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Retrospective Study

Risk Factors and Prediction Model for Inpatient Surgical Site Infection after Elective Abdominal Surgery

Prediction Model for SSI

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Abstract

BACKGROUND

Surgical site infections (SSIs) are the commonest healthcare-associated infection. In addition to increasing mortality, it also lengthens the hospital stay and raises healthcare expenses. SSIs are challenging to predict, with most models having poor predictability. Therefore, we developed a prediction model for SSI after elective abdominal surgery by identifying risk factors.

AIM

To analyse the data on inpatients undergoing elective abdominal surgery to identify risk factors and develop predictive models that will help clinicians assess patients preoperatively.

METHODS

We retrospectively analysed the inpatient records of Shaanxi Provincial People's Hospital from 1 January 2018 to 1 January 2021. We included the demographic data of the patients and their haematological test results in our analysis. The attending physicians provided the Nutritional Risk Screening 2002 (NRS 2002) scores. The surgeons and anaesthesiologists manually calculated the National Nosocomial Infections Surveillance (NNIS) scores. Inpatient SSI risk factors were evaluated using univariate analysis and multivariate logistic regression. Nomograms were used in the predictive models. The receiver operating characteristic and area under the curve values were used to measure the specificity and accuracy of the model.

RESULTS

A total of 3018 patients met the inclusion criteria. The surgical sites included the uterus (42.2%), the liver (27.6%), the gastrointestinal tract (19.1%), the appendix (5.9%), the kidney (3.7%), and the groin area (1.4%). SSI occurred in 5% of the patients (n = 150). The risk factors associated with SSI were as follows: age; gender; marital status; place of residence; history of diabetes; surgical season; surgical site; NRS 2002 score; preoperative white blood cell, procalcitonin (PCT), albumin, and low-density lipoprotein cholesterol (LDL) levels; preoperative antibiotic use; anaesthesia method; incision grade; NNIS score; intraoperative blood loss; intraoperative drainage tube placement; surgical operation items. Multivariate logistic regression revealed the following independent risk factors: a history of diabetes (odds ratio [OR]=5.698, 95% confidence interval [CI] 3.305-9.825, *P*=0.001), antibiotic use (OR=14.977, 95%CI 2.865-78.299, *P*=0.001), an NRS 2002 score of ≥3 (OR=2.426, 95%CI 1.199-4.909, *P*=0.014), general anaesthesia (OR=3.334, 95%CI 1.134-9.806, *P*=0.029), an NNIS score of ≥2 (OR=2.362, 95%CI 1.019-5.476, *P*=0.045), PCT ≥0.05 μg/L (OR=1.687, 95%CI 1.056-2.695, *P*=0.029), LDL <3.37 mmol/L (OR=1.719, 95%CI 1.039-2.842, *P*=0.035), intraoperative blood loss ≥200 mL (OR=29.026, 95%CI 13.751-61.266, *P*<0.001), surgical season (*P*<0.05), surgical site (*P*<0.05), and incision grade I or III (*P*<0.05). The overall area under the receiver operating characteristic curve of the predictive model was 0.926, which is significantly higher than the NNIS score (0.662).

CONCLUSION

The patient's condition and haematological test indicators form the bases of our prediction model. It is a novel, efficient, and highly accurate predictive model for preventing postoperative SSI, thereby improving the prognosis in patients undergoing abdominal surgery.

Key Words: Surgical site infections; Risk factors; Abdominal surgery; Prediction model

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Core Tip: Herein, we retrospectively analysed the data, including patient personal information, test indicators, and surgical information, of patients undergoing elective abdominal surgery and used univariate and multivariate logistic regression analyses to assess risk factors for surgical site infection (SSI) in hospitalised patients. Nomograms were used in the prediction models. Subject working characteristics and area under the curve were used to measure the accuracy of the model up to 97%. R language was used to create a web page for dynamic predictive analysis of abdominal SSIs. A new predictive approach for preventing abdominal SSIs is made easier and more precise.

INTRODUCTION

Surgical site infection (SSI) is the commonest healthcare-associated infection[1] that helps determine patient prognosis. SSIs occur in 2-5% of inpatients undergoing surgery in the United States[2]. The incidence of SSI ranges from 2% to 10% in Europe[3-5], while in China, it ranges from 4% to 6%[6,7]. Patients undergoing complex surgeries associated with high-risk factors are more likely to develop SSI[8]. SSI results in a prolonged hospital length of stay (LOS). It burdens patients physically, psychologically, and economically[9].

Patients with abdominal symptoms requiring abdominal surgeries, such as gastric surgery, colorectal surgery, appendix surgery, *etc*., have a higher incidence of postoperative infection because the human gastrointestinal tract is a cavity that communicates with the outside world, comprising a wide variety of intestinal flora, which can cause infections[10, 11]. The National Quality Partnership, as part of the Surgical Care Improvement Project (SCIP), aims to prevent postoperative SSI. Several preoperative quality indicators, namely preoperative oxygen inhalation, normal body temperature maintenance, adequate circulating glucose, sterile drapes, surgical gowns, wound-protection devices, antimicrobial-coated sutures, incisional wound irrigation, and prophylactic negative-pressure wound therapy, lower the risk of SSI[12]. Despite these efforts, the LOS remained high, and the SSI remained unaffected. The National Nosocomial Infections Surveillance (NNIS) risk index is a traditional tool used to predict SSI[13]. The model comprises the American Society of Anaesthesiologists' preoperative assessment score, incision grade, and surgery time, with the score ranging from 0 to 3. These three elements, however, are insufficient to construct a prediction model. Grant *et al*[14] later developed a prediction model with an area under the receiver operating characteristic curve (AUROC) of 0.65, higher than that of the NNIS. Despite its ease of use, this model could only be applied to colorectal surgery. Therefore, our goal was to establish a novel, efficient, and highly accurate predictive model to prevent postoperative SSI in patients undergoing abdominal surgery.

MATERIALS AND METHODS

Inclusion and exclusion criteria

The clinical data of 3018 patients who underwent abdominal surgeries from January 2018 to January 2021 at Shaanxi Provincial People's Hospital were retrospectively analysed. We included patients aged >18 years and <100 years in the study. This study was performed in accordance with the Declaration of Helsinki. Informed consent was obtained from the patients and their families before surgery. SSI was diagnosed if one of the following occurred: incision infection, deep incision infection, and organ-space infection[15]. The infection prevention and control staff manually diagnosed SSI. This study was approved by the The Ethics Committee of Shaanxi Provincial People's Hospital.

Data collection

The hospital information system (HIS) was used to obtain the following patient-related data:

Basic information: age, gender, marital status, place of residence, and a history of diabetes and hypertension.

Scores: Nutritional Risk Screening 2002 (NRS 2002) and NNIS.

Preoperative biochemical index: red blood cell, white blood cell (WBC), haemoglobin, procalcitonin (PCT), albumin (ALB), triglyceride, low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol, and total cholesterol levels.

Hospitalisation information: Preoperative duration (days from admission to surgery), preoperative antibiotic use, surgical season, anaesthesia method (general anaesthesia or non-general anaesthesia), incision grade (I, II, or III), intraoperative blood loss, intraoperative irrigation, tension reduction suture, incision drainage, multiple tissue excision, and the surgical site.

Statistical methods

22.0 and R 4.2.1 were used to perform statistical analyses. The chi-square test or Fisher's exact test was used to compare enumeration data, and the t-test was used to compare measurement data. SSI was the dependent variable, and the other variables were the independent variables. Significant indicators of SSI after abdominal surgery ($P<0.05$) were identified using the univariate analysis, and multivariate logistic regression was used to identify independent risk factors for SSI after abdominal SSI ($P<0.05$). The "rms" package in R 4.2.1 was used to display the prediction model as a nomogram based on independent risk factors. A nomogram was used to calculate the probability of SSI after abdominal surgery. Scores are assigned to each index. Higher probabilities were associated with a higher score. Receiver operating characteristic curves were constructed, and the area under the curve (AUC) values were calculated. The higher the value, the higher the model's accuracy. The datasets analysed in the current study are not publicly available due to the hospital's restrictions on public resources and confidentiality requirements; however, they are available from the corresponding author upon reasonable request.

RESULTS

A total of 3018 patients were included in this study. Of these, 150 patients were diagnosed with SSI, and 2868 were diagnosed with nonsurgical site infection. The median age of the patients was 45 years. Of the 3018 patients, 900 (29.8%) were males, 2118 (70.2%) were females, 1622 (53.7%) patients lived in urban areas, and 1396 (46.3%) patients lived in rural areas. A total of 539 (17.8%) patients had hypertension, and 402 (13.3%) patients had diabetes. The surgical site distribution was as follows: the uterus

(42.2%), the liver (27.6%), the gastrointestinal tract (19.1%), the appendix (5.9%), the kidney (3.7%), and the groin area (1.4%). Univariate and multivariate logistic regression analyses were performed on SSI development after abdominal surgery. Univariate analyses revealed that gender; age; marital status; place of residence; history of diabetes; the NRS 2002 score; the NNIS score; preoperative WBC, PCT, ALB, and LDL; preoperative antibiotic use; anaesthesia method, incision grade; intraoperative blood loss; intraoperative drainage; multiple tissue excision; surgical season; and surgical site were significantly associated with postoperative abdominal incision infection ($P<0.05$) (Table 1).

Multivariate analysis revealed that diabetes (odds ratio [OR]=5.698, 95% confidence interval [CI] 3.305-9.825, *P*=0.001); antibiotic use (OR=14.977, 95%CI 2.865-78.299, *P*=0.001); an NRS 2002 score of ≥3 (OR=2.426, 95%CI 1.199-4.909, *P*=0.014); an NNIS score of ≥2 (OR=2.362, 95%CI 1.019-5.476, *P*=0.045); PCT ≥0.05 μg/L (OR=1.687, 95%CI 1.056-2.695, *P*=0.029); LDL <3.37 mmol/L (OR=1.719, 95%CI 1.039-2.842, *P*=0.035); surgical sites, such as the gastrointestinal tract (OR=3.646, 95%CI 1.097-12.121, *P*=0.035), appendix (OR=23.056, 95%CI 6.944-76.548, *P*<0.001), kidney (OR=6.256, 95%CI 1.377-29.361, *P*<0.020), and the groin area (OR=53.589, 95%CI 10.354-277.357, *P*<0.001); surgical seasons, including summer (OR=18.948, 95%CI 9.537-37.648, *P*<0.001), autumn (OR=2.648, 95%CI 1.454-4.823, *P*=0.001), and winter (OR=0.481, 95%CI 0.266-0.872, *P*=0.016); incision grade III (OR=11.226, 95%CI 1.689-74.630, *P*=0.012); general anaesthesia (OR=3.334, 95%CI 1.134-9.806, *P*=0.029); intraoperative blood loss >200 mL (OR=29.026, 95%CI 13.751-61.266, *P*<0.001) were independent risk factors for SSI (Table 2).

The multivariate analysis results were incorporated into the nomogram to construct a predictive model of SSI after abdominal surgery using R 4.2.1 (Figure 1). The following points were assigned to the patients based on the nomogram: 0 points for patients without a history of diabetes and 43 points for patients with a history of diabetes; 0 points for patients with a PCT level within the normal range and 19 points for patients with an abnormal PCT level; 0 points for patients with an LDL of ≥3.37 mmol/L and 16 points for patients with an LDL of <3.37 mmol/L; 0 points for patients with an NRS 2002 score of <2 and 17 points for patients with an NRS 2002 score of ≥3; 0 points for patients with an NNIS score of <2 and 12 points for patients with an NNIS score of ≥2; 0 points for patients who received non-general anaesthesia and 38 points for patients who received general anaesthesia; 0 points for preoperative antibiotic use and 71 points for no preoperative antibiotic use; 0 points for patients with an intraoperative blood loss of <200 mL and 91 points for patients with an intraoperative blood loss of ≥200 mL; 0 points if the surgical season was winter, 20 points if the surgical season was spring, 45 points if the surgical season was autumn, and 96 points if the surgical season was summer; in terms of the surgical site, the points were assigned as follows: 0 points for the uterus, 15 points for the liver, 45 points for the stomach, 51 points for the kidney, 82 points for the appendix, and 98 points for the groin area; in terms of the incision grade the points were assigned as follows: 0 points for grade I incision, 48 points for grade II incision, and 68 points for grade III incision. The total score was 500. The predictive value of SSI after abdominal surgery was 90% when the score was >328. Overall, the predictive model had a significantly higher AUC value (0.926) than that of the NNIS (0.662) (Figure 2). SSI occurrence was significantly associated with the SSI risk score obtained on logistic regression. Particularly, the model was associated with an increased incidence of SSI (30%, 70%, 90%, and 100% for score cut-offs of 210-250, 250-290, 290-330, and >330, respectively) as the SSI score increased in the validation cohort (Figure 3). Based on these results, we set up an online tool to better predict SSI risk after abdominal surgery established on the nomogram in this study (https://drzhangjinssi.shinyapps.io/DynNomapp/).

DISCUSSION

SSI after abdominal surgery results in prolonged hospital LOS and significant hospitalisation costs[16]. A survey reported that the additional expenditure per SSI patient could support the hospitalisation costs of 13 normal surgical patients[8]. Therefore, the significance of SSI for hospitals, countries, and patients is obvious[17].

Over the past few years, several SSI prediction models have been developed to help clinicians identify high-risk patients who might benefit from early intervention. Due to its simplicity and convenience, the NNIS risk index is currently the method that is most frequently used. Its three variables, however, are insufficient for a precise evaluation[18, 19]. Mu *et al*[20] established an SSI prediction model based on patient data from 39 countries between 2006 and 2008 (AUROC=0.67). An accurate prediction model might be created using data from 39 additional; however, using such a model in clinical settings could be inconvenient. Although Van Walraven *et al*[21] established a prediction model with an AUROC of 0.80; this model required substantial patient information. Medical personnel are overworked in settings where electronic medical records are not being used. Therefore, it is necessary to construct a prediction model which is accurate and easy to use. In this study, the SSI prediction model is relatively novel and efficient. It can be used to predict SSI after abdominal surgery, and the necessary information involved is within the scope of implementation, making it applicable. In this study, the SSI-related factors were retrospectively examined from the perspectives of fundamental preoperative patient data, preoperative blood test indicators, surgery-related data, and the overall patient condition score, including age, gender, marital status, WBC count, and intraoperative blood loss. Additionally, we included various comprehensive and representative factors, including the NRS 2002 and NNIS scores. Our model is innovative compared with other models[22, 23]. Besides objective test indicators and the patient's personal information, the doctor can establish overall control and evaluate the patient's condition. This model is more practical and credible, as shown by the entire procedure and the AUROC result.

The predictability of the SSI prediction model was comprehensively evaluated using univariate regression, multivariate logistic regression, and R 4.2.1 "rms". Identifying patients at high risk for SSI is important; however, intervention should be the primary action following identification. The SCIP items must first be completed, albeit not all of them need to be covered[24, 25]. Furthermore, when patients undergo elective surgeries, the model should be used comprehensively to determine the probability of infection.

SSI is more likely to occur when the prediction score is high, and precautions must be taken accordingly. Improving the patient's nutrition, appropriate anaesthesia methods, and reducing intraoperative blood loss will help prevent SSIs. Patients with an SSI monitor for post-discharge wound surveillance could help identify and manage the condition at the earliest using intelligent identification programs available in some developed regions of the world. This would improve the effectiveness of hospital visits and foster better communication between doctors and patients[26, 27]. Additionally, a preoperative plan devised by a multidisciplinary team could lower the occurrence of SSI, particularly in critically ill patients, as well as help in a comprehensive assessment and symptomatic treatment[28]. There are four aspects to predicting SSI preoperatively: assessment, intervention, diagnosis, and treatment, which are equally essential for managing SSI[29]. Multidisciplinary discussions and comprehensive step-by-step assessments can help lower the incidence of SSI, thereby improving patient satisfaction and recovery indexes.

The efficacy of our model has been verified; however, it has a few limitations. First, professionals diagnosed and selected the patients for this study; however, there may still be artificial errors that affect our model. Second, as the study was a retrospective analysis, potential selection bias could exist. The prediction model was created based on a broad cohort of patients undergoing abdominal surgery. The model needs constant improvement to be clinically used because the data were only from one institution, and the sample size was insufficient. This challenge could be categorised under clinical big data analysis, as reported by Ejaz[16]. Lastly, in terms of data analysis, several missing variables were excluded, and the model establishment expression form needs improvement.

The following will be considered in our future studies: 1. As a result of the promotion of diagnosis-related groups payment system for hospitalised patients[30], the International Classification of Diseases code[31] will become increasingly standardised as it can be used to screen cases. 2. More validation cohorts need to be included, and patient information can be collected from different regions of the country and globally, making the model more convincing and resilient. 3. The patients' missing data needs to be handled appropriately. Chen *et al*[1] suggested that other variables can be used to replace the factors with too many missing values. As a fundamental step, clinicians need to strengthen their ability to write medical records. 4. The text content in the model will be embedded later and then applied to the entire HIS, making the process more efficient and accurate.

CONCLUSION

SSI prediction models are useful for hospitalised patients and have recently undergone continuous development. However, they lack reliability due to their complex and dynamic nature. Herein, we established a novel model for predicting SSI after abdominal surgery and verified its efficiency and accuracy in preventing postoperative SSI. We anticipate that our study will help improve patient prognosis after abdominal surgery.

ARTICLE HIGHLIGHTS

Research motivation

To establish a predictive model for SSI which is more easily assess the risk of it. And provide timely interventions for high-risk patients to improve the quality of care so as to reduce medical costs and ease the burden on patients.

Research background

Surgical site infections (SSIs) can increase mortality and prolong the length of hospital stay, thereby increasing healthcare costs. Therefore, it is much necessary to develop a prediction model after elective abdominal surgeries in order to identify risk factors of SSI.

Research perspectives

This study developed the accurate model for predicting the risk of elective abdominal SSI.We plan to make larger multi-centre and large sample studies in order to obtain more realistic and valid data results.

Research conclusions

The patient's condition and haematological test indicators formed the bases of our prediction model. It is a novel, efficient, and highly accurate predictive model for preventing postoperative SSI, thereby improving the prognosis in patients undergoing abdominal surgery.

Research results

The key findings indicated that the surgical sites included the uterus (42.2%), the liver (27.6%), the gastrointestinal tract (19.1%), the appendix (5.9%), the kidney (3.7%), and the groin area (1.4%). SSI occurred in 5% of the patients (n = 150). Multivariate logistic regression revealed the following independent risk factors: a history of diabetes, antibiotic use, a Nutritional Risk Screening 2002 score of ≥3, general anaesthesia, a National Nosocomial Infections Surveillance (NNIS) score of ≥2, procalcitonin ≥0.05 μg/L, low-density lipoprotein cholesterol <3.37 mmol/L, intraoperative blood loss ≥200 mL, surgical season, surgical site, and incision grade (all P<0.05. The overall area under the receiver operating characteristic curve of the predictive model was 0.926, which was significantly higher than that of the NNIS (0.662).

Research methods

This observational study was conducted from 1 January 2018 to 1 January 2021 using patient demographic data and haematological test results. Inpatient SSI risk factors were evaluated using univariate analysis and multivariate logistic regression. Nomograms were used in the predictive models. The receiver operating characteristic and area under the curve values were used to measure the specificity and accuracy of the model.

Research objectives

The present study aimed to develop a realistic, feasible, valid and unique model for predicting the risk of elective abdominal SSI.

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