Surgical Site Infections in Orthopedic Patients: Prospective Cohort Study

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Aim To estimate the incidence rate and risk factors of surgical site infections in the orthopedic wards in a major teaching hospital in Serbia.

Methods A 6-month prospective cohort study, with 30 days of patient follow-up after surgery, was conducted at the teaching hospital in Belgrade. We collected patients' basic demographic data and data on underlying disease status, surgical procedures, preoperative preparation of patients, and antibiotic prophylaxis. The National Nosocomial Infections Surveillance (NNIS) risk index was computed for each patient. Descriptive and logistic regression analyses were performed to determine risk factors for surgical site infections.

Results Assessment of 277 patients after operation revealed surgical site infection in 63 patients. In 3 (4.8%) of them, surgical site infections were detected after hospital discharge. The overall incidence rate of surgical site infections was 22.7% (95% confidence interval [95% CI], 17.5-29.1). The incidence increased from 13.2% in clean wounds to 70.0% in dirty wounds. The rates of surgical site infection for the NNIS risk index classes 0 to 3 were 8.1% (13 of 161), 36.4% (32 of 88), 63.0% (17 of 27), and 100% (1 of 1) ($P<0.001$; χ^2 test). Multivariate logistic regression analysis identified the following independent risk factors for surgical site infections: greater number of persons in the operating room (odds ratio [OR], 1.28; 95% CI, 1.02-1.60), contaminated or dirty wounds (OR, 12.09; 95% CI, 5.56-26.28), and American Society of Anesthesiologists' (ASA) score >2 (OR, 3.47; 95% CI, 1.51-7.95). In patients who were shaved with a razor, the period of 12 or more hours between shaving and intervention was also an independent risk factor (OR, 2.77; 95% CI, 1.22-6.28).

Conclusion There is a high incidence of surgical site infections in orthopedic patients in Serbia in comparison with developed countries and some developing countries. Points for intervention could be reduction of personnel during surgery, better treatment of wounds, decreasing ASA score, and reduction of the time between surgical site shaving and the intervention.

Surgical site infections are one of the most common nosocomial infections besides pneumonia, urinary tract infections, and bloodstream infections (1). Although infection control committee and infection control program were legally introduced in each hospital in Serbia several years ago, they have never been implemented, and nosocomial infection surveillance has only recently been established in Serbia. Over the last several years, Serbia has gone through a transition period with limited funds and has been forced to use the existing organizational structure in the best possible way. Surveillance of nosocomial infections in every hospital is performed by an infection control nurse, together with a qualified epidemiologist for infection control in one of 23 regional public health institutes.

According to the first national prevalence study of nosocomial infections, surgical site infections were the most prevalent infections, and one of the highest prevalence rates of nosocomial infections was recorded in the orthopedic wards (2). In Serbia, no prospective study on the incidence of surgical site infections has been conducted.

The objective of our study was to estimate the incidence rate and risk factors of surgical site infections in the orthopedic ward of a leading teaching hospital in Belgrade, Serbia. The National Nosocomial Infections Surveillance (NNIS) risk index was also assessed.

Methods

This single center study was performed at the Department of Orthopedic Surgery, Clinical Center of Serbia in Belgrade. This teaching hospital has a catchment population of approximately 1.5 million people in Belgrade and serves as a reference center for the central part of Serbia.

Prospective cohort study was conducted during the period from February 1 to July 31, 2002. All surgery patients during this period were interviewed and daily observed during their hospitalization by an epidemiologist, together with an infection control nurse. Clinical charts were systematically reviewed and, when necessary, the medical staff was interviewed. When there was clinical suspicion of wound infection, a sample was taken for culture and transported to the bacteriology laboratory of the Clinical Center of Serbia. Diagnosis of the surgical site infection was made in concordance with the primary surgical team, which also performed the internal control of all collected data.

Observations were made while the patient was in the hospital for a 30-day period. Surveillance was continued if the patient was discharged before the end of the 30-day period. It was made by reviewing all the emergency department forms and by making telephone calls. Patients who reported any of the symptoms of wound infection (pain or tenderness, localized swelling, redness, or heat) by telephone were asked to return to the hospital for reexamination.

Observation of the operating theater during the study found satisfactory sterile techniques, such as surgical hand preparation, sterile gloves, and surgical draps, but there was limited ventilation. Products for cleaning and disinfection of surfaces and equipment were mostly available. There was a lack of handrub alcohol dispensers and single rooms for isolation of patients colonized or infected with resistant microorganisms. If necessary, cohort isolation was performed, ie, patients colonized/infected with the same organism were grouped together.

The following data were collected on standardized pre-coded forms: age, sex, admission, operation and discharge date, nutrition status, presence of diabetes mellitus as an underlying disease, smoking habits, type of operation (elective or emergency), wound class, duration of the operation, number of medical personnel during the operation, whether drainage was performed, duration of drainage, and American Society of Anesthesiologists' (ASA) preoperative assessment score, which categorizes patients into five subgroups according to preoperative physical status (Table 1).

Data on preoperative preparation of patients (preoperative bathing, way of shaving, number of hours from shaving to surgery) were also recorded. At the time of surgery, each procedure was classified by the attending surgeon according to the degree of intrinsic microbial contamination of a surgical site modified by Centers for Disease Control and Prevention (CDC) for use in surgical site infection surveillance (Table 1). The CDC standardized surveillance criteria for defining surgical site infections, which involve interpretation of clinical and laboratory findings, were used to detect nosocomial infections. According to these criteria, a surgical site infection is an infection which occurs within 30 days after the operation if no implant is left in place or within 1 year if implant is in place and the infection appears to be related to the operation (3). The NNIS risk index was computed on the basis of the following three risk factors, with one point for each: ASA score higher than 2, wound class of contaminated or dirty wound, and duration of procedure of more than T hours ($t = 75$th percentile). The NNIS index ranges from 0 to 3 (4). The Institutional Ethics Committee approved the study.

Statistical analysis

Point estimates and 95% confidence intervals (95% CI) for incidence rate of surgical site infections were computed. χ^2 test (for categorical data) and *t* test (for variables with normal distribution) or Mann-Whitney U test (for parametric heterogeneous data) were performed to assess the relation between potential risk factors and outcome of interest. Results were expressed as a percentage or as mean ± standard deviation. Univariate analyses of the categorical outcome (development of surgical site infection) and each individual associated factor were conducted. Variables associated with surgical site infection in the univariate analysis were introduced to stepwise forward-Wald multivariate logistic regression analysis, with entry probability of 0.5 and probability of removal of 0.1. The -2 log-likelihood ratio test was used to test the overall significance of the predictive equation. The significance of the variables in the model was assessed by the

Table 1. American Society of Anesthesiologists (ASA) score (3) and Surgical Wound Classification

Physical status classification, ASA score	
Class	Physical status
1	Normal healthy patient
2	Patient with mild systemic disease
3	Patient with severe systemic disease that is not incapacitating
4	Patient with incapacitating disease that is a constant threat to life
5	Moribund patient who is not expected to live 24 h with or without surgery
Surgical wound classification (3)	
Class	Description
I Clean	An uninfected operative wound in which no inflammation is encountered and when the respiratory, alimentary, genital, or uninfected urinary tract is not entered. In addition, clean wounds are primarily closed and, if necessary, drained with closed drainage. Operative incisional wounds that follow non-penetrating trauma should be included in this category if they meet the criteria.
II Clean-contaminated	A non-traumatic wound; no inflammation encountered. An operative wound when the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina, and oropharynx are included in this category, provided no evidence of infection or major break in technique is encountered.
III Contaminated	Open, fresh, accidental wounds. In addition, operations with major breaks in sterile technique or gross spillage from the gastrointestinal tract, and incisions in which acute, nonpurulent inflammation is encountered are included in this category.
IV Dirty/infected	Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. This definition suggests that the organisms causing postoperative infection were present in the operative field before the operation.

Wald χ^2 test and confidence intervals. The fit of the model was assessed by the Hosmer-Lemeshow goodness-of-fit χ^2 test. List-wise deletion was used as conventional method for handling the missing data.

The level of statistical significance was set at $P<0.05$. Analyses were performed using the Statistical Package for Social Sciences, version 8.0 (SPSS Inc, Chicago, IL, USA).

Results

Study population and patient characteristics

During the study period, a total of 277 patients were assessed after operation. The characteristics of these patients and type of surgery are presented in Table 2. The mean age ± standard deviation of the study population was 51.2±2.7 years, and 56.3% were men. ASA score was higher than 2 in 15.2% of patients. When cases were grouped by wound classification, there were 82.3% clean, 10.5% contaminated, and 7.2% dirty/infected wounds out of total 227 patients (Table 2).

Median length of preoperative hospital stay was 4 days (25th percentile, 1 day; 75th percentile, 8.5 days) and of total hospital stay was 28 days (25th percentile, 17 days; 75th percentile, 42 days).

Incidence of surgical site infections

Out of the 277 operated patients included in the study, 63 developed an infection (Table 3). None of the patients had more than one surgical site infection. The incidence rate was 22.7% (95% CI, 17.5-29.1). Out of 63 surgical site infections, 3 infections (4.8%) were detected after hospital discharge. The incidence of surgical site infections significantly depended on wound class, with a rate of 13.2% for clean wounds, 65.5% for contaminated wounds, and 70.0% for dirty wounds ($\chi^2_2=67.54$; $P<0.001$). The surgical site infection rates for the NNIS risk index classes (0 to 3 classes) were 8.1%, 36.4%, 63.0%, and 100%, respectively ($\chi^2_3=57.26$; $P<0.001$).

Table 2. Characteristics of operated patients

Characteristics	No. (%)
Sex:	
female	121 (43.7)
male	156 (56.3)
Age group (years):	
0-18	17 (6.1)
19-64	164 (59.2)
≥65	96 (34.7)
American Society of Anesthesiologists score:	
1 or 2	235 (84.8)
>2	42 (15.2)
Wound class:	
clean	228 (82.3)
contaminated	29 (10.5)
dirty/infected	20 (7.2)
Type of surgery:	
open fracture	43 (15.5)
open reduction and internal fixation	105 (37.9)
amputation	27 (1.8)
gunshot wounds	5 (9.7)
hip arthroplasty	25 (9.0)
knee arthroplasty	19 (6.8)
laminectomy	10 (3.6)
fusion	22 (7.9)
other muskuloskeletal	21 (7.6)

Table 3. Incidence of surgical site infections (SSI)

Surgical site infections	No. of SSI	No. of operated patients	Incidence rate (%)	P†
Total SSIs	63	277	22.7	
SSIs according to wound class:				0.001
clean	25	228	13.5	
contaminated	5	29	65.5	
infected/dirty	14	20	70.0	
SSIs according to NNIS* score:				0.001
0	13	161	8.1	
1	32	88	36.4	
2	17	27	63.0	
3	1	1	100.0	

*ANNIS – National Nosocomial Infections Surveillance.
†χ^2 test.

Pathogens

Fifty-three (84.1%) out of the 63 clinical surgical site infections were culture-positive and 24 (45.3%) of them had polymicrobial infection (18 with two species and 6 with three species). The most frequently isolated bacteria were *Staphyloccocus aureus*, *Acinobacter* spp, *Klebsiella/Enterobacter* spp, *Pseudomonas* spp and *Enterococcus* spp (Table 4). Nineteen (79.2%) of the 24 isolated *Staphulococcus aureus* bacteria were methicilin-resistant (MRSA).

Table 4. Microorganims isolated from 53 culture-positive surgical site infections

Microorganism	No. (%)
*Staphylococcus aureus**	24 (28.9)
Acinetobacter spp	20 (24.1)
Klebsiella/Enterobacter	10 (12.0)
Pseudomonas spp	9 (10.8)
Enterococcus spp	7(8.4)
Coagulase-negative staphylococci	4 (4.8)
Proteus mirabilis	3 (3.6)
Citrobacter spp	2 (2.4)
Other	4 (4.8)
Total	83 (100.0)

*19 of 24 *Staphyloccocus aureus* isolates were methicilin-resistant.

Risk factors

Univariate analysis showed that surgical site infections were significantly associated with diabetes mellitus, open reduction fracture, preoperative shaving with razor, prolonged period from shaving to operation, larger number of persons in the operating room, drainage duration, high degree of wound contamination, and elevated ASA score (Table 5). Preoperative bath or shower was a protective factor. Age, sex, obesity (BMI≥25), smoking, emergency procedures, presence of drain tube, and duration of surgery >75th percentiles were not significantly associated with surgical site infections.

The following variables were included in the multivariate logistic regression analysis: open reduction fracture (yes/no), preoperative shaving with razor (yes/no), number of persons in the operating room, contaminated wound, and dirty/infected wound (yes/no), ASA score >2 vs ≤2, and diabetes mellitus (yes/no). Preoperative bath or shower was not included in the final model of multivariate logistic regression analysis because it was present in a limited number of patients and its effect was weak even among them.

According to this analysis, a larger number of persons in the operating room during the operation, contaminated or dirty/infected wound, and ASA score >2 were independent risk factors for surgical site infections (Table 6). The Hosmer-Lemeshow goodness-of-fit test was 10.379, df = 6, $P = 0.110$. The overall significance of the equation by the -2 log-likelihood test was 206.547 ($P<0.001$) at step 3. The classification correctness was 82.2%.

Table 6. Risk factors for surgical site infections according to multivariate logistic regression analysis

Variables	Odds ratio (95% confidence interval)	*P*
No. of persons in the operating room	1.28 (1.02-1.6)	0.030
Contaminated wound and dirty/infected wound	12.09 (5.56-26.28)	0.001
ASA* score >2	3.47 (1.51-7.95)	0.003
Shaving with razor (12 or more hours before the operation)	2.77 (1.22-6.28)	0.015

*ASA – American Society of Anesthesiologists.

Table 5. Association between surgical site infections and investigated factors, according to univariate logistic regression analysis*

	No. (%) of patients			
Variable	without SSI (No. = 214)	with SSI (No. = 63)	OR (95% CI)	*P*
Age (years, mean)	50.6	53.1	1.01 (0.99-1.02)	0.392
Sex (male)	100 (46.7)	21 (33.3)	1.75 (0.97-3.16)	0.061
Obesity (BMI≥25)	72 (33.6)	23 (36.5)	1.13 (0.63-2.04)	0.674
Smoking	80 (37.4)	28 (44.4)	1.34 (0.76-2.37)	0.313
Diabetes mellitus	15 (7.0)	10 (15.9)	2.50 (1.06-5.89)	0.036
Emergency procedures	31 (14.5)	13 (20.6)	1.54 (0.75-3.15)	0.243
Open reduction fracture	26 (12.1)	17 (27.0)	2.67 (1.34-5.33)	0.005
Preoperative bath or shower	91 (42.5)	9 (14.3)	0.47 (0.29-0.76)	0.002
Preoperative shaving with razor	39 (18.2)	21 (33.3)	2.24 (1.20-4.21)	0.012
Hours between shaving and operation (mean±SD)	12.9 ± 14.5	19.1 ± 21.1	1.02 (1.002-1.04)	0.033
No. of persons in the operating room (mean±SD)	6.0 ± 1.5	6.6 ± 1.5	1.29 (1.07-1.57)	0.009
Presence of drain tube	114 (53.3)	35 (55.6)	1.09 (0.62-1.93)	0.749
Drainage duration (days, mean±SD)	2.9 ± 1.6	4.1 ± 3.4	1.24 (1.05-1.47)	0.010
Contaminated wound and dirty/infected wound	16 (7.5)	33 (52.4)	13.61 (6.69-27.68)	<0.001
ASA score >2	22 (10.3)	20 (31.7)	4.06 (2.04-8.09)	<0.001
Duration of surgery ≥75th percentiles	44 (20.6)	15 (23.8)	1.21 (0.62-2.35)	0.580

*Abbreviations: SSI – surgical site infections; Odds ratio (95% confidence interval) ASA – American Society of Anesthesiologists.

In 214 patients who were preoperatively shaved with razor, period of 12 and more hours between shaving and surgical intervention, was also an independent risk factor for surgical site infections (OR, 2.77; 95% CI, 1.22-6.28). In patients in whom drainage was performed, the time of drainage duration was not, independently of other factors, related to surgical site infection.

The power of the study was not great enough to estimate the effect of less frequent variables.

Impact of surgical site infections

The mean length of postoperative stay was significantly longer for patients with surgical site infections than for those without these infections (mean of 44.2 vs 23.5 days; $P<0.001$).

Discussion

The incidence rate of surgical site infections found in the present study was 22.7%. The independent risk factors for development of surgical site infections identified in the study were a greater number of persons in the operating room during the operation, contaminated or dirty wound, ASA score >2, and a prolonged period between shaving with razor and surgical intervention (≥12 hours). Estimates from the logistic model fit the data at an acceptable level.

The incidence rate in our study was remarkably higher than the incidence rates in orthopedic patients from developed countries (5-7), but it was also higher than the rates in some developing countries (8,9). The incidence rates stratified by wound class exceeded those reported by other studies (9). High rates of contaminated, dirty, and trauma-related wounds in our study might have contributed to the high incidence of surgical site infections. On the other hand, the elevated surgical site infection rates of clean wounds can be explained by the lack of financial resources, outdated equipment, and limited ventilation in the operating theater, as well as limited application of infection control measures. Although some studies found that the higher NNIS index was not associated with higher risk of surgical site infections (10), this indicator is in many countries successfully used as a predictor of surgical site infections (9,11-13). Our study found a strong relationship between the NNIS index and development of surgical site infections.

As a consequence of the rapidly increasing trend of short-stay hospitalization, the majority of surgical site infections occurs after discharge from the hospital (14). Low percentage (4.8%) of surgical site infections after hospital discharge detected in this study is probably the result of a relatively long postoperative period of hospitalization. Only a small proportion of patients (7.2%) were hospitalized for less than one week.

Staphylococcus aureus and gram negative bacteria were the predominant causative agents, as in other studies in a similar setting (9). Although eradication of *Staphylococcus aureus* nasal carriage with mupirocin was found to be effective, this measure reduced the surgical site infections rates only in some studies (15).

A greater number of persons in the operating room can increase the rates of surgical site infections from 1.5 to 3.8 (16). Our operating rooms are old and without adequate system of ventilation. Because the air is an important route for the spread of infection in joint prosthesis operations, routine use of an ultra clean air system and exhaust-ventilated clothing is frequently recommended. However, other less costly measures, including the reduction of the number of persons in the operating room, probably may insure similar preventive effect (17).

Although the usefulness of the traditional wound classification has been doubted (18), it is an important predictor of surgical site infection (19) and this finding was confirmed by our study. ASA score is considered as an important predictor of surgical site infection, and its relationship with the development of infection in orthopedic ward in our study is in line with findings from other countries (10,11).

The present study confirmed the well-known fact that shaving can increase the risk for infection, and CDCs recommended either not to remove hair preoperatively or to do it immediately before the operation, preferably with electric clippers (3).

Our study supports the previously published results that an infection following the surgical intervention prolongs the length of hospitalization (7,20).

There are some limitations of the study. It covered a period of only 6 months and thus may not account for seasonal variations. Demographic characteristics of hospital population (age, for example) may be changed during winter. A single telephone call to the patient within 30 days after the operation theoretically would not represent a satisfactory method for post-discharge surveillance of surgical site infections. However, taking into account that the median length of total hospital stay was 28 days, we assume that the number of surgical site infections, which developed after hospital discharge, were negligible since postsurgical infections would most probably develop within 4 weeks after surgery. Since the number of patients included in the study was relatively small, the power of the study was not great enough to estimate the effect of less frequent variables – therefore, investigation performed on a larger number of patients would be desirable.

This study is the first longitudinal study of surgical site infections at orthopedic wards in Serbia and it is one of the few studies in developing countries that accomplished a complete one-month follow-up. The merit of the study is that it confirmed that active surveillance of surgical site infections might be organized in countries with limited resources. Surgical site infections are a considerable problem in orthopedic wards in Serbia, with incidence rates being much higher than in other countries, particularly in clean wounds. Identification of risk factors for surgical site infections has encouraged the development of national recommendations for prevention.

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