
Gender												
Male	153	16.9	0.288	53	5.7	0.469[b]	58	19.0	0.878	42	25.0	0.143
Female	124	12.4		47	10.6		45	17.8		32	11.9	
Age (years)												
≤70	150	12.0	0.209	52	5.8	0.475[b]	61	13.1	0.093	37	18.9	0.760
>70	127	17.3		48	10.4		42	26.2		37	16.2	
COPD												
No	244	13.9	0.515	90	7.8	0.583[b]	88	15.9	0.108	66	19.7	0.336[b]
Yes	33	18.2		10	10.0		15	33.3		8	0.0	
Heart disease												
No	210	13.8	0.597	73	9.6	0.679[b]	81	18.5	1.000[b]	56	12.5	0.043
Yes	67	16.4		27	3.7		22	18.2		18	33.3	
DM												
No	245	15.5	0.192[b]	87	9.2	0.592[b]	94	20.2	0.204[b]	64	17.2	1.000[b]
Yes	32	6.4		13	0.0		9	0.0		10	20.0	
Multiple comorbidities												
No	122	9.8	0.053	44	6.8	1.000[b]	47	10.6	0.061	31	12.9	0.538[b]
Yes	155	18.1		56	8.9		56	25.0		43	20.9	
Steroid use												
No	267	13.1	0.001	98	6.1	0.006[b]	99	16.2	0.019[b]	70	18.6	1.000[b]
Yes	10	50.0		2	100		4	75.0		4	0.0	
BMI (kg/m^2)												
≤25	236	13.6	0.317	83	7.2	0.621[b]	90	16.7	0.253[b]	63	17.5	1.000[b]
>25	41	19.5		17	11.8		13	30.8		11	18.2	
ASA score												
<3	183	12.0	0.110	69	4.4	0.103[b]	73	15.1	0.168	41	19.5	0.624[b]
≥3	94	19.2		31	16.1		30	26.7		33	15.2	
Colorectal pathology												
Cancer	204	12.8	0.180	77	7.8	1.000[b]	64	12.5	0.046	63	19.1	0.676[b]
Other[c]	73	19.2		23	8.7		39	26.3		11	9.1	
Dukes stage												
A, B	116	12.9	0.701	41	9.8	0.683[b]	36	13.9	1.000[b]	39	15.4	0.721[b]
C, D	81	11.1		34	5.9		27	11.1		20	20.0	
Preoperative hospital stay												
<2 days	166	11.5	0.083	58	5.2	0.275[b]	65	13.9	0.115	43	16.3	0.732
≥2 days	111	18.9		42	11.9		38	26.3		31	19.4	
Preoperative chemoradiation												
No										61	13.1	0.029
Yes										13	38.5	

Multiple comorbidities history of at least two comorbidites between *DM*, heart disease, *COPD*, arterial hypertension, chronic liver disease, chronic renal disease and cerobrovascular accident disease

[a] Chi-square test, except Fisher's exact test

[b] Fisher's exact test

[c] Comprises IBD, diverticular disease, colon infarction, and other colorectal diseases

Table 5 Surgical characteristics, perioperative treatment, and univariate analysis of SSI risk factors

Variable	RCS+LCS+RS (*n*=277)			RCS (*n*=100)			LCS (*n*=103)			RS (*n*=74)		
	Number	SSI %	*P*[a]	Number	SSI %	*P*[a]	Number	SSI %	*P*[a]	Number	SSI %	*P*[a]
Urgent operation												
No	244	13.9	0.515	88	9.1	0.591[b]	85	15.3	0.073	71	18.3	1.000
Yes	33	18.2		12	0.0		18	33.3		3	0.0	
Type of surgery												
Ileocecal resection				11	18.2	0.344						
Right colectomy				81	6.2							
Other colectomy of the right colon				8	12.5							
Left colectomy							55	14.6	0.394			
Segmental left colectomy							45	22.8				
Total colectomy							3	33.3				
Upper rectal resection										26	19.2	0.493
Low anterior resection										22	13.5	
Abdominoperinal resection										13	30.8	
Total proctocolectomy										3	0.0	
Hartmann's procedure										10	0.0	
Type of anastomosis												
Manual	128	9.4	0.416	98	8.2	1.000[b]	25	16.0	0.984	5	0.0	0.510[c]
End-to-end stapler	101	16.8					62	14.5		39	20.5	
Biofragmentable ring	8	12.5		1	0.0		7	14.3				
Coloanal	7	14.3								7	14.3	
Additional surgical procedure[d]												
No	169	14.2	0.887	66	9.1	0.713[b]	58	17.2	0.720	45	17.8	0.953
Yes	108	14.8		34	5.9		45	20.0		29	17.2	
Ostomy creation												
No	214	11.7	0.055	100	8.0		91	14.3	0.008	23	17.4	0.985
Ileostomy	30	23.3					3	66.7		27	18.5	
Colostomy	33	24.2					9	44.4		24	16.7	
Prolonged operation[e]												
No	207	11.6	0.021	75	9.3	0.675[b]	78	16.7	0.411	56	10.7	0.006
Yes	70	22.9		25	4.0		25	24.0		18	38.9	
Postoperative ICU												
No	257	12.8	0.007	95	7.4	0.347[b]	94	14.9	0.010	68	17.7	1.000[b]
Yes	20	35.0		5	20.0		9	55.6		6	16.7	
PRBC transfusion												
No	150	12.7	0.361	47	4.3	0.276[b]	68	16.2	0.408	35	17.1	0.928
Yes	127	16.5		53	11.3		35	22.9		39	18.0	
Wound classification												
Clean–contaminated	226	13.3	0.245	89	7.9	1.000[b]	67	16.4	0.469	70	17.1	0.547[b]
Contaminated+dirty	51	19.6		11	9.1		36	22.2		4	25.0	
NNIS risk index												
0	77	9.1	0.035[c]	43	4.7	0.626[c]	24	20.8	0.256[c]	10	0.0	0.334[c]
1	120	14.2		40	12.5		45	11.1		35	20.0	
2	70	18.6		16	6.2		27	22.2		27	22.2	
3	10	30.0		1	0		7	42.9		2	0.0	

ICU intensive care unit; *NNIS* risk index score, national nosocomial infections surveillance index score (composed of the following: *ASA* score of 3, 4, 5; wound classification of contaminated or dirty–infected; duration of operation greater than 3 h)

[a] Chi-square test except Fisher's exact test and Mantel–Haenszel test

[b] Fisher's exact test

[c] Mantel Haenszel test

[d] Including additional resection of other organs than colon–rectum, hernia repair, extensive lysis of bowel adhesions

[e] Defined as operation lasting more than the 75th percentile of the examined operations. Seventy-fifth percentile of overall colorectal resections=3.45 h (range, 1.06; 8.45), 75th percentile of right colon resections=3.06 h (range, 1.20; 5.05), 75th percentile of left colon resections=3.40 h (range, 1.06; 6.00), 75 of rectum resections=4.17 h (range, 1.55; 8.45)

composition of the flora [21, 22], it should be expected a different SSI incidence according to the segment of the colorectal tract involved during the operation. The low SSI incidence in RCS found in our study is probably associated with the low bacterial density in the right colon while the similar SSI incidence found in LCS and RS group could be explained by a similar contamination from the rectosigmoidal junction microbial flora during this kind of operation.

The SSIs analysis in relation to the colorectal site of resection is also relevant when SSI characteristics are considered. First, our results showed that LCS and RS were associated with a weighty incidence of organ/space infections and that RCS patients developed only incisional infections. The most recent literature is lacking of results about this topic [7, 13, 23]. Considering that organ/space infections are associated with increased perioperative mortality and longer duration of hospital stay [23], in LCS and RS patients a more aggressive diagnostic–therapeutic approach could be suggested in case of signs of abdominal infection.

The second appealing result concerns the importance of post-discharge surveillance with attention to the site of colorectal resection. Post-discharge SSIs can represent nearly 60% of all SSIs [24–26]; however, few studies have specifically analyzed post-discharge SSIs in colorectal surgery, with rates ranging from 1.8% to 41.4% [26–28]. In our study, the median SSI onset was the seventh postoperative day, and the overall post-discharge SSI rate was 7.5%. Our low post-discharge SSI rate can be explained by the fact that the median postoperative hospital stay was higher than the median SSI onset (11 vs 7 days); consequently, the majority of SSIs occurred during the hospital stay. It is indicative that post-discharge SSIs were 25% in RCS, 5.3% in LCS and 0% in RS. These data confirm the usefulness of post-discharge SSI surveillance, expressly for RCS patients and for those patients discharged earlier than the seventh postoperative day.

The distribution of the patients according to three colorectal segments was furthermore effective when SSI risk factors were taken into consideration. The univariate analysis demonstrated that RCS, LCS, and RS patients were associated with different factors involved in the development of a postoperative SSI. The most critical group for SSI occurrence was the LCS group and multivariate analysis confirmed an increased SSI risk for the group formed by LCS and RS patients compared to RCS group, also when a correction for the parameter “multiple comorbidities” was applied.

Most of the analyzed risk factors are already known to be associated with SSI [7, 8, 13, 23, 29–31]. Anyhow, in our study we found two novel SSI predictors, the presence of multiple comorbidities and the need for postoperative intensive care. The parameter “multiple comorbidities” resulted to be a better predictor of SSI than ASA score itself; patients with more than one comorbidity and needing postoperative intensive care probably have an impaired immune response that leads to an increased risk of postoperative infections.

Differently from previous studies [7, 13], we analyzed both elective and urgent surgical operations. An urgent operation is often required in colorectal surgery and the exclusion of this kind of operations could lead to a misleading low SSI incidence. In our study, more than 10% of the patients underwent urgent surgical operation, and the urgent setting was found to be a predictor of SSI in LCS patients. The similar SSI incidence found between colon patients (RCS and LCS) and RS patients, in contrast with the higher SSI incidence in RS patients reported in literature, could probably be explained by the inclusion of urgent surgical procedures that were instead excluded in the previous cited studies [7].

Because of the single-center nature of our study, we could restrain interhospital variations and differences of environmental factors such as operating room discipline and timing of antibiotic prophylaxis; however, some limitations of our study should be stressed. First, we did not analyze other factors that may influence SSI development such as smoking history [32], arterial hypoxiemia [33], and intraoperative hypotension or hypothermia [8, 34]. Second, if our reported SSI rate could be considered low and accounted as a pointer of good surgical quality, regrettably it also limited the power of our study. Expressly, the small number of infected patients resulted to be inadequate to test differences between inpatient SSI risk factors from post-discharge SSI risk factors and to identify differences in causative pathogens of SSIs among the three groups of patients. Thus, our results should be regarded as useful indicators for an SSI surveillance program, but it is binding to verify them in larger groups of patients.

In conclusion, the classification of colorectal surgery into three groups (RCS, LCS, and RS) seems to be useful for an SSI surveillance program because SSI incidence and SSI risk factors resulted to be different among the three groups. This is the first European report that analyzes SSIs in colorectal surgery according to the site of resection. LCS and RS patients, in comparison with RCS patients, have a higher incidence of postoperative SSI and higher rate of organ/space infections. On the contrary, RCS patients show a trend for higher incidence of post-discharge infections.

Therefore, different schemes of antibiotic prophylaxis and different programs of SSI surveillance could be applied for each of the three colorectal groups of patients. An SSI surveillance program based on our proposed tripartition of colorectal surgery could probably lead to an improved quality of work and to a reduction of SSI incidence and SSI-related costs.

Competing interests The authors declare that they have no competing interests.

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