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ORIGINAL RESEARCH

Risk factors for surgical site infection in a teaching hospital: a prospective study of 1,138 patients

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Background: The purpose of this study was to identify risk factors for surgical site infection (SSI) in a teaching hospital.

Methods: A prospective study was initiated to investigate risk factors for SSI at a university-affiliated tertiary care center from July 2013 to December 2014. The chi-square test for categorical variables was used to determine the significance of association, whereas the multivariate logistic regression model was used to examine independent risk factors for SSI.

Results: A total of 1,138 patients met the inclusion criteria, in whom 36 cases of infection occurred during the hospitalization period and two cases occurred after discharge. Univariate analysis showed that SSI was associated with the type of operation, wound classification, volume of blood loss, blood transfusion, American Society of Anesthesiology score before surgery, risk index, duration of surgery, diabetes, cancer, gastrointestinal catheter, urinary catheter, postoperative drainage, and preprocedural white blood cell count. Multivariate analysis identified six independent parameters correlating with the occurrence of SSI: diabetes (odds ratio [OR] 6.400; 95% confidence interval [CI] 2.582–15.866; P=0.000); cancer (OR 2.427; 95% CI 1.028–5.732; P=0.043); preprocedural white blood cell count more than 10×10^9/L (OR 6.988; CI 3.165–15.425; P=0.000); wound classification (clean contaminated [OR: 7.893; CI: 2.244–27.762; P=0.001]; contaminated [OR: 7.031; CI: 1.652–29.922; P=0.008]; dirty [OR: 48.778; CI: 5.418–439.164; P=0.001]); operative duration more than 120 minutes (OR 4.289; CI 1.773–10.378; P=0.001); and postoperative drainage (OR 3.957; CI 1.422–11.008; P=0.008).

Conclusion: Our data suggest that all these risk factors could be regarded as potential indicators of SSI and that relevant preventive measures should be taken to reduce SSI and improve patient outcomes.

Keywords: wound classification, surgical site infection, nosocomial infection, risk factors

Introduction

The surgery department is a place with a high incidence of nosocomial infection, and accumulating evidence suggests advances have been made in infection control practices,[1,2] including improved operating room ventilation, sterilization methods, barriers, surgical techniques, and availability of antimicrobial prophylaxis. However, surgical site infection (SSI) remains a substantial cause of morbidity, prolongs hospitalization, and increases death. SSI rates have been reported to range from less than 1% to more than 10%, and 75% of SSI-associated deaths are directly attributable to SSI.[3] The occurrence of SSI is not only a serious threat to the patient's health and life, but also imposes a substantial economic burden on the patient's family and society.[4–6] Early diagnosis and treatment of infection is essential in the care of surgical patients. Thus, it is urgent that we identify the factors responsible for SSI and, if possible, corresponding measures should be taken to prevent the occurrence of nosocomial infection, alleviate patients' pain, speed their recovery, and reduce their medical expenses.

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Subjects and methods

This study was carried out prospectively at the Department of Infection Control, Zhongda Hospital, which has more than 2,600 beds and is affiliated to Southeast University. The study was approved by the ethics committee of Southeast University.

Study population

A total of 1,138 patients who had surgery at the teaching hospital affiliated to Southeast University from July 2013 to December 2014, were studied prospectively. Patients admitted to the hospital for more than 1 day were included, while outpatients and those who had surgery elsewhere before referral to our hospital were excluded.

Survey method

Based on patient information gathered from the computer network system and from ward rounds in the teaching hospital, system monitoring of SSI was filled in survey forms according to the software of Nosocomial Infection Monitoring Management System developed by Beijing Minke Medical Electronic Technology Research Institute. All patients were followed up from the time of admission until the time of discharge and 30 days postoperatively to inspect the incidence of SSI.[7]

Diagnostic criteria

Patients were evaluated for SSI according to the Nosocomial Infection Diagnostic Criteria published by China's Ministry of Health in 2001.[8]

Risk index calculation

According to the Monitoring Standard of Nosocomial Infection requirements issued by the Ministry of Health, the risk index for each operation in this survey was calculated according to the accumulation points of three risk factors, ie, operative duration, surgical wound classification system, and American Society of Anesthesiology (ASA) score. In our daily work, the risk index for each operation was automatically generated by the Nosocomial Infection Monitoring Management System software using the aforementioned factors.

Statistical analysis

All of the data were checked and analyzed with Statistical Package for the Social Sciences version 19.0 software (SPSS Inc., Chicago, IL, USA). First, descriptive statistics, including count and percentage, were used to describe the demographic characteristics of the subjects. Univariate analysis for association between identified risk factors and SSI was performed using chi-square tests for discrete variables, and $P<0.05$ was accepted as statistically significant. When the P-value was less than 0.05, multivariate logistic regression was performed using the stepwise forward method to identify those factors most significantly associated with risk of infection; the P-value for significance was set at 0.01 and the results are presented with an odds ratio (OR) and a 95% confidence interval (CI).

Study limitation

Either chlorhexidine bathing or normothermia could have contributed to the low prevalence of SSI.

Results

Patient information

Details on 1,138 patients who underwent breast, hernia, esophagus, stomach, appendix, colon, or rectal surgery at a university-affiliated tertiary care center were retrieved from an SSI database. The mean patient age was 54.62 (range 2–92) years; 542 were male and 596 were female.

Incidence and cause of SSI

Our analysis showed that 38 of the 1,138 patients suffered from SSI, giving an incidence of 3.34%. Thirty-six of the SSI cases occurred during hospitalization and two occurred after discharge. The 38 cases comprised 30 superficial incisional infections, six deep incisional infections, and six, two organ/space infections. Twenty bacterial strains were isolated from the infected surgical incision sites, including *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*.

Univariate analysis

The association between potential risk factors and SSI was performed using the chi-square test for discrete variables. Risk factors significantly associated with SSI were diabetes, cancer, wound classification, ASA scores before surgery, preprocedural white blood cell count (WBC), type of surgery, volume of blood loss, blood transfusion, operative duration, risk index, use of a gastrointestinal or urinary catheter, and postoperative drainage. In contrast, risk factors determined not to be significantly associated with SSI were sex, age, skin preparation, use of a trachea cannula, antibiotic prophylaxis, and type of anesthesia ($P>0.05$; Table 1).

Multivariate logistic regression analysis

Based on the results of the chi-square test, six risk factors identified in univariate analysis were analyzed further by mul-

Table 1 Analysis of patient factors related to surgical site infections using the chi-square test

Risk factor (n)	Infection cases (incidence, %)	χ^2 (*P*-value)
Sex		
Male (542)	19 (3.5)	0.089
Female (596)	19 (3.2)	(0.776)
Age (years)		
<75 (977)	29 (3.0)	2.944
≥75 (161)	9 (5.6)	(0.086)
Pre-morbidity		
Diabetes		
Yes (77)	11 (14.3)	30.660
No (1,061)	27 (2.5)	(0.000)
Cancer		
Yes (119)	10 (8.4)	10.559
No (1,019)	28 (2.7)	(0.001)
Wound classification		
Clean (639)	3 (0.5)	
Clean contaminated (379)	24 (6.3)	60.768
Contaminated (112)	8 (7.1)	(0.000)
Dirty (8)	3 (37.5)	
ASA score before operation		
Level I (387)	3 (0.8)	
Level II (576)	19 (3.3)	33.411
Level III (139)	13 (9.4)	(0.000)
Level IV (9)	2 (22.2)	
Level V (27)	1 (3.7)	
Skin preparation		
Yes (423)	13 (3.1)	0.147
No (715)	25 (3.5)	(0.701)
Preprocedural WBC (×10⁹/L)		
≤10 (988)	20 (2.0)	40.151
>10 (150)	18 (12.0)	(0.000)
Type of surgery		
Selective (972)	24 (2.5)	15.628
Emergency (166)	14 (8.4)	(0.000)
Type of anesthesia		
General anesthesia (812)	32 (3.9)	4.225
Balanced anesthesia (48)	2 (4.2)	(0.376)
Epidural anesthesia (13)	0 (0.0)	
Local anesthesia (263)	4 (1.5)	
Other (2)	0 (0.00)	
Volume of blood loss (mL)		
<200 (869)	19 (2.2)	
200–400 (213)	13 (6.1)	18.057 (0.000)
≥400 (56)	6 (10.7)	
Blood transfusion		
Yes (56)	6 (10.7)	9.925
No (1,082)	32 (3.0)	(0.002)
Risk index		
0 (673)	9 (1.3)	
1 (377)	22 (5.8)	22.001
2 (78)	4 (5.1)	(<0.000)
3 (10)	3 (30.0)	
Operative duration (minutes)		
<120 (553)	8 (1.4)	11.937
≥120 (585)	30 (5.1)	(0.001)
Catheter		
Gastrointestinal catheter		
Yes (353)	25 (7.1)	22.212
No (785)	13 (1.7)	(0.000)
Urinary catheters		
Yes (421)	23 (2.1)	9.339
No (717)	15 (5.5)	(0.002)
Trachea cannula		
Yes (402)	13 (3.2)	0.021
No (736)	25 (3.4)	(0.884)
Postoperative drainage		
Yes (539)	33 (6.1)	24.576
No (599)	5 (0.8)	(0.000)
Antibiotic prophylaxis		
Yes (944)	28 (3.0)	2.388
No (194)	10 (5.2)	(0.122)

Abbreviations: ASA, American Society of Anesthesiologists; WBC, white blood cell count.

tivariate logistic regression analysis using a forward conditional model (Table 2). This analysis identified six parameters as independent markers for occurrence of SSI: diabetes (OR 6.400; 95% CI 2.582–15.866; P=0.000); cancer (OR 2.427; CI 1.028–5.732; P=0.043); preprocedural WBC more than 10×10^9/L (OR 6.988; CI 3.165–15.425; P=0.000); wound classification (clean contaminated [OR: 7.893; CI: 2.244–27.762; P=0.001]; contaminated [OR: 7.031; CI: 1.652-29.922; P=0.008]; dirty [OR: 48.778; CI: 5.418–439.164; P=0.001]); operative duration more than 120 minutes (OR 4.289; CI 1.773–10.378; P=0.001); and postoperative drainage (OR 3.957; CI 1.422–11.008; P=0.008).

Discussion

SSIs are the second most common type of adverse events occurring in hospitalized patients following surgery and are one of the most common surgical complications.[9–12] SSI surveillance is integral to hospital infection control and quality improvement programs, with feedback of SSI rates being an important component of SSI reduction strategies.[13] The incidence of SSI differs widely from hospital to hospital and from one geographic location to another.[14] In the People's Republic of China, surgical site infections are still one of the leading causes of morbidity and mortality among patients undergoing major surgery. The incidence of SSI in various hospitals varies from 13.0% to 18.0%, and accounts for 25.0% of all nosocomial infection,[1] which is higher than in other countries.[3] The incidence of SSI in our survey was 3.34%, which is far lower than that of the national average.[15] This finding is likely to be the result of

Table 2 Analysis of risk factors for surgical site infection using a multivariate logistic regression model

Risk factor	Variables in the equation						Reference
	β	SE	Wald	*P*-value	OR	95% CI	
Diabetes	1.856	0.463	16.059	0.000	6.400	2.582–15.866	No
Cancer	0.887	0.438	4.093	0.043	2.427	1.028–5.732	No
Preprocedural WBC ($\times 10^9$/L)							
>10	1.944	0.404	23.157	0.000	6.988	3.165–15.425	≤ 10
Wound classification							
Clean contaminated	2.066	0.642	10.364	0.001	7.893	2.244–27.762	Clean
Contaminated	1.950	0.739	6.966	0.008	7.031	1.652–29.922	
Dirty	3.887	1.121	12.020	0.001	48.778	5.418–439.164	
Operative duration (minutes)							
≥ 120	1.456	0.451	10.433	0.001	4.289	1.773–10.378	<120
Postoperative drainage	1.375	0.522	6.942	0.008	3.957	1.422–11.008	No

Notes: β indicates the partial regression coefficient, and 95% CI is credibility interval of 95% standard partial regression coefficient.
Abbreviations: CI, confidence interval; OR, odds ratio; SE, standard error; WBC, white blood cell count.

a multifactorial approach to improving patient safety and outcomes, especially the clinical real-time network monitoring performed since 2011. Moreover, the results of logistic regression analysis showed that SSI was related to type of operation, wound classification, volume of blood loss, blood transfusion, ASA score before operation, risk index, operative duration, diabetes, cancer, use of a gastrointestinal or urinary catheter, postoperative drainage, preprocedural WBC, suggesting that all patients having any type of operative procedure should be monitored for potential triggers of SSI in routine clinical practice.

The potential risk factors for SSI in surgical patients in our present study were assessed, and details were recorded preoperatively, intraoperatively, and postoperatively. Various patient risk factors were found to predict the incidence of SSI, in agreement with previously reported findings.[16] In our present study, an association was found between the age of surgical patients and SSI, suggesting that patients aged over 75 years (5.6%) were more likely to develop SSI than those under the age of 75 years (3.0%). However, this association failed to reach statistical significance ($P>0.05$). The lack of a significant association in this study may be due to the fact that elderly patients with chronic underlying disease often have decreased physiological defense mechanisms and poorer immune function. Therefore, elderly patients should undergo elective surgery when their bodies are in good condition.

The clinical relevance of these findings is that patients suffering from serious pre-existing disease, such as diabetes or cancer, are at high risk of developing SSI. In this study, there was a significant correlation between existing cancer and the likelihood of SSI. This is similar to the findings of other study of SSI.[7] Further, published reports have demonstrated that patients with diabetes are more susceptible to wound infection because of impaired neutrophil chemotaxis and phagocytosis.[17,18] The incidence of SSI in diabetic patients was higher, and there was a significant difference between the diabetic and non-diabetic groups in our survey. This is in accordance with the literature, which shows that patients suffering from pre-morbid diseases are at high risk of SSI.[19] Moreover, the results of our multivariate logistic regression analysis showed that diabetes was an independent risk factor for SSI (OR 6.400; 95% CI 2.582–15.866). As we know, the risk of SSI is very different for a patient who is having surgery to remove cancer when compared with a patient who is healthy and having knee replacement surgery. Thus, pre-existing disease may be one of the possible risk factors of SSI, but it is important to consider the type of disease presented.

Despite improvements in operating room practices, instrument sterilization methods, surgical technique, and the best efforts of infection prevention strategies, SSI remains a major cause of hospital-acquired infections and rates are increasing globally even in hospitals with the most modern facilities and standard protocols for preoperative preparation.[7] Thus, SSI is considered to be one of the most common and serious anesthetic and surgical complications.[20] It is well known that intraoperative or postoperative variable factors for SSI may reflect surgical technique more than patient case-mix. Emergency operative procedures do not allow for the standard preoperative preparation normally done within a facility for a scheduled operation (eg, confirmation of stable vital signs, adequate antiseptic skin preparation, and decontamination of the colon in advance of colon surgery). As shown in Table 1, the incidence of SSI in emergency surgery cases was higher than in elective surgery cases (8.4% versus 2.5%, respectively), which is in accordance with other studies.[21,22] Patients with acute abdominal pain account for the majority of emergency surgeries, and are at high perioperative risk for SSI because of the infected operation, especially at the preoperative infection lesions. On the other hand, most of the emergency surgeries were carried out beyond normal duty working hours and inadequate preoperative preparation might be a possible explanation for the higher incidence of SSI. Therefore, it is of high importance to strengthen the management of emergency surgery.

The type of anesthesia used depends on the procedure being performed and the patient's health, age, and preferences. Several studies have reported an increased SSI rate in patients undergoing general anesthesia when compared with those undergoing regional anesthesia.[23,24] However, there was no significant difference between them in our study. This finding has been proved by another study.[15]

Before each operative procedure, at least one incision (including for the laparoscopic approach) is made through the skin or mucous membrane, or reoperation via an incision that was left open.[25] Surgical wound classification has long been established as an important predictor of postoperative SSI.[26] The present survey showed that the incidence of SSI was higher in patients with a contaminated incision than in those with a clean or clean contaminated incision. The results of our multivariate logistic regression analysis further showed that wound classification was an independent risk factor for SSI, and the 95% CI for a dirty wound was much wider than the other ones of wound classification, but this may reflect the relatively small number of patients. We isolated 20 strains of bacteria, including *E. coli*, *S. aureus*, and *P. aeruginosa*, from infected surgical incision sites. Therefore, preventive measures should be strengthened for operations involving a contaminated incision, such as skin incision protection, minimizing contamination in the surgical field, and use of antibiotics. Reducing SSI while minimizing antibiotic resistance remains a challenge for many health care institutions. Use of perioperative antibiotics for incisions susceptible to infection did not seem to reduce the risk of SSI in our setting, as in other reports.[27,28] The lack of statistical significance could be explained in part by the lack of a perioperative antibiotic policy regarding different procedures for those patients in our study. Further, use of surgical drains as well as arteriovenous catheters and tracheal cannulae has been reported to be associated with an increased risk of SSI,[29,30] and multivariate analysis identified use of an arteriovenous catheter as a risk factor for SSI in our study. In contrast, tracheal cannulation was not associated with SSI. Thus, arteriovenous catheterization can alert surgeons to the increased risk of SSI, and nurses should be familiar with the monitoring and management of surgical drains to reduce this risk.[31] An operative duration of longer than 2 hours has previously been reported to be associated with SSI due to the increased duration of exposure to microorganisms in the operating theater,[32,33] and appeared to be a risk factor for SSI in our univariate analysis. It has also been demonstrated elsewhere by multivariate regression that increasing operative duration is associated with a stepwise increase in SSI.[1] Our multivariate logistic regression results further showed that operative duration was an independent risk factor for SSI, with an OR of 4.289 and a 95% CI of 1.773–10.378. Therefore, SSI prevention strategies focusing on longer surgical duration are needed to improve the outcomes for patients.

The relationship between blood products and SSI has been a matter of debate for more than 2 decades. It has been established that the incidence of SSI increases with increasing volume of blood transfusion.[34] In our study, the incidence of SSI in patients who received transfusions (10.7%) was higher than in those who did not (3.0%), suggesting that surgical patients who receive blood transfusion are more prone to SSI. Therefore, clinicians should not use blood transfusions unless absolutely necessary.

The ASA score evaluates the basal status of individuals including their comorbidities, so is also a good predictor of SSI.[2] SSI rates were significantly higher in patients with ASA II–V than in those with ASA I, which is in agreement with previous reports,[35,36] suggesting that the ASA score before surgery has a strong influence on SSI rates in clean and clean contaminated cases.

According to the National Nosocomial Infection Surveillance SSI index (comprising ASA, potential for surgical wound contamination, and duration of surgery),[37] the incidence of SSI was increased for scores 0, 1, 2, and 3 (corresponding to 1.3%, 5.8%, 5.1%, and 30.0%, respectively); although the rate in patients with a score of 1 was higher than in those with a score of 2, this difference was not statistically significant, which is most likely due to the small size of the sample available for subanalysis. Based on our study and those reported by others,[38,39] the incidence of SSI can be expected in those patients with high-risk factors.

Like other major inflammatory markers, the WBC is a stable, well standardized, widely available, and inexpensive biomarker of systemic inflammation.[40] Using multiple logistic regression, we found that an elevated procedural WBC level was an independent risk factor for development of SSI in patients undergoing a surgical procedure, which is in contrast with the findings of a previous study.[41] These different results between hospitals may be related to different reference values being used in the laboratory and the number of patients involved.

The main limitations of our study are related to our data set, lack of analysis of chlorhexidine bathing, normothermia, and other possible risk factors that may contribute to the low prevalence of SSI. In addition, less than 2 years of data (from July 2013 to December 2014) was considered in the analysis, and our results are not necessarily representative of other years. However, despite these limitations, our data suggest that six independent parameters are correlated with the risk of SSI and that relevant preventive measures should be implemented to reduce the incidence of SSI.

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Disclosure

The authors report no conflicts of interest in this work.

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