Risk factor identification and contribution to surgery-specific surgical site infection

(Magnus) Johan Magnus van Niekerk (✉ j.m.vanniekerk@utwente.nl)

Universiteit Twente <https://orcid.org/0000-0002-4737-5809>

Margreet C Vos

Erasmus MC

Alfred Stein

Universiteit Twente Faculteit Geo-Informatie Wetenschappen en Aardobservatie

(Annemarie) M A Braakman-Jansen

Universiteit Twente

Anne F Voor in't holt

Erasmus MC

(Lisette) Julia Elisabeth Wilhelmina Cornelia van Gemert-Pijnen

Universiteit Twente

Research article

Keywords: Surgical Wound Infection; Risk Factors; Digestive System Surgical Procedures; Thoracic Surgery; Orthopaedic Procedures

Posted Date: April 15th, 2019

DOI: <https://doi.org/10.21203/rs.2.9189/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background: To identify common risk factors for the future occurrence of SSI across digestive system surgical procedures, thoracic surgery and orthopaedic procedures and quantify what the marginal contribution of explaining the future occurrence of SSI is of risk factors specific to each group of surgeries. **Methods:** Retrospective data from serial point-prevalence studies, performed at the Erasmus MC University Medical Center, Rotterdam, The Netherlands were used, together with medical data, from 3.250 surgical procedures, during the period January 2013 to 29 June 2014. Common risk factors across three groups of surgical procedures were identified by scanning literature and univariate analysis. A multivariate forward-step logistic regression model was used to identify the marginal contribution of the risk factor specific to each group of surgical procedure using the increase in the Gini coefficient. **Results:** For digestive system surgical procedures, antibiotic use, temperature, smoking status, age, CRP, thrombocyte, during of surgery and surgical urgency are risk factors for SSI, where the last four were specific to the digestive system group of surgical procedures and increased the Gini coefficient by 9.5% (0.63 to 0.69). Preoperative length of stay, antibiotic use and Leukocyte are risk factors for orthopaedic surgical procedures. Temperature, age and the use of antibiotics were significant for thoracic surgical procedures. **Conclusion:** ASA class, body mass index (BMI), Preoperative length of stay, diabetes, antibiotic use, age, Leukocyte, temperature and smoking status as general risk factors common to digestive, orthopaedic and thoracic surgical procedures using existing literature and univariate logistic regression. Risk factors for SSI, specific to a surgical procedure group can increase the ability to explain the future occurrence of SSI by 9.5%. The models developed in this study can aid healthcare workers to improve preoperative counselling and help identify potentially modifiable risk factors.

Background

Surgical site infections (SSI), as defined by the European Centre for Disease Prevention and Control (ECDC) [1], make up 19.6% of the total number of healthcare-associated infections (HAIs) in Europe. With an estimated 81.089 patients in Europe having an HAI on any given day, almost 16.000 people in Europe are suffering from some form of SSI at any given time [2]. The burden of SSI can be measured in terms of increased length of stay in hospital, additional (surgical) procedures required, increased morbidity and mortality as well as in economic terms [3].

The use of surgical antimicrobial prophylaxis (SAP) has altered the outcome of surgery dramatically with early studies already showing odds of SSI being less than half after SAP was administered [4]. Risk factors relating to the patient, procedure and the environment also alter the odds of developing an SSI. Research has been done to identify risk factors for SSI with the hope that it will lead to pre-emptive action to reduce the incidence rate of SSI [5–11].

Patient related risk factors for SSI, such as obesity, diabetes, surgery duration and the American Society of Anaesthesiologists (ASA) score are risk factors for digestive system, thoracic and orthopaedic surgical procedures [15], [18–28]. Some risk factors are only relevant to certain types of surgical procedures, but

the marginal contribution of these surgery specific risk factors to explain the occurrence of SSI has yet to be reported.

The ECDC reports the SSI surveillance data in 10 national health safety network (NHSN) categories, which combines ICD-10-CM surgical procedure codes together [1]. The literature, concerning risk factors for SSI, is segmented by the same categories and is done for good reason. Segmentation makes it possible to find useful and relevant risk factors unique to each segment. For this study, we focus on digestive system, thoracic and orthopaedic surgical procedures. Digestive system surgical procedures are more prone to SSI and the severity vary. The occurrence of SSI after thoracic and orthopaedic surgeries are both relatively low, but the severity of an SSI after a thoracic is much higher compared to orthopaedic surgeries. It has yet to be shown which risk factors are common across these three different group of surgical procedures and what the benefit is of including risk factors unique to them.

Risk factors common across three groups of surgeries are identified from existing literature and the marginal contribution of the risk factors unique to each of them when predicting SSI is quantified.

Methods

The Erasmus MC University Medical Center in Rotterdam, the Netherlands (Erasmus MC), is the largest university medical hospital in the Netherlands with more than 1.300 beds. [21]

We used the verified output from the infection control practitioners (ICP) for the SSI output variable. Weekly (alter two-weekly) prevalence surveys were performed during January 2013 until June 2014 using a semi-automated algorithm [21,22]. In short, an algorithm was used to calculate a nosocomial infection index (NII) which was then verified by infection control practitioners (ICP) in case of a positive outcome to determine whenever HAI was present or not. All patients with a NII > 7 are verified by an ICP, and a definite outcome SSI was concluded by the ICP using the electronic patient data system.

We included 3,250 surgical procedures, performed on 2,929 distinct patients. Data were extracted from a centralised database, containing cross-departmental data, and clinical synopsis reports, infectious disease consultation reports, laboratory results and imaging reports. Surgeries were included if they form part of the three types of surgeries under investigation in this study and had a point prevalence study within 30 days after the surgery took place. If the surgery took place within 30 days after an included surgery, then the latter surgery was excluded.

The data used for this study were anonymized in accordance to the Dutch Personal Data Protection Act (WBP). Approval of the Medical Ethical Committee was obtained (MEC-2018-1185). There was no need to obtain informed consent because this is a fully anonymous retrospective study and no further interaction with the patients were necessary.

Risk factors relating to digestive system surgical procedures, thoracic surgery and orthopaedic procedures were identified from existing literature using the corresponding medical subject headings (MeSH). For a risk factor to be included in this study, it had to be significant in the multivariate analysis of

the literature considered. The risk factors which are common to all three groups of surgeries, according to our literature scan, are called “general risk factors”.

Statistical analysis

During the initial analysis of the data, a missing value analysis is performed. Using IBM SPSS Statistics for Windows, Version 25, we performed t-tests to determine if the differences in the averages of variables with missing values and those without were statistically significant. These tests, together with Little’s MCAR test, convinced us that the missing values were not completely randomly missing and that we could not make use of more simple imputation methods. We chose to use conditional Markov chain Monte Carlo (MCMC) with multiple imputations for the imputation process. [23,24]

Tests for significant differences in the occurrence of SSI across all three groups of surgeries were performed using the Wilcoxon-Kruskal-Wallis test for continuous variables and Pearson chi-square test for categorical variables. In this study we consider variables to be statistically significant if the corresponding p-value is less than 0.05.

In order to build a prognostic prediction model for SSI, Hosmer et al. suggests fitting a univariate logistic regression model to each variable separately and if the p-value is less than a certain p-value, 0.1 is this case, then consider the variable good enough to include in the multivariate logistic regression model. [26] The data were split according to the different groups of surgeries in order to evaluate them separately. A univariate analysis was performed for each of the three groups of surgeries using all the variables identified across the three different groups. Significant variables in the univariate analysis are then also added to the list of variables associated with each group of surgery, together with the variables identified from the literature. This results in an extended list of general risk factors as more risk factors are common across the three groups of surgeries.

A multivariate logistic regression model was applied using a forward stepwise approach.(28) The multivariate model was first built using the general risk factors and then, using the result as a starting point, the surgery group specific risk factors were added to the model in order of the Akaike information criterion (AIC) until convergence is reached. In this case, we chose the conversion of the model to imply that there are no additional variables which can be added which will be statistically significant with a p-value of less than 0.05 or an AIC of 3.8415.

Each variable contributes information about the SSI outcome variable, which in turn reduces the error or residual of the model. For a logistic regression model, the residual or error can be stated in terms of deviance. To determine the importance of the different variables in the final model, we calculate the difference in model deviance caused by the exclusion of each variable. Model performance are determined using the Gini coefficient after each step of the multivariate modelling process and the difference is reported as the marginal contribution of surgery group specific risk factors for this study. [27]

Results

In total, 55 risk factors were identified across the three types of surgical procedures from literature [15], [18–28]. Of the risk factors identified, ASA class, body mass index (BMI), Preoperative length of stay and diabetes were identified as general risk factors. The complete list of risk factors identified from literature can be found in Table 6 as part of the Appendix. There are 24 risk factors unique to digestive system surgical procedures, 14 to orthopaedic procedures and 15 to thoracic surgeries. Of the 55 risk factors identified from the literature, 23 could be extracted from our own data to use in this study. These 23 risk factors included in this study, together with the number of surgery groups they occurred in (N), are shown in Table 1.

Table 1: Variables names and definitions used to investigate the future occurrence of SSI in this study

Variable	Abbreviation	N	Definition
Demographic			
Gender	GEN	2	Gender of patient
Age	AGE	2	Age of patient
ASA class	ASA	3	ASA class of patient
BMI	BMI	3	BMI of patient at the time of surgery.
Behavioural			
Alcohol use	ALC	2	Alcohol use of patient at the time of surgery.
Smoking	SMO	2	Smoking status of patient at the time of surgery.
Comorbidities			
Heart disease	HEA	2	Patient has a history of heart disease at the time of surgery.
Liver disease	LIV	2	Patient has a history of heart liver at the time of surgery.
Hepatitis	HEP	1	Hepatitis of patient at the time of surgery.
Hyper tension	HYP	1	Patient has a history of hyper tension.
Diabetes	DIA	3	Diabetes of patient at the time of surgery.
Measurement			
Highest temperature	TEM	1	Highest temperature of patient in the past 7 days before surgery.
Highest CRP	CRP	1	Highest CRP of patient in the past 7 days before surgery.
Highest Leukocyte	LEU	2	Highest Leukocyte of patient in the past 7 days before surgery.
Highest protein	PRO	1	Highest protein of patient in the past 7 days before surgery.
Highest alkaline phosphatase	ALK	1	Highest alkaline phosphatase of patient in the past 7 days before surgery.
Highest glucose	GLU	1	Highest glucose of patient in the past 7 days before surgery.
Highest haemoglobin	HEM	1	Highest haemoglobin of patient in the past 7 days before surgery.
Highest thrombocyte	THR	1	Highest thrombocyte of patient in the past 7 days before surgery.

Operative			
Preoperative length of stay (days)	LOS	3	Preoperative length of stay (days) of patient at the time of surgery.
Antibiotic use	ANT	1	Antibiotic use of patient at the time of surgery.
Urgency	URG	2	Urgency of the surgical procedure.
Duration of surgery	DUR	2	Duration of the surgical procedure.

The test for differences for risk factors in Table 1 are shown in Table 2. The variables indicating the type of surgery was statistically significant but there was no significant difference between the ASA classes of patients for which SSI occurred. Diabetes and BMI were also not significant. Preoperative length of stay was the only general risk factor which was statistically significant. Antibiotics use, temperature and CRP were significant during initial analysis across the groups of surgeries with pvalue of less than 0.001.

Table 2: Test for differences preoperative and operative characteristic for the occurrence of SSI

Variable	SSI = No (3.078)	SSI = Yes (172)	p-value
Gender			
Female	1243 (95.2)	63 (4.8)	0.328
Male	1835 (94.4)	109 (5.6)	
Age	46.7 (26)	49 (23.5)	0.522
ASA class			
ASA CLASS I	426 (96.6)	15 (3.4)	0.124
ASA CLASS II	1043 (94.6)	60 (5.4)	
ASA CLASS III	1239 (94.8)	68 (5.2)	
ASA CLASS IV	356 (93.0)	27 (7.0)	
ASA CLASS V	14 (87.5)	2 (12.5)	
BMI	24.8 (5.1)	24.7 (4.7)	0.966
Alcohol use			
Current	1702 (95.0)	89 (5.0)	0.659
Never	1180 (94.3)	71 (5.7)	
Past	196 (94.2)	12 (5.8)	
Smoking			
Current	1396 (93.3)	101 (6.7)	0.002
Never	978 (95.7)	44 (4.3)	
Past	704 (96.3)	27 (3.7)	
Heart disease			
No	2942 (94.8)	161 (5.2)	0.225
Yes	136 (92.5)	11 (7.5)	
Liver disease			
No	2989 (94.7)	166 (5.3)	0.651
Yes	89 (93.7)	6 (6.3)	
Hepatitis			
No	3015 (94.6)	171 (5.4)	0.178
Yes	63 (98.4)	1 (1.6)	

Hyper tension			
No	2440 (94.5)	142 (5.5)	0.299
Yes	638 (95.5)	30 (4.5)	
Diabetes			
No	2807 (94.9)	151 (5.1)	0.129
Yes	271 (92.8)	21 (7.2)	
Highest temperature	38.1 (0.9)	38.9 (1)	<0.001
Highest CRP	38.8 (69.3)	81.8 (105.2)	<0.001
Highest Leukocyte	11.6 (6.7)	12.6 (7.1)	0.06
Highest protein	63.1 (10.4)	59.3 (11.8)	<0.001
Highest alkaline phosphatase	110.3 (102.5)	123.3 (104.1)	0.04
Highest glucose	9.4 (3.3)	10.1 (3.5)	0.002
Highest haemoglobin	8.1 (1.2)	8 (1.3)	0.262
Highest thrombocyte	207.8 (103.7)	171.6 (92.9)	<0.001
Preoperative length of stay (days)	6.4 (24.5)	10 (28.8)	<0.001
Antibiotic use			
No	2051 (97.7)	49 (2.3)	<0.001
Yes	1027 (89.3)	123 (10.7)	
Type of surgery			
Digestive System Surgical Procedures	1010 (90.5)	106 (9.5)	<0.001
Orthopaedic Procedures	941 (97.1)	28 (2.9)	
Thoracic Surgery	1127 (96.7)	38 (3.3)	
Urgency			
Elective	1586 (96.4)	59 (3.6)	<0.001
Emergency	1492 (93.0)	113 (7.0)	
Duration of surgery	245.1 (131.1)	274.4 (163.2)	0.125

The significant univariate results of digestive system, orthopaedic and thoracic surgical procedures are shown in Table 3 and the full results can be found in Table 5, Table 6 and Table 7 in the Appendix. Antibiotic use, age, Leukocyte, temperature and smoking status were added to the list of general risk factors after being found statistically significant in the univariate analysis – increasing the number of

general risk factors to 9. BMI and diabetes were two risk factors identified as general Risk factors from the literature but were not found significant in any of the three univariate analyses in our own study.

Table 3: Digestive system surgical procedures: univariate analysis of risk factors for the future occurrence of SSI

Characteristic	SSI = No (3.078)	SSI = Yes (172)	Univariate OR (95% CI, p-value)
Digestive system surgical procedures			
Age			
23	310 (30.7)	9 (8.5)	
23	700 (69.3)	97 (91.5)	4.77 (2.51-10.28, p<0.001)
ASA class			
ASA CLASS I	140 (13.9)	6 (5.7)	
ASA CLASS II	452 (44.8)	46 (43.4)	2.37 (1.07-6.31, p=0.052)
ASA CLASS III	343 (34.0)	40 (37.7)	2.72 (1.21-7.28, p=0.026)
ASA CLASS IV	75 (7.4)	14 (13.2)	4.36 (1.67-12.73, p=0.004)
Smoking			
Current	492 (48.7)	67 (63.2)	
Never	337 (33.4)	20 (18.9)	0.44 (0.25-0.72, p=0.002)
Past	181 (17.9)	19 (17.9)	0.77 (0.44-1.29, p=0.342)
Highest temperature			
38	647 (64.1)	28 (26.4)	
(38,39]	243 (24.1)	40 (37.7)	3.80 (2.31-6.36, p<0.001)
39	120 (11.9)	38 (35.8)	7.32 (4.34-12.47, p<0.001)
Highest CRP			
164	905 (89.6)	75 (70.8)	
164	105 (10.4)	31 (29.2)	3.56 (2.22-5.63, p<0.001)
Highest protein			
57	321 (31.8)	53 (50.0)	
57	689 (68.2)	53 (50.0)	0.47 (0.31-0.70, p<0.001)
Highest glucose			
8.2	494 (48.9)	31 (29.2)	
8.2	516 (51.1)	75 (70.8)	2.32 (1.51-3.63, p<0.001)
Highest thrombocyte			

225	692 (68.5)	95 (89.6)	
225	318 (31.5)	11 (10.4)	0.25 (0.13-0.46, p<0.001)
Antibiotic use			
No	581 (57.5)	19 (17.9)	
Yes	429 (42.5)	87 (82.1)	6.20 (3.80-10.64, p<0.001)
Urgency			
Elective	548 (54.3)	34 (32.1)	
Emergency	462 (45.7)	72 (67.9)	2.51 (1.65-3.89, p<0.001)
Duration of surgery			
530	971 (96.1)	89 (84.0)	
530	39 (3.9)	17 (16.0)	4.76 (2.53-8.62, p<0.001)
Orthopaedic surgical procedures			
Highest temperature			
38	747 (79.4)	15 (53.6)	
38	194 (20.6)	13 (46.4)	3.34 (1.54-7.14, p=0.002)
Highest CRP			
144	883 (93.8)	20 (71.4)	
144	58 (6.2)	8 (28.6)	6.09 (2.44-13.96, p<0.001)
Highest Leukocyte			
17.3	820 (87.1)	17 (60.7)	
17.3	121 (12.9)	11 (39.3)	4.39 (1.95-9.48, p<0.001)
Preoperative length of stay (days)			
7	853 (90.6)	16 (57.1)	
7	88 (9.4)	12 (42.9)	7.27 (3.27-15.79, p<0.001)
Antibiotic use			
No	720 (76.5)	11 (39.3)	
Yes	221 (23.5)	17 (60.7)	5.03 (2.35-11.23, p<0.001)
Thoracic surgical procedure			
Age			

17	246 (21.8)	17 (44.7)	
17	881 (78.2)	21 (55.3)	0.34 (0.18-0.67, p=0.001)
Smoking			
Current	525 (46.6)	22 (57.9)	
Never	316 (28.0)	13 (34.2)	0.98 (0.48-1.95, p=0.959)
Past	286 (25.4)	3 (7.9)	0.25 (0.06-0.73, p=0.025)
Highest temperature			
37	316 (28.0)	2 (5.3)	
(37,38]	612 (54.3)	20 (52.6)	5.16 (1.50-32.47, p=0.027)
38	199 (17.7)	16 (42.1)	12.70 (3.56-80.90, p=0.001)
Antibiotic use			
No	750 (66.5)	19 (50.0)	
Yes	377 (33.5)	19 (50.0)	1.99 (1.04-3.82, p=0.037)
Urgency			
Elective	605 (53.7)	14 (36.8)	
Emergency	522 (46.3)	24 (63.2)	1.99 (1.03-3.98, p=0.044)

The general risk factors which were significant for digestive system surgical procedures were antibiotic use, temperature, smoking status and age according to the multivariate analysis results shown in Table 4. The additional significant risk factors, indicated in bold, which were unique to the digestive system surgery group, were CRP, thrombocyte, duration of the surgery and if the surgery was an elective or not. In this case, the general risk factors reduced the residual deviance from 700.66 to 570.24. The risk factors identified to be unique to digestive system surgical procedures reduced the residual deviance from 570.24 to 531.05 and improved the Gini coefficient from 0.63 to 0.69. Important to know, the variables CRP and thrombocyte were the biggest contributors in the increase in model performance with both decreasing the residual deviance by almost 14. Pre-operative length of stay, antibiotic use and Leukocyte were significant general risk factor for the orthopaedic group of surgeries, resulting in a Gini coefficient of 0.6. Temperature, age and antibiotic use were significant general risk factors for the thoracic group of surgical procedures and produced a Gini coefficient of 0.51. Neither the orthopaedic nor the thoracic group of surgical procedures had any significant risk factors unique to the group of surgeries.

Table 4: Multivariate analysis of risk factors for the future occurrence of SSI by group of surgeries (Risk factors in bold are the additional risk factors not part of the general risk factors)

Surgery type & variable	Coefficient	Multivariate OR (95% CI)	p-value	Residual deviance
Digestive System Surgical Procedures				
(Intercept)	-4.560	0.010 (0.004 - 0.024)	<0.001	700.660
Antibiotic use Yes	0.911	2.488 (1.355 - 4.797)	0.005	636.770
Highest temperature (38, 39]	0.962	2.616 (1.526 - 4.527)	<0.001	588.810
Highest temperature 39	1.757	5.796 (3.226 - 10.517)	<0.001	588.810
Smoking = Never	-0.929	0.395 (0.218 - 0.688)	<0.001	578.020
Smoking = Past	-0.551	0.577 (0.308 - 1.040)	0.075	578.020
Age 23	1.122	3.071 (1.347 - 7.578)	0.010	570.240
Highest CRP 164	1.074	2.928 (1.681 - 5.038)	<0.001	556.300
Highest thrombocyte 225	-0.983	0.374 (0.179 - 0.720)	0.005	542.650
Duration of surgery 530	1.221	3.390 (1.612 - 6.957)	<0.001	535.180
Urgency Emergency	0.529	1.698 (1.018 - 2.883)	0.045	531.050
Orthopaedic Surgical Procedures				
(Intercept)	-4.682	0.009 (0.004 - 0.017)	<0.001	253.650
Preoperative length of stay7	1.552	4.721 (2.035 - 10.674)	<0.001	232.920
Antibiotic use Yes	1.224	3.402 (1.521 - 7.839)	0.003	223.240
Highest Leukocyte 17.3	1.254	3.505 (1.511 - 7.819)	0.003	215.080
Thoracic Surgical Procedures				

(Intercept)	-4.195	0.015 (0.002 - 0.053)	<0.001	334.890
Highest temperature (37,38]	1.311	3.709 (1.055 - 23.515)	0.081	315.670
Highest temperate 38	1.826	6.209 (1.676 - 40.324)	0.018	315.670
Age 17	-1.742	0.175 (0.062 - 0.463)	<0.001	311.810
Antibiotic use Yes	1.549	4.708 (1.846 - 13.172)	0.002	300.860

The resultant equations of the multivariate logistic regression models are provided in Equation 1 to Equation 3. The abbreviations of the variable names are provided in Table 1.

We summarise the findings concerning the statistical significance of the risk factors by surgical procedure in Table 5. The stage of significance indicates the last stage of the analysis where this risk factor was statistically significant for corresponding group of surgeries. The source indicates where the reason why each risk factor was considered for each group of surgeries. In the last section we see the risk factors we found in literature but were not significant for any of the groups of surgeries for both the univariate and multivariate analysis. Risk factors which were significant in the multivariate analysis, but not the univariate analysis are shown in the first part of Table 5.

Table 5: Statistical significance of risk factors and the source which lead them to be considered by surgical procedure

Stage of significance (Source)	Digestive System	Orthopaedic	Thoracic
Multivariate Analysis (Literature)			
Age	*		
Preoperative length of stay (days)		*	
Duration of surgery	*		
Highest temperature	*		
Highest thrombocyte	*		
Smoking	*		
Urgency	*		
Multivariate Analysis (Univariate Analysis)			
Antibiotic use	*	*	*
Age			*
Highest CRP	*		
Highest Leukocyte		*	
Highest temperature			*
Univariate Analysis (Literature)			
ASA class	*		
Highest CRP		*	
Highest glucose	*		
Highest Leukocyte	*		
Highest protein	*		
Urgency			*
Univariate Analysis (Univariate Analysis)			
Highest temperature		*	
Smoking			*
None (Literature)			
Age		*	
ASA class		*	*
BMI	*	*	*

Preoperative length of stay (days)	*		*
Diabetes	*	*	*
Alcohol use	*	*	
Duration of surgery		*	
Gender	*	*	
Heart disease		*	*
Hepatitis	*		
Highest alkaline phosphatase	*		
Highest haemoglobin	*		
Highest Leukocyte			*
Hyper tension	*		
Liver disease	*		*
Smoking		*	

Discussion

We aimed to identify general risk factors, common across three groups of surgeries, using literature and univariate analysis to quantify the marginal contribution of the risk factors not common to those three groups of surgeries.

From the literature we could identify ASA class, BMI, preoperative length of stay (days) and diabetes as general risk factors. We added antibiotic use, age, Leukocyte, temperature and smoking status as to the list of general risk factors by using the results of the univariate analysis. These risk factors might have been overlooked should this study have focussed on only one type of surgery. Using this process, researchers may find useful risk factors to explain the future occurrence of SSI in their own environment, but not generally reported by literature of the specific type of surgery under investigation.

This study produced three prognostic prediction models (Equation 1 – 3) for the future occurrence of SSI within a 30 days period after undergoing one of the three group of surgical procedures. Using existing literature and the results of the univariate analysis, we identified general risk factors across three groups of surgical procedures and showed that the marginal contribution for models predicting SSI could be up to 9.5% in terms of discriminatory power by including surgery group specific risk factors. We also showed that this benefit can be measured in terms of reduced model error and ability to discriminate using the Gini as performance measure.

The initial results of the missing data analysis revealed that the variables relating to the CRP and Leukocyte levels have a sizeable amount of missing values. The difference in the preoperative length of

stay led us to believe that most of these missing values were caused by patients who did not stay sufficiently long in the hospital to have the laboratory tests before the surgical procedure took place. A possible explanation could be that most of the missing values were due to short-stay elective or emergence surgery patients or the absence of signs of infections which would lead to not requesting this chemical test. These laboratory tests are usually only done in case the patient is suspected of already having an infection. Our conclusion was that final model might be prone to overestimate the probability of SSI since the missing values were imputed using data from patients with greater risk of infection.

We used a 30-day outcome period in which we observe if an SSI was present or not, but according the CDC definition, this outcome period should be 1 year for surgical implantation procedures. Since our data only spans over 18 months, it was not possible to use a 12-month outcome windows for all surgical implantation procedures, which is a limitation of this study. Another limitation is that for all three groups of surgical procedures, the use of antibiotics is predictive of occurrence of SSI. This could mean that the patient is already fighting off some kind infection and is receiving treatment for a present condition which has nothing to do with the surgery under investigation. This study was performed in as a single centre study, which limits the generalisability of this study. Future research can repeat this research on multiple patient populations in order produce more generalisable results.

The predictive models were designed with the aim to use it to investigate more variables as potential risk factors for the future occurrence of SSI, 30 days after a surgical procedure. The administration of prophylaxis and the optimal timing thereof is an important risk factor however, these data were not available, but in future we recommend that these data should also be included in similar studies. Although some research has been done in this regard, to our knowledge, it has not been done for this patient population and confounders identified in this study.

The length of stay before a surgical procedure had mixed outcomes as a risk factor in the literature. Abuzaid et al. found it to be not significantly associated with SSI after isolated coronary artery bypass grafting, while Sang et al. found it to be highly significant [5,7]. Preoperative length of stay can also be a proxy for the severity of a patient's condition, if we assume that patients in worse conditions are more likely to have been in hospital for a longer period before undergoing a surgical procedure. This variable was significant in both the univariate and multivariate case for the orthopaedic surgeries group. The cause of the increased lengths of stay could be investigated as a potential modifiable risk factor.

Another opportunity for future research is to investigate which risk factors are predictive for the occurrence of SSI over different time periods. Doing this will enable healthcare workers to identify which risk factors explain the occurrence of SSI soon after surgery and which are better explain the occurrence of SSI nearing the end of the 30-day period or even later for implantation surgeries. This can help set guidelines to determine the vigilance necessary to mitigate the risk of SSI on a patient level.

Conclusion

We identified ASA class, body mass index (BMI), Preoperative length of stay, diabetes, antibiotic use, age, Leukocyte, temperature and smoking status as general risk factors common to digestive, orthopaedic and thoracic surgical procedures using existing literature and univariate logistic regression. We used a systematic approach to quantify the marginal contribution of the surgical procedure group specific risk factors using the results of a serial prevalence study and retrospective medical data. For digestive system surgical procedures, it is possible to increase the predictive power to explain the future occurrence of SSI by 9.5% by including CRP, thrombocyte, duration of the surgery and if the surgery will be elective or not. Pre-operative length of stay, antibiotic use and Leukocyte were significant general risk factor for the orthopaedic group of surgeries. Temperature, age and antibiotic use were significant general risk factors for the thoracic group of surgical procedures. Neither the orthopaedic nor the thoracic group of surgical procedures predictive risk factors unique to the group of surgeries. This is important because these results can help healthcare workers provided better preoperative counselling and aid researchers in identifying potentially modifiable risk factors in future research.

List Of Abbreviations

AIC Akaike information criterion

ASA American society of anaesthesiologists

ATC Anatomical therapeutic chemical

AUC Area under the curve

BSI Bloodstream infection

CDC Centers for disease control and prevention

CRP C-reactive protein

ECDC European centre for disease prevention and control

HAI Healthcare associated infection

ICP Infection control practitioner

LRTI Lower respiratory tract infection

MCAR Missing completely at random

MCMC Markov chain Monte Carlo

MEC Medical ethical committee

MeSH Medical subject headings

NHSN National health safety network

NII Nosocomial infection index

ROC Receiver operator characteristic

SAP Surgical antimicrobial prophylaxis

SSI Surgical site infections

SSI Surgical site infections

UTI Urinary tract infection

WBP Dutch personal data protection act

Declarations

Ethics approval and consent to participate

Approval from Medical Ethical Committee of Erasmus MC (MEC-2018-1185)

Consent for publication

All authors read and approved the manuscript.

Availability of data and material

The data that support the findings of this study are available from Erasmus MC but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Erasmus MC.

Competing interests

None

Funding

The research was funded by Interreg VA, EurHealth-1Health project (<http://www.eurhealth-1health.eu/>).

Author's contributions

JM, JEW, A and MC contributed to the conceptualization of the research and commenting on the draft and final version of the paper. MC contributed as the main medical expert and provided guidance on all medical aspects of this study, including sourcing and understanding the data. MC, LMA, AF contributed in editing and writing the draft and final version of the paper. JM performed the data analysis, statistical analysis and wrote the draft and final version of the paper.

Acknowledgements

We would like to thank C. P. (Conrad) van der Hoeven, A.G.D (Arnim) Mulder and M. (Marius) Vogel for their help and constant willingness to help with questions regarding the data used for this study. Also, thanks to R. H. (Roel) Streefkerk for the work done to organise and combine the data as well as producing the SSI outcome variable used in this study.

References

1. European Centre for Disease Prevention and Control. Surveillance of surgical site infections in European hospitals – HAISSI protocol [Internet]. 2012. 1-47 p. Available from: http://www.ecdc.europa.eu/en/publications/Publications/120215_TED_SSI_protocol.pdf
2. Zarb P, Coignard B, Griskeviciene J, Muller A, Vankerckhoven V, Weist K, et al. point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals. Vol. 17, *Eurosurveillance*. 2012. 1-16 p.
3. Jenks PJ, Laurent M, McQuarry S, Watkins R. Clinical and economic burden of surgical site infection (SSI) and predicted financial consequences of elimination of SSI from an English hospital. *J Hosp Infect*. 2014;86(1):24–33.
4. Westerman EL. Antibiotic prophylaxis in surgery: Historical background, rationale, and relationship to prospective payment. *Am J Infect Control*. 1984;12(6):339–43.
5. Leung S, Sang W, Chaturvedi R, Alam A, Samoukovic G, Varennes B De. Preoperative hospital length of stay as a modifiable risk factor for mediastinitis after cardiac surgery. *J Cardiothorac Surg* [Internet]. 2013;8(1):45. Available from: *Journal of Cardiothoracic Surgery*
6. Triantafyllopoulos G, Stundner O, Memtsoudis S, Poultsides LA. Patient, Surgery, and Hospital Related Risk Factors for Surgical Site Infections following Total Hip Arthroplasty. *Sci World J*. 2015;2015:1–9.
7. Abuzaid A, Zaki M, Al Tarief H. Potential risk factors for surgical site infection after isolated coronary artery bypass grafting in a Bahrain Cardiac Centre: A retrospective, case-controlled study. *Heart Views*. 2015;16(3):79.
8. Schimmel JJP, Horsting PP, de Kleuver M, Wonders G, van Limbeek J. Risk factors for deep surgical site infections after spinal fusion. *Eur Spine J*. 2010;19(10):1711–9.
9. Guohua X, cheng keping, Li J, Kong Q, Wang C, Nanyuan Y. Risk factors for surgical site infection in a teaching hospital: a prospective study of 1,138 patients. *Patient Prefer Adherence*. 2015;9:1171.
10. Gomila A, Carratalà J, Biondo S, Badia JM, Fracalvieri D, Shaw E, et al. Predictive factors for early- and late-onset surgical site infections in patients undergoing elective colorectal surgery. A multicentre, prospective, cohort study. *J Hosp Infect*. 2018;99(1):24–30.

11. Martin ET, Kaye KS, Knott C, Nguyen H, Santarossa M, Evans R, et al. Diabetes and Risk of Surgical Site Infection: A Systematic Review and Meta-analysis. *Infect Control Hosp Epidemiol*. 2016;37(01):88–99.
12. Takahashi Y, Takesue Y, Fujiwara M, Tatsumi S, Ichiki K, Fujimoto J, et al. Risk factors for surgical site infection after major hepatobiliary and pancreatic surgery. *J Infect Chemother* [Internet]. 2018;24(9):739–43. Available from: <https://doi.org/10.1016/j.jiac.2018.05.007>
13. Silvestri M, Dobrinja C, Scomersi S, Giudici F, Turollo A, Princic E, et al. Modifiable and non-modifiable risk factors for surgical site infection after colorectal surgery: a single-center experience. *Surg Today*. 2018;48(3):338–45.
14. Fukuda H. Patient-related risk factors for surgical site infection following eight types of gastrointestinal surgery. *J Hosp Infect* [Internet]. 2016;93(4):347–54. Available from: <http://dx.doi.org/10.1016/j.jhin.2016.04.005>
15. Kokudo T, Uldry E, Demartines N, Halkic N. Risk factors for incisional and organ space surgical site infections after liver resection are different. *World J Surg*. 2015;39(5):1185–92.
16. Isik O, Kaya E, Dundar HZ, Sarkut P. Surgical Site Infection: Re-assessment of the Risk Factors. *Chirurgia (Bucur)* [Internet]. 2015;110(5):457–61. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/26531790>
17. Moreno Elola-Olaso A, Davenport DL, Hundley JC, Daily MF, Gedaly R. Predictors of surgical site infection after liver resection: A multicentre analysis using National Surgical Quality Improvement Program data. *Hpb*. 2012;14(2):136–41.
18. Lola I, Levidiotou S, Petrou A, Arnaoutoglou H, Apostolakis E, Papadopoulos GS. Are there independent predisposing factors for postoperative infections following open heart surgery? *J Cardiothorac Surg* [Internet]. 2011;6(1):151. Available from: <http://cardiothoracicsurgery.biomedcentral.com/articles/10.1186/1749-8090-6-151>
19. Chen LF, Arduino JM, Sheng S, Muhlbaier LH, Kanafani ZA, Harris AD, et al. Epidemiology and outcome of major postoperative infections following cardiac surgery: Risk factors and impact of pathogen type. *Am J Infect Control*. 2012;40(10):963–8.
20. Jolivet S, Lescure FX, Armand-Lefevre L, Raffoul R, Dilly MP, Ghodbane W, et al. Surgical site infection with extended-spectrum β -lactamase-producing Enterobacteriaceae after cardiac surgery: incidence and risk factors. *Clin Microbiol Infect* [Internet]. 2018;24(3):289–94. Available from: <https://doi.org/10.1016/j.cmi.2017.07.004>
21. Streefkerk RHRA, Moorman PW, Parlevliet GA, van der Hoeven C, Verbrugh HA, Vos MC, et al. An Automated Algorithm to Preselect Patients to Be Assessed Individually in Point Prevalence Surveys for

- Hospital-Acquired Infections in Surgery. *Infect Control Hosp Epidemiol* [Internet]. 2014;35(7):886–7. Available from: <http://www.jstor.org/stable/info/10.1086/676868>
22. Streefkerk RHRA, Borsboom GJJM, van der Hoeven CP, Vos MC, Verkooijen RP, Verbrugh HA. Evaluation of an Algorithm for Electronic Surveillance of Hospital-Acquired Infections Yielding Serial Weekly Point Prevalence Scores. *Infect Control Hosp Epidemiol* [Internet]. 2014 [cited 2017 Jul 18];35(07):888–90. Available from: https://www.cambridge.org/core/product/identifier/S0899823X00192372/type/journal_article
23. Asendorpf JB, Van De Schoot R, Denissen JJA, Hutteman R. Reducing bias due to systematic attrition in longitudinal studies: The benefits of multiple imputation. *Int J Behav Dev*. 2014;38(5):453–60.
24. Buuren S Van. Multiple imputation of discrete and continuous. *Stat Methods Med Res*. 2007;16(3):219–42.
25. Fayyad UM, Irani KB. Multi-Interval Discretization of Continuous-Valued Attributes for Classification Learning. *Proc Int Jt Conf Uncertain AI*. 1993;1022–7.
26. Hosmer DW, Lemeshow S. *Applied logistic regression* [Internet]. Wiley. 2000. 118-128 p. Available from: <http://onlinelibrary.wiley.com/book/10.1002/9781118548387>
27. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*. 2014;143(1):29–36.
28. In Lee K, Koval JJ. Determination of the best significance level in forward stepwise logistic regression. *Commun Stat - Simul Comput*. 2007;26(2):559–75.
29. Liu J, Li N, Hao J, Li Y, Liu A, Wu Y, et al. Impact of the antibiotic stewardship program on prevention and control of surgical site infection during peri-operative clean surgery. *Surg Infect (Larchmt)*. 2018;19(3):326–33.

Appendix

Table 6: Variables identified from literature and present in the data sample by group of surgeries

Risk Factor	Found in data	Digestive System	Orthopaedic	Thoracic	Total
ASA class	1	1	1	1	3
BMI	1	1	1	1	3
Preoperative length of stay (days)	1	1	1	1	3
Diabetes	1	1	1	1	3
Age	1	1	1		2
Alcohol use	1	1	1		2
Duration of surgery	1	1	1		2
Gender	1	1	1		2
Heart disease	1		1	1	2
Highest Leukocyte	1	1		1	2
Liver disease	1	1		1	2
Smoking	1	1	1		2
Urgency	1	1		1	2
Hepatitis	1	1			1
Highest alkaline phosphatase	1	1			1
Highest CRP	1		1		1
Highest glucose	1	1			1
Highest haemoglobin	1	1			1
Highest protein	1	1			1
Highest temperature	1	1			1
Highest thrombocyte	1	1			1
Hyper tension	1	1			1
Immunosuppression			1	1	2
Anaesthesia			1		1
Antibiotic treatment in the previous 3 months				1	1
Bypass time				1	1
CDC Surgical wound classification (SWC)		1			1

Cerebrovascular accident		1	1
Chronic lung disease		1	1
Dialysis		1	1
Estimated blood loss (EBL) > 600ml	1		1
History of previous SSI		1	1
HIV		1	1
Hospitalization in the previous year		1	1
ICU admission during the preceding 6 months		1	1
Incision cleanness 2–4		1	1
Intraoperative hypothermia	1		1
Open fracture		1	1
Peripheral vascular disease		1	1
Postoperative ICU stay (days)		1	1
Preoperative open wound/infection	1		1
Previous coronary artery bypass graft surgery		1	1
Previous surgery		1	1
Prior operation on same joint		1	1
Re-admission to the CVICU		1	1
Revision or primary surgery		1	1
Spinal level of surgery		1	1
Surgery involving the sacrum or pelvis		1	1
Type of surgery procedure		1	1
Use of antibiotic prophylaxis		1	1

Table 7: Digestive system univariate analysis preoperative and operative characteristic for the future occurrence of SSI

Characteristic	SSI = Yes	SSI = No	Univariate OR (95%CI, p-value)
Gender			
Female	433 (42.9)	40 (37.7)	
Male	577 (57.1)	66 (62.3)	1.24 (0.82-1.88, p=0.309)
Age			
23	310 (30.7)	9 (8.5)	
23	700 (69.3)	97 (91.5)	4.77 (2.51-10.28, p<0.001)
ASA class			
ASA CLASS I	140 (13.9)	6 (5.7)	
ASA CLASS II	452 (44.8)	46 (43.4)	2.37 (1.07-6.31, p=0.052)
ASA CLASS III	343 (34.0)	40 (37.7)	2.72 (1.21-7.28, p=0.026)
ASA CLASS IV	75 (7.4)	14 (13.2)	4.36 (1.67-12.73, p=0.004)
BMI	23.7 (5)	24.2 (4.4)	1.02 (0.98-1.06, p=0.286)
Alcohol use			
Current	473 (46.8)	47 (44.3)	
Never	457 (45.2)	51 (48.1)	1.12 (0.74-1.71, p=0.585)
Past	80 (7.9)	8 (7.5)	1.01 (0.43-2.10, p=0.987)
Smoking			
Current	492 (48.7)	67 (63.2)	
Never	337 (33.4)	20 (18.9)	0.44 (0.25-0.72, p=0.002)
Past	181 (17.9)	19 (17.9)	0.77 (0.44-1.29, p=0.342)
Heart disease			
No	960 (95.0)	97 (91.5)	
Yes	50 (5.0)	9 (8.5)	1.78 (0.80-3.57, p=0.126)
Liver disease			
No	967 (95.7)	101 (95.3)	
Yes	43 (4.3)	5 (4.7)	1.11 (0.38-2.63, p=0.825)
Hepatitis			
No	980 (97.0)	105 (99.1)	

Yes	30 (3.0)	1 (0.9)	0.31 (0.02-1.47, p=0.253)
Hyper tension			
No	841 (83.3)	90 (84.9)	
Yes	169 (16.7)	16 (15.1)	0.88 (0.49-1.50, p=0.666)
Diabetes			
No	931 (92.2)	93 (87.7)	
Yes	79 (7.8)	13 (12.3)	1.65 (0.85-2.98, p=0.117)
Highest temperature			
38	647 (64.1)	28 (26.4)	
(38,39]	243 (24.1)	40 (37.7)	3.80 (2.31-6.36, p<0.001)
39	120 (11.9)	38 (35.8)	7.32 (4.34-12.47, p<0.001)
Highest CRP			
164	905 (89.6)	75 (70.8)	
164	105 (10.4)	31 (29.2)	3.56 (2.22-5.63, p<0.001)
Highest Leukocyte	12.2 (7.4)	12.2 (7.6)	1.00 (0.97-1.03, p=0.992)
Highest protein			
57	321 (31.8)	53 (50.0)	
57	689 (68.2)	53 (50.0)	0.47 (0.31-0.70, p<0.001)
Highest Leukocyte	149.8 (128.7)	138.2 (108.6)	1.00 (1.00-1.00, p=0.372)
Highest glucose			
8.2	494 (48.9)	31 (29.2)	
8.2	516 (51.1)	75 (70.8)	2.32 (1.51-3.63, p<0.001)
Highest haemoglobin	7.9 (1.3)	7.9 (1.2)	1.02 (0.88-1.19, p=0.758)
Highest thrombocyte			
225	692 (68.5)	95 (89.6)	
225	318 (31.5)	11 (10.4)	0.25 (0.13-0.46, p<0.001)
Preoperative length of stay (days)	7.2 (26.1)	10.1 (32.8)	1.00 (1.00-1.01, p=0.286)
Antibiotic use			
No	581 (57.5)	19 (17.9)	

Yes	429 (42.5)	87 (82.1)	6.20 (3.80-10.64, p<0.001)
Urgency			
Elective	548 (54.3)	34 (32.1)	
Emergency	462 (45.7)	72 (67.9)	2.51 (1.65-3.89, p<0.001)
Duration of surgery			
530	971 (96.1)	89 (84.0)	
530	39 (3.9)	17 (16.0)	4.76 (2.53-8.62, p<0.001)

Table 8: Orthopaedic surgical procedures univariate analysis preoperative and operative characteristic for the future occurrence of SSI

Characteristic	SSI = Yes	SSI = No	Univariate OR (95%CI, p-value)
Gender			
Female	404 (42.9)	10 (35.7)	
Male	537 (57.1)	18 (64.3)	1.35 (0.63-3.08, p=0.448)
Age	49 (21.4)	48.4 (18)	1.00 (0.98-1.02, p=0.880)
ASA class			
ASA CLASS I	254 (27.0)	9 (32.1)	
ASA CLASS II	411 (43.7)	9 (32.1)	0.62 (0.24-1.60, p=0.314)
ASA CLASS III	247 (26.2)	8 (28.6)	0.91 (0.34-2.43, p=0.856)
ASA CLASS IV	29 (3.1)	2 (7.1)	1.95 (0.29-8.02, p=0.409)
BMI	25.8 (5)	27.2 (4.6)	1.06 (0.98-1.13, p=0.140)
Alcohol use			
Current	486 (51.6)	16 (57.1)	
Never or Past	455 (48.4)	12 (42.9)	0.80 (0.37-1.70, p=0.567)
Smoking			
Current	379 (40.3)	12 (42.9)	
Never	325 (34.5)	11 (39.3)	1.07 (0.46-2.47, p=0.875)
Past	237 (25.2)	5 (17.9)	0.67 (0.21-1.82, p=0.451)
Heart disease			
No	889 (94.5)	26 (92.9)	
Yes	52 (5.5)	2 (7.1)	1.32 (0.21-4.57, p=0.714)
Liver disease			
No	914 (97.1)	27 (96.4)	
Yes	27 (2.9)	1 (3.6)	1.25 (0.07-6.24, p=0.827)
Hyper tension			
No	781 (83.0)	23 (82.1)	
Yes	160 (17.0)	5 (17.9)	1.06 (0.35-2.62, p=0.906)
Diabetes			
No	864 (91.8)	25 (89.3)	

Yes	77 (8.2)	3 (10.7)	1.35 (0.32-3.95, p=0.633)
Highest temperature			
38	747 (79.4)	15 (53.6)	
38	194 (20.6)	13 (46.4)	3.34 (1.54-7.14, p=0.002)
Highest CRP			
144	883 (93.8)	20 (71.4)	
144	58 (6.2)	8 (28.6)	6.09 (2.44-13.96, p<0.001)
Highest Leukocyte			
17.3	820 (87.1)	17 (60.7)	
17.3	121 (12.9)	11 (39.3)	4.39 (1.95-9.48, p<0.001)
Highest protein	62.2 (10.4)	59.5 (11)	0.98 (0.94-1.01, p=0.181)
Highest alkaline phosphatase	89.8 (72.3)	79.6 (40.9)	1.00 (0.99-1.00, p=0.455)
Highest glucose	8.6 (3)	9.2 (4)	1.06 (0.94-1.17, p=0.282)
Highest haemoglobin	8.1 (1.2)	7.9 (1.3)	0.90 (0.65-1.24, p=0.510)
Highest thrombocyte	185 (94.2)	157.8 (90.2)	1.00 (0.99-1.00, p=0.134)
Preoperative length of stay (days)			
7	853 (90.6)	16 (57.1)	
7	88 (9.4)	12 (42.9)	7.27 (3.27-15.79, p<0.001)
Antibiotic use			
No	720 (76.5)	11 (39.3)	
Yes	221 (23.5)	17 (60.7)	5.03 (2.35-11.23, p<0.001)
Urgency			
Elective	433 (46.0)	11 (39.3)	
Emergency	508 (54.0)	17 (60.7)	1.32 (0.62-2.93, p=0.483)
Duration of surgery	205.4 (111.2)	199.6 (108.6)	1.00 (1.00-1.00, p=0.788)

Table 9: Thoracic surgical procedures univariate analysis preoperative and operative characteristic for the future occurrence of SSI

Characteristic	SSI = Yes	SSI = No	Univariate OR (95%CI, p-value)
Gender			
Female	406 (36.0)	13 (34.2)	
Male	721 (64.0)	25 (65.8)	1.08 (0.56-2.20, p=0.819)
Age			
17	246 (21.8)	17 (44.7)	
17	881 (78.2)	21 (55.3)	0.34 (0.18-0.67, p=0.001)
ASA class			
ASA CLASS II	212 (18.8)	5 (13.2)	
ASA CLASS III	649 (57.6)	20 (52.6)	1.31 (0.52-3.96, p=0.597)
ASA CLASS IV	266 (23.6)	13 (34.2)	2.07 (0.77-6.54, p=0.173)
BMI	24.9 (5.1)	24.1 (4.8)	0.97 (0.91-1.03, p=0.323)
Alcohol use			
Current	743 (65.9)	26 (68.4)	
Never	333 (29.5)	8 (21.1)	0.69 (0.29-1.47, p=0.359)
Past	51 (4.5)	4 (10.5)	2.24 (0.64-6.03, p=0.147)
Smoking			
Current	525 (46.6)	22 (57.9)	
Never	316 (28.0)	13 (34.2)	0.98 (0.48-1.95, p=0.959)
Past	286 (25.4)	3 (7.9)	0.25 (0.06-0.73, p=0.025)
Hyper tension			
No	818 (72.6)	29 (76.3)	
Yes	309 (27.4)	9 (23.7)	0.82 (0.36-1.69, p=0.612)
Diabetes			
No	1012 (89.8)	33 (86.8)	
Yes	115 (10.2)	5 (13.2)	1.33 (0.45-3.20, p=0.557)
Highest temperature			
37	316 (28.0)	2 (5.3)	
(37,38]	612 (54.3)	20 (52.6)	5.16 (1.50-32.47, p=0.027)

38	199 (17.7)	16 (42.1)	12.70 (3.56-80.90, p=0.001)
Highest CRP	30.5 (60)	40.6 (61.6)	1.00 (1.00-1.01, p=0.313)
Highest Leukocyte	11.2 (6.6)	12 (6.2)	1.02 (0.97-1.06, p=0.470)
Highest protein	65.6 (9.5)	65.4 (9.7)	1.00 (0.97-1.03, p=0.865)
Highest alkaline phosphatase	92.1 (86.1)	114.1 (114.7)	1.00 (1.00-1.00, p=0.134)
Highest glucose	10.3 (3.2)	10.5 (2.8)	1.02 (0.92-1.12, p=0.684)
Highest haemoglobin	8.3 (1.1)	8.2 (1.4)	0.97 (0.72-1.28, p=0.814)
Highest thrombocyte	243.3 (102.5)	233 (110.8)	1.00 (1.00-1.00, p=0.545)
Preoperative length of stay (days)	6.4 (21.9)	5.5 (11.1)	1.00 (0.97-1.01, p=0.806)
Antibiotic use			
No	750 (66.5)	19 (50.0)	
Yes	377 (33.5)	19 (50.0)	1.99 (1.04-3.82, p=0.037)
Urgency			
Elective	605 (53.7)	14 (36.8)	
Emergency	522 (46.3)	24 (63.2)	1.99 (1.03-3.98, p=0.044)
Duration of surgery	291.6 (126.7)	270.1 (156.2)	1.00 (1.00-1.00, p=0.307)