Original Article

Risk Factors and Independent Predictors of Surgical Site Infection Following Abdominal Surgery: A Prospective Observational Cohort Study

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Abstract

Background: A surgical site infection (SSI) is a frequent postoperative complication after abdominal operations. It leads to morbidity, to longer hospital stays or to higher health care costs. The aim of this study was to calculate the rate of SSI and establish independent predictors following abdominal surgery. **Material and Methods:** Prospective observational study of 300 adult patients with elective or emergency abdominal surgery was carried out at a tertiary care teaching hospital. Patients were followed up for 30 days post-surgery and SSI diagnosed following the Centers for Disease Control and Prevention (CDC) criteria. Univariable and multivariable logistic regression analyses were carried out to identify independent risk factors for SSI. **Results:** 46 patients out of 300 patients in the study developed SSI with an incidence rate of 15.3%. The most common subtype of SSI was superficial incisional (52.2%). Multivariable analysis identified advanced age (aOR 1.36, 95% CI 1.08–1.72), diabetes mellitus (aOR 2.44, 95% CI 1.25–4.76), obesity (aOR 2.16, 95% CI 1.09–4.30), hypoalbuminemia (aOR 2.58, 95% CI 1.28–5.20), ASA class III–IV (aOR 2.80, 95% CI 1.36–5.77), emergency surgery (aOR 2.27, 95% CI 1.19–4.35), operative duration $\geq$120 minutes (aOR 2.98, 95% CI 1.53–5.81), and contaminated/dirty wounds (aOR 2.36, 95% CI 1.19–4.67) as independent predictors of SSI (all $p<0.05$). Appropriate perioperative antimicrobial prophylaxis was found to significantly decrease the risk of SSI (aOR 0.44, 95% CI 0.21–0.93). The discrimination of the prediction model was excellent (AUC=0.862). **Conclusion:** SSI is still a relevant type of complication after abdominal surgery. Timely identification of high-risk patients, optimization of modifiable risk factors, and following evidence-based principles for perioperative infection prevention could spare people from postoperative SSIs and enhance surgical outcomes.

Keywords: Surgical site infection; Abdominal surgery; Risk factors; Predictors; Prospective study; Logistic regression.

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Introduction

Surgical site infection (SSI) is one of the most prevalent and common healthcare-associated infections and is one of the largest contributors to post-operative morbidity, hospital stay, healthcare costs and death globally.[1,2] The World Health Organization (WHO) estimated that SSI represents a significant fraction of nosocomial infections and could be responsible for more than 20% of infections in certain surgical populations in low- and middle-income countries.[3,4] A number of factors contribute to the comparatively high risk of SSI after abdominal surgery, such as contamination with endogenous gastrointestinal flora, extensive tissue manipulation, long surgical time, and the presence of emergency surgery and contaminated surgical wound.[5,6]

SSI has a negative impact on the clinical outcomes and healthcare systems. Patients who develop SSI have a higher rate of reoperation, prolonged antibiotic therapy, intensive postoperative care and rehospitalization, and higher antibiotic treatment costs, and are likely to experience a significant reduction in quality of life.[7,8] Moreover, SSI is associated with longer hospital stay, post-operative disability and increased mortality, making its prevention influential criterion of surgical quality, and patient safety.[9,10]

Multifactorial, an intricate relationship between patient-related, procedural and microbial factors is responsible for the development of SSI. Multiple parameters such as advanced age, diabetes mellitus, obesity, malnourishment, anemia, smoking habits, immunosuppression and hypoalbuminemia have consistently been found to be associated with higher risk to postoperative wound infection.[11,12] Additional risk factors for SSIs are surgical characteristics of emergency surgery, duration of surgery, contaminated or dirty wounds, blood loss during surgery, blood transfusion in the perioperative period and inappropriate timing of antibiotic prophylaxis.[13] Although there have been many preventive measures proposed through international recommendations, the clinical load of SSI remains high indicating that there is a wide variation in risk factors in different healthcare settings and patient groups.[14]

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International organizations have issued evidence-based guidelines that have focused on peri-operative precautions for preventing infections, including proper antimicrobial prophylaxis, use of skin antisepsis, maintenance of normothermia, glycemic control and surgical technique.[2,10] Even with implementation of these recommendations, SSI rates can vary and factors such as patient risk factors, practice techniques of health care providers, and the types of microbes present in the hospital and the availability of resources are all significant. Therefore, it is important to identify locally relevant predictors to implement preventive interventions and optimize of the peri-operative management.

Prospective observational studies offer a chance to assess whether there are temporal associations between peri-operative risk factors and the development of SSI minimizing recall bias and while data was collected using a standardized protocol. Prospective assessment can help identify independent risk factors for infection to help stratify patients, aid clinical decision-making and implement individual infection prevention strategies. The aim of the present prospective observational study was to assess the incidence of surgical site infection after abdominal surgery and to explore the independent predictors of surgical site infection early in the perioperative period.

Materials and Methods

Study setting and study design: Prospective observational study was conducted in the department of General Surgery of a tertiary care teaching hospital. Patients were selected and included in the study as they underwent elective or abdominal surgery due to an emergency, by consecutive sampling for adult patients (aged 18 years or older). It excluded patients who had previous surgical site infection, minor surgery (no incision required), incomplete perioperative data, or had either dropped out of the scan in the first 30 days after the surgery or were lost to follow-up. The study was approved by the Institutional Ethics Committee and informed written consent was signed by all the respondents.

Data collection and outcome assessment: Baseline demographic data and aspects of comorbidities (such as diabetes mellitus, hypertension, obesity, anemia, smoking status), American Society of Anesthesiologists (ASA) General Physical Status, laboratory parameters and peri operative variables including type of surgery (elective/emergency), operating time, blood loss, blood transfusion, antimicrobial prophylaxis and placement of drain were recorded on a uniformly defined case record sheet. The postoperative period lasted for 30 days. Surgical site infections (SSIs) were classified based on the Centers for Disease Control and Prevention (CDC) definition: superficial incisional, deep incisional and organ/space.

Statistical analysis: Statistical data were analysed by IBM SPSS Statistics version 29 (IBM Corp., Armonk, NY, USA). The continuous variables were expressed as mean ± standard deviation or median (interquartile range) while categorical variables were expressed as frequencies and percentages. Independent T-test and Mann Whitney U test were used to compare continuous data and the chi-square test and Fisher's exact test were used to compare the categorical data between the patients who developed SSI and those who did not. Univariable analysis was used to identify variables with p value < 0.20, as well as clinically relevant covariates; those were then included in a multivariable logistic regression model to assess the independent predictors of SSI. The Hosmer–Lemeshow goodness-of-fit test (HL) and the area of the receiver operating characteristic curve (AUC) were used to evaluate model performance. Odds ratios adjusted for model and 95% confidence intervals (CIs) are reported and a P value < 0.05 is considered statistically significant.

Ethical Considerations: This study followed the principles of Declaration of Helsinki (2013 revision) and was reported according to the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting observational research. Participants were kept anonymous in the study and data were anonymized before statistical analysis.

Results

Finally, 300 patients who underwent abdominal surgery were included, with a 100% 30-day follow-up obtained after surgery. The incidence of surgical site infection (SSI) was 46 patients (15.3%) and an uncomplicated postoperative course was seen in 254 patients (84.7%). Demographic parameters, peri-operative factors and outcomes were systematically assessed to identify factors associated with SSI.

The baseline demographic and clinical data for the study population are summarized in [Table 1]. The majority of patients had elective open abdominal surgery at a mean age of 49.8 ± 15.6 years with a higher proportion of male patients.

In [Table 2], the clinical profile and outcome of patients with SSI are presented. Most of the infections were superficial incisional SSIs (during the first week after surgery); a few infections led to reoperation and/or intensive care unit admission.

The results of the univariable analysis that compared patients with SSI against those without an SSI are shown in [Table 3]. A higher ASA grade, public lap of wound, blood transfusion, emergency surgery, more advanced patient age, longer surgery, diabetes mellitus, and hypoalbuminemia were significantly associated with the occurrence of SSI.

Results of the multivariable logistic regression analysis for the identification of independent factors associated with SSI are presented in [Table 4]. Diabetes mellitus, obesity, hypoalbuminemia, higher ASA class, emergency surgery, contaminated wound classification, and increasing age brought a higher risk of SSI, while appropriate antimicrobial prophylaxis reduced the risk of SSI, which remained significant after adjustment for the confounding variables.

The incidence of SSI in clinically relevant patient subgroups is provided [Table 5]. Patients older than 60 years at surgery, obese, diabetics, patients who underwent emergency surgery, prolonged operative procedures, or contaminated/dirty wounds had significantly increased postoperative SSI rates.

The monthly trend of abdominal surgeries and incidence of SSI are shown in [Figure 1]. Overall incidence of SSI was 15.3% while modest temporal variation existed.

The distribution of microorganisms isolated in culture from cases of SSI is illustrated in [Figure 2]. The predominant pathogen was Escherichia coli followed by Klebsiella pneumoniae and Staphylococcus aureus, with gram-negative organisms making up the bulk of the isolates.

The results show operative time as the X-axis and predicted probability of SSI as the Y-axis [Figure 3]. Infection rates rose gradually and with an increasing length of operation, especially when longer than 120 minutes, which is the same trend found in the multivariable modelling of the data.

Table 1: Baseline demographic and clinical characteristics of the study population (N = 300)

Variable	Category/Unit	Value
Age (years)	Mean ± SD	49.8 ± 15.6
Age group, n (%)	18–39 years	78 (26.0)
	40–59 years	124 (41.3)
	≥60 years	98 (32.7)
Sex, n (%)	Male	176 (58.7)
	Female	124 (41.3)
Body mass index (kg/m²)	Mean ± SD	25.7 ± 4.8
BMI category, n (%)	<18.5	18 (6.0)
	18.5–24.9	132 (44.0)
	25.0–29.9	101 (33.7)
	≥30.0	49 (16.3)
Smoking status, n (%)	Current smoker	82 (27.3)
	Non-smoker	218 (72.7)
Alcohol consumption, n (%)	Yes	64 (21.3)
	No	236 (78.7)
Diabetes mellitus, n (%)	Yes	86 (28.7)
	No	214 (71.3)
Hypertension, n (%)	Yes	92 (30.7)
	No	208 (69.3)
Anemia (Hb <10 g/dL), n (%)	Yes	70 (23.3)
	No	230 (76.7)
Serum albumin (g/dL)	Mean ± SD	3.72 ± 0.54
ASA physical status, n (%)	I	74 (24.7)
	II	145 (48.3)
	III	69 (23.0)
	IV	12 (4.0)
Type of surgery, n (%)	Elective	198 (66.0)
	Emergency	102 (34.0)
Surgical approach, n (%)	Open	214 (71.3)
	Laparoscopic	86 (28.7)
Operative duration (minutes)	Mean ± SD	118.4 ± 39.6
Estimated blood loss (mL)	Median (IQR)	220 (150–360)
Perioperative blood transfusion, n (%)	Yes	46 (15.3)
	No	254 (84.7)
Surgical drain inserted, n (%)	Yes	158 (52.7)
	No	142 (47.3)
Wound classification, n (%)	Clean	38 (12.7)
	Clean-contaminated	172 (57.3)
	Contaminated	63 (21.0)
	Dirty	27 (9.0)
Hospital stay (days)	Median (IQR)	7 (5–10)
Thirty-day follow-up completed, n (%)	Yes	300 (100.0)

Table 2: Characteristics and clinical outcomes of surgical site infections (n = 46)

Variable	Category	Value
Overall SSI incidence	Cases/Total (%)	46/300 (15.3)
Time to SSI diagnosis (days)	Median (IQR)	7 (5–11)
CDC classification, n (%)	Superficial incisional	24 (52.2)
	Deep incisional	15 (32.6)
	Organ/space	7 (15.2)
Method of diagnosis, n (%)	Clinical examination only	18 (39.1)
	Clinical + microbiological confirmation	28 (60.9)
Positive wound culture, n (%)	Yes	39 (84.8)
	No growth	7 (15.2)
Polymicrobial infection, n (%)	Yes	9 (19.6)
	No	37 (80.4)
Antibiotic modification after culture, n (%)	Yes	31 (67.4)

	No	15 (32.6)
Surgical wound debridement required, n (%)	Yes	17 (37.0)
	No	29 (63.0)
Reoperation due to SSI, n (%)	Yes	8 (17.4)
	No	38 (82.6)
Intensive care admission, n (%)	Yes	6 (13.0)
	No	40 (87.0)
Duration of postoperative antibiotic therapy (days)	Median (IQR)	9 (7–13)
Length of hospital stay (days)	Median (IQR)	14 (11–19)
Thirty-day readmission, n (%)	Yes	10 (21.7)
	No	36 (78.3)
Thirty-day mortality, n (%)	Yes	2 (4.3)
	No	44 (95.7)
Complete wound healing within 30 days, n (%)	Yes	34 (73.9)
	No	12 (26.1)

Table 3: Univariable analysis of factors associated with surgical site infection following abdominal surgery

Variable	SSI (n = 46)	No SSI (n = 254)	Crude OR (95% CI)	P value
Age (years), mean ± SD	57.9 ± 14.3	48.3 ± 15.2	1.04 (1.02–1.07)*	<0.001
Male sex, n (%)	31 (67.4)	145 (57.1)	1.56 (0.80–3.05)	0.187
BMI ≥30 kg/m², n (%)	15 (32.6)	34 (13.4)	3.12 (1.53–6.39)	0.001
Current smoker, n (%)	21 (45.7)	61 (24.0)	2.66 (1.37–5.18)	0.003
Diabetes mellitus, n (%)	24 (52.2)	62 (24.4)	3.39 (1.76–6.55)	<0.001
Hypertension, n (%)	20 (43.5)	72 (28.3)	1.95 (1.01–3.79)	0.046
Anemia (Hb <10 g/dL), n (%)	19 (41.3)	51 (20.1)	2.80 (1.43–5.49)	0.002
Serum albumin <3.5 g/dL, n (%)	23 (50.0)	56 (22.0)	3.55 (1.84–6.85)	<0.001
ASA class III–IV, n (%)	25 (54.3)	56 (22.0)	4.20 (2.16–8.17)	<0.001
Emergency surgery, n (%)	26 (56.5)	76 (29.9)	3.05 (1.59–5.84)	<0.001
Open surgery, n (%)	40 (87.0)	174 (68.5)	3.08 (1.26–7.53)	0.010
Operative duration ≥120 min, n (%)	31 (67.4)	89 (35.0)	3.84 (1.98–7.45)	<0.001
Estimated blood loss ≥300 mL, n (%)	22 (47.8)	53 (20.9)	3.47 (1.79–6.73)	<0.001
Perioperative blood transfusion, n (%)	15 (32.6)	31 (12.2)	3.47 (1.66–7.24)	<0.001
Surgical drain inserted, n (%)	34 (73.9)	124 (48.8)	2.97 (1.46–6.05)	0.002
Contaminated/dirty wound class, n (%)	24 (52.2)	66 (26.0)	3.12 (1.62–6.03)	<0.001
Appropriate antimicrobial prophylaxis, n (%)	34 (73.9)	219 (86.2)	0.46 (0.21–0.99)	0.044

Table 4: Multivariable logistic regression analysis identifying independent predictors of surgical site infection following abdominal surgery (N = 300)

Predictor Variable	β Coefficient	Standard Error	Wald χ²	Adjusted OR (95% CI)	P value
Age (per 10-year increase)	0.31	0.12	6.68	1.36 (1.08–1.72)	0.010
Diabetes mellitus	0.89	0.34	6.84	2.44 (1.25–4.76)	0.009
BMI ≥30 kg/m²	0.77	0.35	4.84	2.16 (1.09–4.30)	0.028
Serum albumin <3.5 g/dL	0.95	0.36	7.01	2.58 (1.28–5.20)	0.008
ASA class III–IV	1.03	0.37	7.75	2.80 (1.36–5.77)	0.005
Emergency surgery	0.82	0.33	6.18	2.27 (1.19–4.35)	0.013
Operative duration ≥120 min	1.09	0.34	10.28	2.98 (1.53–5.81)	0.001
Contaminated/dirty wound class	0.86	0.35	6.03	2.36 (1.19–4.67)	0.014
Appropriate antimicrobial prophylaxis	−0.82	0.38	4.66	0.44 (0.21–0.93)	0.031

Performance of the Final Logistic Regression Model

Model Performance Parameter	Value
Hosmer–Lemeshow goodness-of-fit χ² (df = 8)	6.21
Hosmer–Lemeshow P value	0.624
Nagelkerke R²	0.412
Cox & Snell R²	0.278
Area under ROC curve (AUC) (95% CI)	0.862 (0.804–0.919)
Overall classification accuracy	86.3%
Sensitivity	78.3%
Specificity	88.2%
Positive predictive value (PPV)	55.4%
Negative predictive value (NPV)	95.2%

Table 5: Subgroup analysis of the incidence of surgical site infection according to clinically relevant perioperative characteristics (N = 300)

Subgroup	Total Patients (n)	SSI Cases, n (%)	Relative Risk (95% CI)	P value
Age				
<60 years	202	22 (10.9)	Reference	—

≥60 years	98	24 (24.5)	2.25 (1.34–3.77)	0.002
Body Mass Index				
<30 kg/m²	251	31 (12.4)	Reference	—
≥30 kg/m²	49	15 (30.6)	2.47 (1.46–4.18)	<0.001
Diabetes Mellitus				
No	214	22 (10.3)	Reference	—
Yes	86	24 (27.9)	2.72 (1.61–4.59)	<0.001
Type of Surgery				
Elective	198	20 (10.1)	Reference	—
Emergency	102	26 (25.5)	2.52 (1.49–4.26)	<0.001
Operative Duration				
<120 minutes	180	15 (8.3)	Reference	—
≥120 minutes	120	31 (25.8)	3.10 (1.78–5.39)	<0.001
Wound Classification				
Clean/Clean-contaminated	210	22 (10.5)	Reference	—
Contaminated/Dirty	90	24 (26.7)	2.54 (1.51–4.27)	<0.001

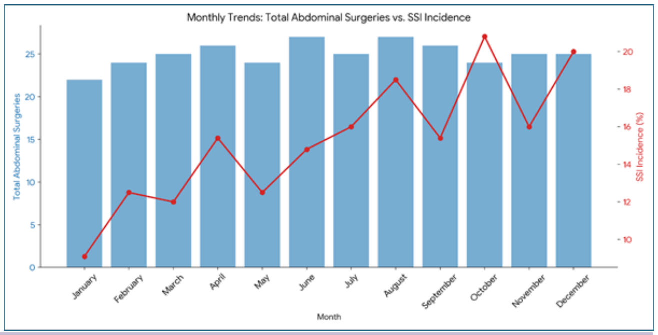

Figure 1: Monthly trend in abdominal surgeries and surgical site infection incidence during the study period

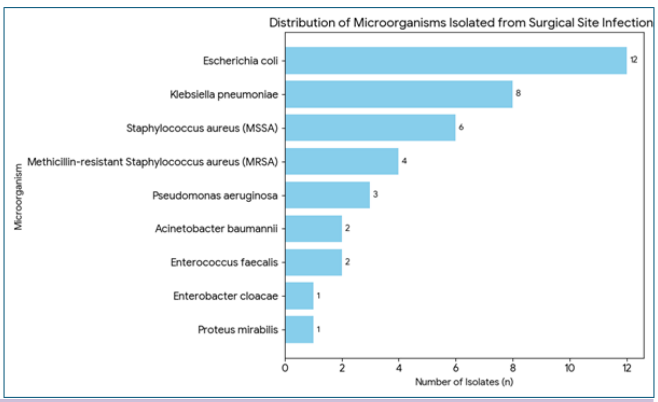

Figure 2: Distribution of microorganisms isolated from surgical site infections (n = 39 culture-positive isolates)

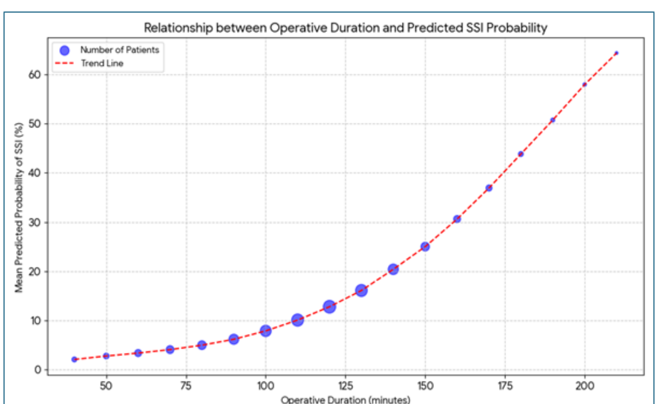

Figure 3: Relationship between operative duration and predicted probability of surgical site infection

Discussion

In spite of the progress in perioperative care, SSI is still one of the rarest causes of postoperative morbidity after abdominal surgery. The overall incidence of SSI in this prospective observational study was 15.3% and superficial incisional SSI was the most prevalent type. Factors associated with the presence of SSI were independent predictors of advanced age, obesity, diabetes mellitus, hypoalbuminemia, higher ASA grade, emergency surgery, longer operative time and contaminated or dirty wound, while adequate perioperative antimicrobial prophylaxis was found to significantly decrease the risk of SSI.

Our study results corroborate recent data on the SSI incidence. According to Marzoug et al,[3] the rate of SSI after abdominal surgery is usually approximately 10-25% and varies with patient risk factors and the surgical procedure involved. Likewise, Nigerian Surgical Research Collaborative,[6] and Nakhleh et al,[2] showed that SSI was a post-operative commonplace in LMIC countries, highlighting the impact of emergency surgeries, wound contamination, and comorbidities. This supports the clinical importance of the burden of SSI seen within the cohort.

The risk of SSI was positively associated with age, and with delayed wound healing and immune response. This result corroborates that of the nationwide prospective cohort study conducted by Yang et al,[4] and a systematic review of contemporary studies performed by Xu et al,[5] which showed age to be an important factor in prediction models nationwide.

Additionally, obesity and DMT were independent predictors in our study. Obesity has a negative impact on tissue perfusion and has a negative effect on the complexity of the surgical procedure, whereas diabetes affects the immune system and wound healing. Such connections have been repeatedly observed by research groups, such as Marzoug et al,[3] Yang et al,[4] and Zhang et al,[11] and are considered to be risk factors after abdominal surgery.

Hypophysiological and nutritional state also significantly affected the occurrence of SSI. Hypoalbuminemia and ASA class III-IV grade patients were at significantly high risk of developing postoperative infection, thus the need for preoperative optimization. Xu et al,[5] and McLean et al,[8] showed similar results and that risk stratification models for SSIs are considerably strengthened by nutritional related factors and ASA classification.

Emergency surgery, the operative length ≥120 min, and contaminated/dirty wounds were still significant independent factors after considering other operative factors. These findings are in accordance with the findings of Yang et al,[4] and Marzoug et al,[3] who also found operative complexity, operative time, and wound contamination as the major factors associated with SSI. Friedlander et al,[6] also observed in their Nigerian Research that operating room time, operative complexity, and wound contamination were found to be the preeminent factors associated with SSI.

Appropriate peri-operative antimicrobial prophylaxis reduced the incidence of postoperative SSI in our cohort; thus, evidence-based infection prevention was crucial. The NIHR Global Health Research Unit on Global Surgery reported similar findings in the ChEETAh trial,[1] and standardized SSI surveillance and preventative measures have also been shown to greatly enhance postoperative outcomes, as reported by Mehtar et al.[14] The work by Qin et al,[9] has also shown that optimizing operative techniques are contributing to the reduction of SSI after abdominal surgery.

The final multivariable model had very good predictive capacity (AUC = 0.862), suggesting good discrimination between patients who did and did not develop SSI. Other studies, such as those of Yang et al,[4] have reported similar findings, and systematic reviews by Xu et al,[5] and McLean et al,[8] have demonstrated that multivariable models that include demographic, physiological, and operative risk factors are reliable for risk stratification and can be used as tools for individualised data-driven prevention strategies.

Overall, our results further support the notion that many patient and procedure factors play roles in the development of SSI after abdominal surgery. Depending on the surgical procedure, surgical outcomes can be significantly enhanced and reduce the incidence of postoperative SSI if the patient is identified as being at high risk, their nutrition and metabolic status optimized, antimicrobial prophylaxis adopted, and careful perioperative care provided.

Limitations: Findings of this study may not be generalizable due to the study's single-site tertiary-care centre. Some potential unmeasured variables precluding complete exclusion of residual confounding of major perioperative variables were collected prospectively. Moreover, the prediction model needs to be externally validated in larger multicentered cohorts before application to wider use in the clinic.

Conclusion

A common reason for surgical infection is a skin incision, and viral and fungal infections account for about one-fifth of hospital-acquired infections, as well as surgical site infections. Surgical site infection is a frequent postoperative infection in abdominal surgery, accounting for approximately 20% of the cases in this cohort, with viral and fungal infections accounting for approximately 20% of hospital-acquired infections. A positive trend was observed for postoperative wound infections associated with inappropriate antimicrobial prophylaxis, while complete preoperative wound cleaning and soiled/soiled wounds were also independently associated with infections. With the exception of these four factors, no other factors were found to be independently associated with postsurgical wound infections. Advanced age, obesity, diabetes mellitus, and higher ASA PS were independently associated with SSI, although appropriate perioperative antimicrobial prophylaxis was a significant protective factor against the infection.

The findings highlight the need to undertake an integrated preoperative risk assessment, optimise patient-related risk factors, and closely follow evidence-based perioperative infection prevention measures. The multivariable prediction model performed very well as a discriminatory predictor and has the potential to be used as a predictor tool for selecting high-risk persons to respond to targeted preventive interventions. The model should be validated in other large and diverse cohorts from different centres to generalize results and increased the applicability in other healthcare settings in the future.

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Conflicts of interest

There are no conflicts of interest.

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