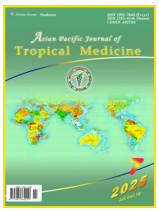

Original Article

Asian Pacific Journal of Tropical Medicine

apjtm.org

doi: 10.4103/apjtm.apjtm_148_25

Surgical site infections following colectomy and associate factors: A cross-sectional study

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ABSTRACT

Objective: To determine the surgical site infection (SSI) rate and related factors in patients undergoing colectomy at the University Medical Center Ho Chi Minh City.

Methods: A cross-sectional study was conducted on 298 patients, aged 18 years or older, who underwent colectomy at the University Medical Center Ho Chi Minh City from January to October 2023. Demographic, general characteristics, and surgical characteristics data were collected from medical records using a structured questionnaire. SSIs were diagnosed within 30 days after surgery based on CDC criteria. Multivariate logistic regression analysis was used to identify factors influencing infection rates, with significance set at $P<0.05$.

Results: A total of 298 patients underwent colectomy, with a median age of 64 years, 54.4% of them were male, and 47.3% had a normal BMI. The SSI rate was 12.1% and *Klebsiella pneumoniae* was the most frequent pathogen. Key characteristics of SSI included abscess formation (83.3%) and the presence of pus or exudate (100%). The risk factors for SSI included preoperative hospital stay (*OR* 1.13, 95% *CI* 1.03-1.22; $P=0.008$), surgical approach (*OR* 0.32, 95% *CI* 0.14-0.76; $P=0.01$), and surgical incision classified as infected (*OR* 3.21, 95% *CI* 1.22-8.45; $P=0.018$).

Conclusions: SSI after colectomy is relatively common. Patient health status and surgery-related factors, which independently influence the 30-day risk of SSI, should be carefully considered before surgery.

KEYWORDS: Surgical site infection; Colectomy; Risk factor; Pathogens

1. Introduction

Surgical site infection remains a major challenge in infection control in hospitals in Vietnam, and is also a burden on the

Summary

Question: What is the surgical site infection rate after colectomy? What factors drive this infection rate?

Findings: In a cross-sectional study of 298 eligible colectomy patients, the surgical site infection rate was 12.1%, with *Klebsiella pneumoniae* as the predominant pathogen. Significant risk factors included prolonged preoperative stays, open surgical approach, and wound contamination level.

Meaning: Surgical site infection after colectomy poses a significant challenge, and targeting controllable risk factors like preoperative stay and surgical approach, while understanding uncontrollable factors such as wound classification, can effectively reduce infection rates and enhance patient care.

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How to cite this article: Phuong TND, Minh QL, Hoang HH, Truong NPT, Minh TH. Surgical site infections following colectomy and associate factors: A cross-sectional study. Asian Pac J Trop Med 2025; 18(7): 323-333.

Article history: Received 18 March 2025 Revision 10 July 2025
Accepted 11 July 2025 Available online 26 July 2025

global health system. In recent years, SSI has been one of the most common postoperative complications and is increasing in developing countries, with an infection rate of 11.8% per 100 surgeries[1], leading to unplanned readmissions of up to 25.8% and causing a 2 to 11 times higher risk of death than uninfected patients[2,3].

The rate of SSI in digestive organ surgery ranges from 10%-25%, depending on the level of contamination, much higher than infections in other locations[4]. In particular, colectomy is a group of surgeries that mainly fall into the categories of clean-contaminated and dirty surgery[5]. Therefore, manipulating the digestive organs can facilitate pathogens to invade and cause infections more easily. In 2014, the Centers for Disease Control and Prevention (CDC) surveyed the rate of hospital-acquired infections in 10 states in the United States. In 22% of SSI cases, the number of infections related to colorectal surgery accounted for 14.5%, ranking first among infected surgical organs[6]. In Vietnam, SSI after colectomy has not been studied clearly and specifically, most studies only evaluate SSI in digestive organs in general. However, in recent years, the number of patients with colon-related diseases requiring surgery has increased dramatically, especially colon cancer, with the number of patients ranking 5th in 2020[7]. Several studies have shown that SSI following colectomy is the leading complication, accounting for 12.7%, and can be up to 33% after monitoring at 7 major hospitals across the country[8,9].

Although there are many risk factors from the patient, environment, surgery, and pathogens interacting to increase the risk of SSI. However, factors associated with surgery and factors associated with the patient such as age, comorbidities, nutritional status, smoking, and length of hospital stay have also been found in many previous medical literature[5,10]. The University Medical Center Ho Chi Minh City is one of the country's major surgical centers, with colon surgeries accounting for approximately one-third of all digestive procedures annually[11]. Given this high volume, greater attention should be directed toward controlling postoperative SSI.

Therefore, this study was conducted to determine the incidence of SSI in patients undergoing colectomy and to identify associated risk factors. Surgical site infection in this study was defined according to CDC criteria as an infection occurring within 30 days after colectomy[12]. It includes superficial incisional SSI involving the skin or subcutaneous tissue, deep incisional SSI affecting the fascia and muscle layers, and organ or space SSI involving internal organs or anatomical spaces manipulated during surgery. The findings may support the implementation of effective preventive strategies and help reduce the burden on infection control programs.

2. Methods

2.1. Study design and participants

A cross-sectional study was conducted on patients undergoing colectomy at the University Medical Center Ho Chi Minh City. Eligible participants for this study included individuals aged 18 years or older at the time of hospital admission who had undergone colectomy at the University Medical Center Ho Chi Minh City from January 2023 to October 2023. Exclusion criteria comprised patients who underwent a secondary procedure on the same incision within the monitoring period of the initial colectomy, those who had a colectomy performed on the same incision during the monitoring period of previous surgery, patients who underwent colectomy concurrently with another type of surgery, and patients with incomplete demographic or surgical data.

2.2. Sample size and sampling

The sample size was calculated using the formula for estimating a population proportion:

$$n=\frac{Z^2_{(1-\frac{\alpha}{2})}\,p(1-p)}{d^2}$$

To the best of our knowledge, no specific studies have been found in Vietnam on the rate of SSI in patients undergoing colectomy for colon-related diseases in general. Therefore, this study used a value of p=0.218, representing the SSI rate after colectomy in patients over 18 years old, based on a study conducted in Greece from 2019 to 2021 with an estimated margin of error of d=0.05 and a 95% confidence interval (α=0.05)[13]. The study did not account for sample loss, as patients without complete demographic information or who did not undergo colectomy were excluded. Thus, the minimum required sample size was 262 patients.

From January 2023 to October 2023, there were 339 patients who underwent colectomy, while the minimum initial sample size required was 262. Therefore, to achieve the most accurate results, the study applied a method of collecting all data that met the inclusion and exclusion criteria for colectomy patients during this period.

2.3. Data collection and tools

The study used a structured questionnaire to collect data from patients' medical records. The study was conducted as a cross-sectional analysis, sampling patients who met the inclusion and exclusion criteria between January 2023 and October 2023. Data on patients' general characteristics were collected from the first day of hospital admission until the beginning of the 30-day follow-up after colectomy.

2.4. Variables

The study collected information on general characteristics, including age, sex, date of admission, date of surgery, body mass index (BMI), comorbidities, number of comorbidities, and the American Society of Anesthesiologists (ASA) physical status classification. The ASA score is a standardized system used to assess a patient's preoperative health status by categorizing their physiological condition and comorbidity burden. It ranges from ASA Ⅰ (a completely healthy patient) to ASA Ⅴ (a critically ill patient unlikely to survive without surgery), helping to estimate surgical risk and guide perioperative management[14].

In addition, the study assessed patients' comorbidities using the Charlson Comorbidity Index (CCI), a validated scoring system designed to predict long-term mortality risk based on the presence and severity of underlying conditions. Although originally developed to estimate mortality risk in chronic diseases, CCI is also a useful tool for estimating the cumulative impact of comorbidities on the risk of acute hospital-acquired infections[15]. This index assigns weighted scores to specific chronic conditions, including cardiovascular disease, diabetes, cancer, and chronic kidney disease, with higher scores indicating a greater disease burden and an increased risk of postoperative complications, including hospital-acquired infections[16].

Key surgical characteristics, such as operative time, type and approach of surgery, wound classification, prophylactic antibiotic use, and postoperative drainage, were documented. The degree of wound contamination at the time of surgery is classified into four categories: clean (surgery without infection or inflammation, not involving organs containing bacteria such as the respiratory, digestive, genital, or urinary tracts, or surgery following closed trauma), clean-contaminated (surgery involving organs containing bacteria but performed under controlled conditions without unusual contamination), contaminated (surgery on open wounds, breaches of aseptic technique, major gastrointestinal perforations, or in the presence of uncontrolled infection), and dirty (wounds with obvious infection or heavy contamination from soil, feces, or foreign bodies). For colectomy procedures, the wound classification ranges from clean-contaminated to dirty, depending on the level of infection and the patient's clinical condition at the time of surgery[12].

For patients who developed SSI, data were collected on infection occurrence, clinical features, bacterial culture results, identified pathogens, and SSI classification, providing insights into infection patterns and risk factors.

In this study, SSI following colectomy was defined according to the CDC criteria as an infection occurring within 30 days after the operation. Surgical site infections were classified into three categories based on the anatomical location of the infection[12]:

-Superficial incisional SSI: Infection involving only the skin or subcutaneous tissue at the surgical incision site. Diagnostic criteria include signs such as localized redness, swelling, heat, pain, purulent drainage, or identification of pathogens from wound cultures.

-Deep incisional SSI: Infection involving the deeper soft tissues, including the fascia and muscle layers of the incision. It is characterized by purulent drainage, spontaneous wound dehiscence, signs of systemic infection such as fever (>38 ℃), or evidence of abscess formation on clinical or radiological examination.

-Organ/space SSI: Infection involving any internal organ or anatomical space opened or manipulated during colon surgery, such as the abdominal cavity. Diagnostic indicators include purulent discharge from a drain placed in the organ/space, positive culture results from fluid or tissue in the organ/space, or radiological/histopathological confirmation of an abscess.

Following colectomy, patients presenting with clinical signs or symptoms that met the CDC-defined criteria for SSI were categorized into one of three types: superficial incisional, deep incisional, or organ/space SSI.

According to the CDC's definition, a surgical site infection is an infection that occurs at the site of colon surgery within 30 days from the date of surgery. A patient is considered to have the SSI if they meet the diagnostic criteria for the SSI classification, which includes superficial incisional SSI, deep incisional SSI, and organ/space SSI[12]. The superficial incisional SSI is an infection that occurs in the skin or subcutaneous tissue of the surgical incision. These infections develop within 30 days post-surgery, and the criteria include at least one sign of infection (localized swelling, heat, redness, or pain), organisms identified from a specimen from the superficial incision or purulent discharge from the surgical site, or a diagnosis of superficial SSI made by a physician. In the deep SSI, the infection occurs in the fascia or muscle layers of the incision and the patient has at least one of the following signs: purulent drainage from the deep incision; spontaneous wound dehiscence or surgical reopening by the surgeon, organisms identified from deep soft tissue specimens, and at least one sign of infection (fever >38 ℃, localized pain); or evidence of an abscess through direct examination exam, imaging test, or histopathology exam. The organ/space SSI involves any part of the anatomy in organs or spaces other than the incision that was opened during the surgery. The patient must have at least one of the following signs: purulent drainage from a drain placed into the organ/space; organisms isolated from a culture of fluid or tissue in the organ/space; or evidence of an abscess related to the organ/space.

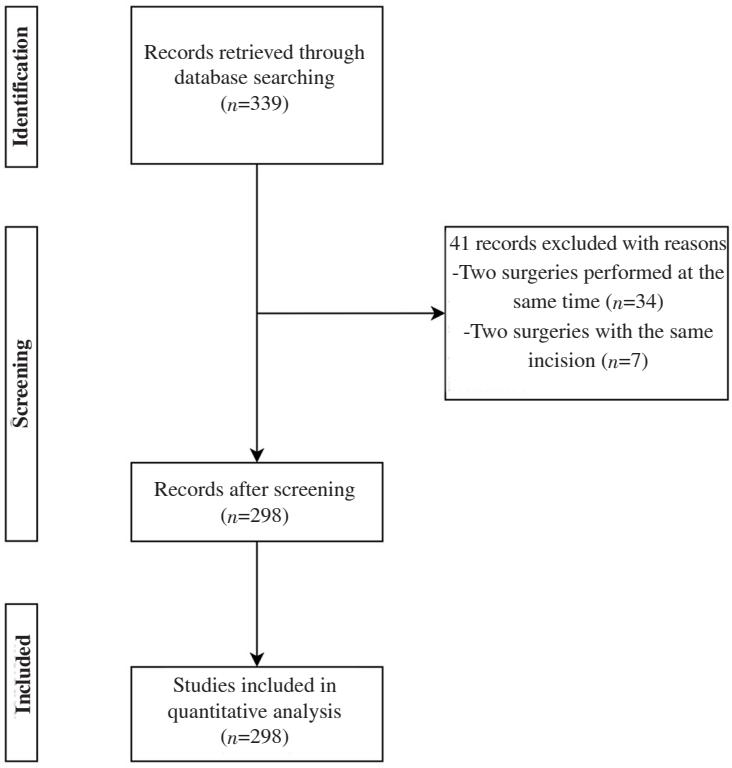

Figure 1. Flowchart of the study.

The study utilized the National Nosocomial Infections Surveillance (NNIS) risk index, a tool that has been incorporated into the Ministry of Health's surgical site infection surveillance guidelines, to assess the risk of SSIs following colectomy[10]. This index ranges from 0 to 3 and is determined by evaluating three factors, each contributing 1 point if it meets the corresponding threshold value: (1) ASA score $\geqslant$3, indicating that the patient has severe underlying conditions or poor health; (2) wound classification, with contaminated and dirty wounds carrying a higher risk of infection; (3) surgery duration exceeding 60 minutes. A higher NNIS score reflects a greater risk of infection. This study utilizes this index to assess the prediction of infection risk for colectomy, a type of surgery with a high infection risk due to its involvement with the digestive system.

2.5. Controlling bias

To control bias in the selection process of study participants, a list of patients aged 18 years or older was made based on patient codes (according to hospital codes) and had undergone colectomy to avoid duplication and comply with the criteria set out in the selection process of study subjects.

In addition, the information collection form is designed, concisely, and easily understood. Variables need to be defined specifically and accurately. Before the survey, the investigators are thoroughly trained on the content of the form to avoid information errors.

2.6. Statistical methods

After checking the information filled in on the form, the data was entered and cleaned using Microsoft Excel 2024 software. Then, the data was analyzed using Stata 17.0 software.

The collected data were summarized using appropriate descriptive statistics. Qualitative variables were described using frequencies and percentages. For quantitative variables, normally distributed data were presented as means and standard deviations, while skewed distributions were summarized using medians and interquartile ranges.

The *Chi*-square test and univariate logistic regression were used to assess the association between each factor and SSI. When more than 20% of the cells had expected counts less than 5, Fisher's exact test was applied instead of the *Chi*-square test. Results were presented as odds ratios (*OR*) with 95% confidence intervals (95% *CI*). An association was considered statistically significant when $P<0.05$ and the 95% *CI* of the *OR* did not include the value 1. Variables with $P<0.2$ in the univariate analysis were included in the multivariate logistic regression model to control for potential confounding factors and to identify independent factors associated with SSI.

Table 1. General characteristics of patients undergoing colectomy (*n*=298).

Characteristics	SSIs (*n*=36)	Non-SSIs (*n*=262)	Total (*n*=298)
Age, median (IQR), years	67 (58-74)	64 (52-71)	64 (53-71)
Sex			
Male	21 (58.3)	141 (53.8)	162 (54.4)
Female	15 (41.7)	121 (46.2)	136 (45.6)
BMI*			
Underweight	4 (11.1)	34 (13.0)	38 (12.8)
Normal weight	17 (47.2)	124 (42.3)	141 (47.3)
Overweight-Obesity	15 (41.7)	104 (39.7)	119 (39.9)
Comorbidities			
No	9 (25.0)	58 (22.1)	67 (22.5)
Yes	27 (75.0)	204 (77.9)	231 (77.5)
Number of comorbidities (*n*=231), median (IQR)	1 (1-2)	1 (1-2)	1 (1-2)
Cardiovascular disease	21 (58.3)	153 (58.4)	174 (58.4)
Diabetes	11 (30.6)	60 (22.9)	71 (23.8)
Neuropathy	6 (16.7)	31 (11.8)	37 (12.4)
Stomach ulcers	3 (8.3)	18 (6.9)	21 (7.1)
Cancer	4 (11.1)	15 (5.7)	19 (6.4)
Chronic kidney disease	4 (11.1)	11 (4.2)	15 (5.0)
Chronic liver disease	2 (5.6)	10 (3.8)	12 (4.0)
Acute respiratory disease	2 (5.6)	9 (3.4)	11 (3.7)
Peripheral vascular disease	4 (11.1)	7 (2.7)	11 (3.7)
COPD	0 (0.0)	8 (3.1)	8 (2.7)
Connective tissue disease	3 (8.3)	3 (1.1)	6 (2.0)
Cushing's syndrome	2 (5.6)	3 (1.1)	5 (1.7)
Thyroid disease	0 (0)	5 (1.9)	5 (1.7)
ASA score			
1 point	4 (11.1)	21 (8.0)	25 (8.4)
2 points	13 (36.1)	112 (42.8)	125 (41.9)
3 points	14 (38.9)	127 (48.5)	141 (47.3)
4 points	5 (13.9)	2 (0.7)	7 (2.4)
CCI score, median (IQR)	3 (2-5)	2 (1-4)	2 (1-4)

Data are expressed as *n* (%) unless indicated. SSI: Surgical site infection. *BMI: Body mass index, with Underweight (<18.5 kg/m²), Normal weight (18.5-24.9 kg/m²), and Overweight-Obesity (≥23 kg/m²); COPD: Chronic obstructive pulmonary disease; ASA: American Society of Anesthesiologists; CCI: Charlson comorbidity index.

2.7. Ethical considerations

The questions in the study are clearly presented, non-discriminatory, non-offensive, and do not infringe upon the personal freedoms of participants. All personal information and collected data are encrypted to ensure confidentiality, used exclusively for the scientific research purposes of this study, and absolutely not for any other purpose. The study results are utilized strictly in line with the established objectives.

The study protocol has been approved in terms of research ethics from the Ethical Council in Biomedical Research of the University of Medicine and Pharmacy at Ho Chi Minh City, reference number: 113/HĐĐĐ-DHYD, signed on January 16, 2024. Permission to access and collect data from medical records was granted by the University Medical Center Ho Chi Minh City, and the requirement for written informed consent was waived by the Ethics Committee. All procedures in this study adhered to the ethical principles of the Declaration of Helsinki.

3. Results

The study was conducted on 339 patients who underwent colectomy between January 2023 and October 2023. However, the study enrolled 298 patients who met the criteria for inclusion in the analysis, with a response rate of 88%. Of those excluded, 34 patients had colectomy and another type of surgery at the same time, and 7 patients had colectomy in the same incision as another type of surgery during the surveillance period, so they were excluded (Figure 1).

3.1. General characteristics of the patient

The characteristics of the participants are described in Table 1 as follows:

Patients in the SSI group were older than those without SSI, with a median age of 67 years (IQR: 58-74) *versus* 64 years (IQR: 52-

Table 2. Surgical characteristics of patients undergoing colectomy (*n*=298).

Characteristics	SSIs (*n*=36)	Non-SSIs (*n*=262)	Total (*n*=298)
Preoperative hospital stay, median (IQR), day	4 (2-8)	4 (2-6)	4 (2-6)
Surgery time, median (IQR), minutes	157 (125-190)	160 (138-198)	155 (125-190)
Type of surgery, *n* (%)			
Emergency	11 (30.6)	50 (19.1)	61 (20.5)
Elective	25 (69.4)	212 (80.9)	237 (79.5)
Surgical approach, *n* (%)			
Open	18 (50.0)	54 (20.6)	72 (24.2)
Laparoscopy	18 (50.0)	208 (79.4)	226 (75.8)
Prophylactic antibiotics, *n* (%)			
Yes	20 (55.6)	197 (75.2)	81 (27.2)
No	16 (44.4)	65 (24.8)	217 (72.8)
Wound classification, *n* (%)			
Clean-Contaminated	23 (63.9)	236 (90.1)	259 (86.9)
Contaminated	10 (27.8)	23 (8.8)	33 (11.1)
Dirty	3 (8.3)	3 (1.1)	6 (2.0)
Postoperative drainage, *n* (%)			
Yes	4 (11.1)	39 (14.9)	43 (14.4)
No	32 (88.9)	223 (85.1)	255 (85.6)
NNIS index, *n* (%)			
1 point	13 (36.1)	122 (46.6)	135 (45.3)
2 points	14 (38.9)	125 (47.7)	139 (46.6)
3 points	9 (25.0)	15 (5.7)	24 (8.1)

SSI: Surgical site infection. NNIS: National Nosocomial Infections Surveillance.

71). A male predominance was observed in both groups, higher in the SSI cohort (58.3% *vs*. 53.8%). Nutritional assessment revealed a greater proportion of overweight or obese patients among those who developed SSI compared to those who did not.

Patients undergoing colectomy mostly had chronic comorbidities, with the median number of comorbid conditions in both groups being one. The most common comorbidities included cardiovascular disease, diabetes mellitus, and neurological disorders. Notably, the prevalence of diabetes and neurological conditions was markedly higher in the SSI group compared to the non-SSI group. Some rare conditions, such as connective tissue diseases, Cushing's syndrome, and thyroid disorders, were almost exclusively observed in the non-SSI group.

Regarding overall operative risk, most patients in both cohorts were classified as ASA grade 3. However, ASA grade 4 was considerably more frequent among patients with SSI compared to those without SSI (13.9% *vs*. 0.7%). Likewise, the median CCI score was higher for the SSI group at 3 points (IQR: 2-5) compared to 2 points (IQR: 1-4) in the non-SSI group (Table 1).

3.2. Surgical characteristics

The results in Table 2 indicate that the median preoperative hospital stay was identical for both groups at 4 days, with interquartile ranges (IQR) of 2-8 days for the SSI group and 2-6 days for the non-SSI group. Additionally, the median surgery duration was almost comparable between the two groups, with 157 minutes (IQR: 125-190 minutes) for the SSI group and 160 minutes (IQR: 138-198 minutes) for the non-SSI group.

The study also revealed that, in the SSI group, the proportion of emergency surgeries and open surgical approaches was significantly higher compared to the non-SSI group. Additionally, the rate of prophylactic antibiotic use before surgery in this group was 55.6%, which was lower than that in the non-SSI group. Furthermore, wound classification showed that the SSI group had a markedly higher proportion of wounds categorized as dirty.

Postoperative drainage placement was relatively uncommon and did not differ significantly between the two groups. Moreover, the proportion of patients with an SSI risk assessment score of 3 tended to be higher in the SSI group (Table 2).

3.3. Surgical site infection following colectomy

In Table 3, the study noted that 12.1% of patients had SSI after colon surgery, of which superficial infections were the majority. Through the survey, the characteristics to identify SSI such as swelling, heat, redness, pain more than normal, and pus or secretion appeared quite commonly. More than half of the cases used the type of test specimen as surgical wound fluid and the main bacteria found was *Klebsiella pneumoniae* (Table 3).

Table 3. Surgical site infection in patients undergoing colectomy (*n*=298).

Characteristics	*n* (%)
Surgical site infection (*n*=298)	
Yes	36 (12.1)
No	262 (87.9)
Type of infection (*n*=36)	
Superficial incisional SSI	14 (38.8)
Deep incisional SSI	11 (30.6)
Organs/space SSI	11 (30.6)
Symptoms (*n*=36)	
Swelling, heat, redness, pain at the surgical site	36 (100)
Pus/fluid from the surgical wound or drainage tube	30 (83.3)
Abscess found by imaging/re-examination/re-operation	23 (63.9)
The incision opens spontaneously or opens as indicated	21 (58.3)
Microorganisms from surgical fluid/tissue	14 (38.9)
Fever > 38 ℃	9 (25.0)
Specimens tested positive (*n*=14)	
Wound fluid	8 (57.2)
Pus	3 (21.4)
Abdominal fluid	3 (21.4)
Bacteria (*n*=13)	
Klebsiella pneumoniae	8 (61.5)
Escherichia coli	5 (38.5)
Enterococcus spp.	2 (15.4)
Acinetobacter baumannii	2 (15.4)
Pseudomonas aeruginosa	2 (15.4)
Enterobacter spp.	1 (7.7)
Bacteroides fragilis	1 (7.7)
Staphylococcus aureus	1 (7.7)
Streptococcus spp.	1 (7.7)
Morganella morganii	1 (7.7)
Staphylococcus haemolyticus	1 (7.7)

SSI: Surgical site infection.

3.4. Factors associated with surgical site infection following colectomy

In the univariate analysis, several factors were found to be associated with the incidence of SSIs following colectomy. To minimize potential confounding effects, a multivariate logistic regression analysis was conducted. Variables with a *P*-value <0.2 in the univariate analysis were included in the multivariate model. These variables included: the number of comorbidities; specific comorbidities such as peripheral vascular disease, connective tissue disease, chronic kidney disease, and Cushing's syndrome; ASA score; preoperative hospital stay; type of surgery (emergency or elective); surgical approach (open or laparoscopic); prophylactic antibiotic use; wound classification; and NNIS risk index.

The results of the model showed that preoperative hospital stay, surgical approach, and wound classification were significantly associated with the risk of SSIs.

Specifically, the duration of preoperative hospital stay was significantly associated with an increased risk of SSI (*P*=0.008), with each additional day corresponding to a 1.13-fold increase in the odds of developing an SSI (*OR* 1.13, 95% *CI* 1.03-1.22). Patients undergoing laparoscopic surgery had approximately a 68% lower risk of SSIs compared to those undergoing open surgery (*OR* 0.32, 95% *CI* 0.14-0.76; *P*=0.01). Compared to patients with clean or clean-contaminated wounds, those with contaminated wounds had a 3.21 times higher risk of developing SSIs (*OR* 3.21, 95% *CI* 1.22-8.45; *P*=0.018). Meanwhile, patients with dirty wounds also showed a tendency toward increased risk of SSIs (*OR* 4.70), though this association did not reach statistical significance (95% *CI* 0.75-29.45; *P*=0.098) (Table 4).

4. Discussion

Until now, SSI remains one of the common complications after colectomy and significantly affects the health and psychology of the patient[17]. The study results recorded 12.1% of surgical site infections in patients undergoing colectomy. This rate is 8.9% higher than the study by Tran Manh Hung[18], Nguyen Minh Thao 10%[19], and lower than other studies in the world[13,20,21]. This difference depends on many factors such as environmental disinfection conditions, equipment, and aseptic procedures during surgery, especially the SSI monitoring system at each hospital. In addition, this study was conducted at a certain time in 2023 and surveyed all patients who had colectomy while other studies were conducted over a longer period and only on people with colorectal cancer who needed surgery, so there is the above difference. The rate of SSI after colectomy is still quite high and needs more attention, especially in developing countries where this number may be even higher.

Among patients with SSI, superficial infections accounted for 38.8%. In addition, the most common symptoms of infection in patients with SSI in this study were pus discharge, pain, swelling, and redness. These symptoms will depend on the characteristics of the wound and the immune system of each person; the body will show different signs of infection and this is also one of the factors for clinicians to assess the level of infection. Paying attention to these signs contributes to early detection of SSI, providing timely treatment, and preventing the spread of infection.

Among patients with SSI, only 38.9% underwent microbial culture, as some cases had previously received antibiotic treatment, leading to inaccurate culture results and impacting diagnostic effectiveness. In the cultured samples, the primary bacteria identified were

Table 4. Results of univariate and multivariate logistic regression analyses for factors associated with surgical site infection after colectomy (n=298).

Characteristics	Univariate analysis		Multivariate analysis	
	OR (95% *CI*)	*P*-value	*OR* (95% *CI*)	*P*-value
Age	1.01 (0.99-1.04)	0.335[#]		
Sex		0.609[^]		
Male	1			
Female	0.83 (0.41-1.69)			
BMI				
Underweight	1			
Normal weight	1.16 (0.37-3.69)	0.795		
Overweight-Obesity	1.22 (0.38-3.95)	0.733		
Comorbidities		0.702[^]		
No	1			
Yes	0.85 (0.38-1.92)			
Number of comorbidities	1.38 (1.06-1.80)	0.019[#]	1.03 (0.61-1.77)	0.900
Comorbidities				
Cardiovascular disease	0.99 (0.49-2.02)	0.994[^]		
Diabetes	1.48 (0.69-3.18)	0.323[^]		
Neuropathy	1.49 (0.57-3.87)	0.427[&]		
COPD	Unknown	0.601[&]		
Peripheral vascular disease	4.55 (1.26-16.41)	0.033[&]	0.67 (0.09-4.87)	0.732
Connective tissue disease	7.85 (1.52-40.49)	0.018[&]	0.80 (0.22-2.92)	0.173
Stomach ulcers	1.23 (0.34-4.41)	0.753[&]		
Chronic liver disease	1.48 (0.31-7.05)	0.635[&]		
Chronic kidney disease	2.85 (0.86-9.49)	0.113[&]		
Cancer	2.06 (0.64-6.58)	0.251[&]		
Thyroid disease	Unknown	1.003[&]		
Cushing's syndrome	5.08 (0.82-21.49)	0.109[&]		
Acute respiratory disease	1.65 (0.34-7.98)	0.551[&]		
ASA score				
1 point	1		1	
2 points	0.61 (0.18-2.05)	0.424	0.41 (0.10-1.71)	0.221
3 points	0.58 (0.17-1.93)	0.373	0.23 (0.04-1.32)	0.099
4 points	13.12 (1.85-92.95)	0.010	2.18 (0.14-34.20)	0.570
CCI score	1.21 (1.02-1.42)	0.022[#]	1.11 (0.85-1.46)	0.455
Preoperative hospital stay, day	1.09 (1.00-1.19)	0.048[#]	1.13 (1.03-1.22)	0.008
Surgery time minutes	1.00 (0.99-1.01)	0.552[#]		
Type of surgery		0.126[^]		
Emergency	1			
Elective	0.54 (0.25-1.16)			
Surgical approach		<0.001[^]		0.010
Open	1		1	
Laparoscopy	0.26 (0.13-0.53)		0.32 (0.14-0.76)	
Prophylactic antibiotics		0.017[^]		0.732
No	1		1	
Yes	0.41 (0.20-0.84)		0.80 (0.22-2.92)	
Wound classification				
Clean-Contaminated	1		1	
Contaminated	4.46 (1.89-10.51)	0.001	3.21 (1.22-8.45)	0.018
Dirty	10.26 (1.96-53.78)	0.006	4.70 (0.75-29.45)	0.098
Postoperative drainage		0.533[^]		
No	1			
Yes	1.40 (0.47-4.18)			
NNIS index				
1 point	1		1	
2 points	1.05 (0.47-2.32)	0.902	1.10 (0.41-2.96)	0.843
3 points	5.63 (2.06-15.38)	0.001	-	-

Multivariable analysis was adjusted for the following factors: Number of comorbidities, Peripheral vascular disease, Connective tissue disease, Chronic kidney disease, Cushing's syndrome, ASA score, CCI score, Preoperative hospital stay, Type of surgery, Surgical approach, Prophylactic antibiotics, Wound classification, and NNIS index. [^]*Chi*-square test; [&]Fisher exact test; [#]Logistic regression. BMI: Body mass index; COPD: Chronic obstructive pulmonary disease; CCI: Charlson comorbidity index; ASA: American Society of Anesthesiologists.

Klebsiella pneumoniae (61.5%) and *Escherichia coli* (38.5%), with wound exudate specimens accounting for the highest proportion (57.2%). These are pathogens that often reside in the digestive tract and are found most in CDC reports as well as across countries[22,23].

Regarding surgical characteristics, patients undergoing laparoscopic surgery have a lower risk of SSI compared to those undergoing open surgery. An analysis by Rahim Aimaq and colleagues using data from the American College of Surgeons National Surgical Quality Improvement Program also showed that laparoscopic colectomy was associated with a significantly lower SSI rate (9.4%) compared to open colectomy (15.7%)[24]. When performing laparoscopic surgery, the incision will be small, the contact between the surgeon's hands and the incision is less, and the surgery time is also much shorter than with open surgery. In open surgery, the wound is long, the contact between the technician's hands and the incision is also more, more instruments are used, and the surgery time is much longer than with laparoscopic surgery, so the risk of SSI will be much higher[25].

The study also identified an association between preoperative hospital stay and the classification of surgery. Specifically, the longer the hospital stay before surgery, the higher the risk of infection due to prolonged exposure to the healthcare environment and diagnostic procedures, which facilitate bacterial invasion and growth. The study by Yanet Pedroso-Fernandez and colleagues also demonstrated that a prolonged preoperative hospital stay is an independent predictor of SSI[26]. In addition, classifying wounds as infected or dirty significantly increases the risk of SSI. This is consistent with a study conducted in China, which found that the SSI rate in patients with clean-contaminated wounds was significantly lower than in those with infected or dirty wounds (6.0% *vs*. 25.9%, $P<0.001$)[27]. This result is consistent with the Ministry of Health's guidelines on SSI prevention[5], the risk of SSI increases with the type of surgery. Clean surgery has a risk of SSI from 1%-5%; clean-contaminated is from 5%-10%; contaminated is 10%-15% and dirty is >25%.

The study showed that there was no statistically significant relationship between sex and the rate of SSI. This could be explained by the fact that SSI can occur in any sex, regardless of the individual characteristics of the patient. However, there is still a need for research topics with a larger number of surgical patients to confirm the influence of sex on SSI. The study also found no relationship between age, comorbidities, and nutritional status of patients before surgery and the rate of SSI.

While previous studies have reported an association between SSI and both the ASA physical status classification, the CCI and NNIS index the multivariable analysis in this study did not demonstrate such findings. The National Healthcare Safety Network of the CDC also includes an ASA score $\geqslant$3 as a component in its risk-adjusted models for predicting SSI[28]. Therefore, although these variables did not show statistical significance in the current model, the evaluation and management of patients' overall physical condition and the severity of comorbidities prior to surgery remain important components in strategies for preventing SSIs.

Although the rate of SSI was higher in the emergency surgery group compared to the elective group in the descriptive analysis (30.9% *vs*. 69.4%), no statistically significant association was found between the type of surgery and SSI (P=0.126). This result is consistent with the findings of Hennessey[20]. It also reflects the real-world situation, where the risk of SSI in emergency surgeries is higher due to the inability to prepare patients as thoroughly as in scheduled surgeries. At the University Medical Center Ho Chi Minh City, hundreds of surgeries are performed each day[29], and the high rate of SSI among emergency surgery patients is inevitable. Several factors may contribute to this, such as suboptimal environmental cleaning between surgeries, inadequate preoperative preparation by nurses, and less careful administration of prophylactic antibiotics in emergency cases compared to elective procedures. All of these may increase the risk of SSI in patients undergoing emergency surgery. Additionally, the study did not find any association between surgical site infection and factors such as surgery duration, prophylactic antibiotic use, or the presence of postoperative drainage.

The results of this study still have some limitations. First, although the study achieved the minimum sample size, it was only conducted within a certain scope. Therefore, the results will not be generalized to all patients undergoing colectomy in other healthcare facilities in Ho Chi Minh City. Second, the study has not fully assessed factors associated with the surgical environment or factors associated with patient habits. Therefore, it is not possible to comprehensively assess the factors that are associated with SSI.

Conflict of interest statement

No potential conflict of interest relevant to this article was reported.

Acknowledgments

We would like to thank the leaders of the University Medical Center Ho Chi Minh City and the leaders of the Department of Infection Control for approving and facilitating this study.

Funding

This research was funded by the University of Medicine and Pharmacy at Ho Chi Minh City under contract number 136/2024/HĐ-ĐHYD, dated 17/04/2024.

Authors' contributions

NDPT, HMT and LMQ contributed to the conception and design of the study. NDPT and HHH were involved in data acquisition. The data analysis and interpretation were conducted by NDPT, LMQ, HHH, PTTN. NDPT searched the literature and wrote the manuscript. NDPT, HMT, LMQ, PTTN edited and revised manuscript according to journal's instructions. All the authors approved the final version of the manuscript.

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Publisher's note

Edited by Pan Y, Lei Y, Zhang Q