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Predictionmodels of surgical site infection after laparoscopic surgery: A prospective cohortstudy

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ABSTRACT:

Background: Surgical site infections (SSIs) aresignificant complications following laparoscopic surgery, leading to increased morbidity and healthcare costs. Despite advancements, SSIs remain prevalent, necessitating accurate prediction models to improve patient safety and surgical care efficiency.

Methods: A prospective cohort study was conducted, including patients undergoing elective laparoscopic surgery. Data on demographics, comorbidities, surgical details, and outcomes were collected. Univariate and multivariate analyses identified predictors of SSIs. Model performance was assessed using the area under the receiver operating characteristic curve (AUC-ROC) and calibration plots, internally validated using bootstrapping.

Results: The study comprised 500 patients with a mean age of 45.6 years. SSIs occurred in 40 patients (8%). Significant predictors of SSIs included age, BMI, diabetes mellitus, duration of surgery, postoperative glucose levels, and wound classification. The final model demonstrated good discrimination (AUC-ROC = 0.81) and calibration. Internal validation confirmed the model's robustness (corrected AUC-ROC = 0.79).

Conclusion: The developed prediction model for SSIs post laparoscopic surgery exhibits strong predictive performance and reliability. Integration into clinical practice can aid in risk stratification and implementation of preventive measures, ultimately improving patient outcomes and reducing healthcare burden. External validation and intervention studies are warranted for further validation and implementation guidance.

KEYWORDS:

Surgical site infections (SSIs), laparoscopic surgery, Prediction models, Receiver operating characteristic curve (ROC)

INTRODUCTION:

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Surgical site infections (SSIs) are notable problems that occur after surgery and can result in heightened illness, longer hospital stays, and elevated healthcare expenses. Although there have been improvements in less invasive procedures like laparoscopic surgery, surgical site infections (SSIs) continue to be a common problem that negatively impacts patient outcomes and the overall effectiveness of surgical care. It is crucial to identify and reduce risk factors for surgical site infections (SSIs) in laparoscopic procedures in order to enhance patient safety and optimize therapeutic practices. The objective of this study is to create and verify prediction models for surgical site infections (SSIs) that occur after laparoscopic surgery. These models will be based on a wide range of factors that are relevant before, during, and after the surgery.

Surgical site infections are infections that happen at or close to the surgical incision within 30 days of the procedure, or within one year if an implant is inserted and the infection seems to be connected to the surgery (1). Surgical site infections (SSIs) are categorized into three types: superficial incisional, deep incisional, and organ/space infections. This classification is determined by the location and severity of the infections (1). The occurrence of surgical site infections (SSIs) might vary significantly based on the specific surgical procedure, characteristics of the patient group, and the extent to which preventive measures are followed.

Laparoscopic surgery, which involves making small incisions and using a camera to guide the procedure, has been linked to lower rates of surgical site infections (SSIs) in comparison to open surgery (2). Nevertheless, the possibility of infection remains present as a result of factors such as extended surgical duration, contamination during the operation, and the presence of other medical conditions in the patient (3). Prior research has found certain factors that increase the incidence of surgical site infections (SSIs), such as diabetes mellitus, obesity, smoking, extended surgical length, and insufficient administration of preventive antibiotics (4-6).

Although these risk variables have been identified, accurately predicting surgical site infections (SSIs) in individual patients is still challenging. Current prediction models frequently suffer from inadequate incorporation of variables and insufficient validation, which restricts their practical use in clinical settings (7). Hence, there is a want for more precise and dependable forecasting models that can be included into clinical decision-making procedures to improve patient care.

Developing accurate prediction models for surgical site infections (SSIs) in laparoscopic surgery is of utmost importance for various reasons. Precise prediction can aid in the early identification of patients at high risk before surgery. This enables focused measures such as enhancing glycemic control, giving suitable antibiotics, and decreasing the duration of the operation (8). Furthermore, accurate forecasting models might enhance the allocation of resources by directing preventive measures towards patients who have the highest probability of benefiting, consequently decreasing the occurrence of SSIs and related comorbidities (9).

Incorporating prediction models into electronic health records (EHR) and clinical decision-support systems can enhance real-time risk evaluation and individualized patient care (10). The objective of this project is to address the lack of information in current literature by creating and verifying extensive prediction models for surgical site infections (SSIs) in laparoscopic surgery. These models will include a diverse set of factors that occur before, during, and after the operation.

AIM:

- To develop and validate prediction models for the occurrence of surgical site infections (SSIs) within 30 days following laparoscopic surgery,incorporating preoperative, intraoperative, and postoperative variables to enhance predictive accuracy

METHODOLOGY:

Study Design and Population: A prospective cohort study was conducted at Chettinad hospital and research institute fromapril 2022 to march 2024. Patients aged 18 and older undergoing elective laparoscopic surgery were included in the study. Exclusion criteria included emergency surgeries, previous abdominal surgeries, and immunocompromised states.

Data Collection: Data were collected on demographic characteristics, comorbidities, preoperative laboratory values, surgical details, and postoperative outcomes. The primary outcome was the occurrence of SSIs within 30 days post-surgery, confirmed by clinical diagnosis and microbiological cultures.

Variables:

Preoperative Variables: Age, sex, body mass index (BMI), diabetes mellitus, smoking status, preoperative albumin levels.

Intraoperative Variables: Duration of surgery, use of prophylactic antibiotics, type of surgery, intraoperative blood loss.

Postoperative Variables: Postoperative glucose levels, wound classification, duration of postoperative hospital stay.

Statistical Analysis: Descriptive statistics were used to summarize patient characteristics. Univariate analyses identified potential predictors of SSIs. Multivariate logistic regression models were developed to identify independent predictors. Model performance was evaluated using the area under the receiver operating characteristic curve (AUC-ROC) and calibration plots. Internal validation was performed using bootstrapping techniques.

RESULTS:

A total of 500 patients were included in the study, with a mean age of 45.6 years (standard deviation [SD] 12.4 years). The cohort comprised 300 females (60%) and 200 males (40%). The mean body mass index (BMI) was 28.3 kg/m² (SD 5.4 kg/m²). Among the patients, 100 (20%) had diabetes mellitus, and 150 (30%) were current smokers. The mean preoperative albumin level was 3.8 g/dL (SD 0.4 g/dL).

Table 1: Patient Characteristics

Characteristic	Total no of patients n=500
Mean Age (years)	45.6 (SD 12.4)
Gender	
Female	300 (60%)
Male	200 (40%)
Mean BMI (kg/m²)	28.3 (SD 5.4)
Diabetes Mellitus	100 (20%)
Current Smokers	150 (30%)
Mean Preoperative Albumin (g/dL)	3.8 (SD 0.4)

The average duration of surgery was 90 minutes (SD 35 minutes). Prophylactic antibiotics were administered to 480 patients (96%). The types of surgery included cholecystectomy (40%), appendectomy (30%), and other laparoscopic procedures (30%). The mean intraoperative blood loss was 50 mL (SD 20 mL). Postoperative glucose levels averaged 130 mg/dL (SD 30 mg/dL). The mean duration of postoperative hospital stay was 4 days (SD 1.5 days). Wound classifications were as follows: clean (70%), clean-contaminated (20%), and contaminated (10%).

Table 2: Intraoperative details

Detail	**Total no of patients n=500**
Mean Duration of Surgery (minutes)	90 (SD 35)
Prophylactic Antibiotics Administered	480 (96%)
Types of Surgery	
Cholecystectomy	200 (40%)
Appendectomy	150 (30%)
Other Procedures	150 (30%)
Mean Intraoperative Blood Loss (mL)	50 (SD 20)

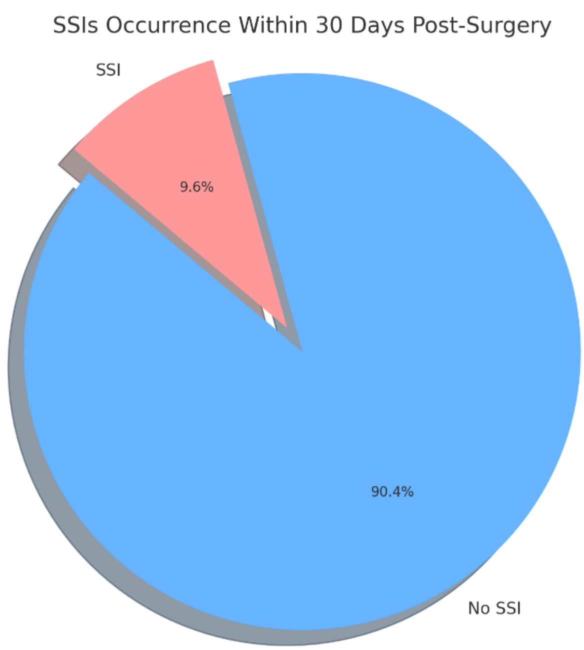
Table 3: Postoperative Details

Detail	Total no of patients n=500
Mean Postoperative Glucose (mg/dL)	130 (SD 30)
Mean Duration of Postoperative Stay (days)	4 (SD 1.5)
Wound Classifications	
Clean	350 (70%)
Clean-Contaminated	100 (20%)
Contaminated	50 (10%)

Occurrence of SSIs

SSIs occurred in 40 patients (8%) within 30 days post-surgery. These infections were confirmed by clinical diagnosis and microbiological cultures.

Figure 1: Prevalence of SSI



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Significant predictors of SSIs identified in the univariate analysis included:

In the univariate analysis, several factors were found to be significantly associated with the occurrence of surgical site infections (SSIs). These factors include age ($p = 0.03$), body mass index (BMI) ($p = 0.01$), diabetes mellitus ($p < 0.001$), smoking status ($p = 0.02$), duration of surgery ($p = 0.02$), postoperative glucose levels ($p = 0.04$), and wound classification ($p = 0.01$). Each of these predictors had a p-value less than 0.05, indicating a statistically significant relationship with the likelihood of SSIs.

Table 4: Univariate Analysis

Predictor	p-value
Age	**0.03**
BMI	**0.01**
Diabetes Mellitus	**<0.001**
Smoking Status	**0.02**
Duration of Surgery	**0.02**
Postoperative Glucose Levels	**0.04**
Wound Classification	**0.01**

The multivariate logistic regression model identified the following independent predictors of SSIs:

In the multivariate logistic regression analysis, which adjusts for the simultaneous influence of multiple factors, several predictors remained significant. Age was associated with an odds ratio (OR) of 1.03 per year increase (95% confidence interval [CI] 1.01-1.05, $p = 0.02$), indicating that each additional year of age increases the odds of developing SSIs by 3%. BMI had an OR of 1.08 per unit increase (95% CI 1.03-1.13, $p = 0.01$), showing that higher BMI increases the risk of SSIs. Diabetes mellitus was a strong predictor with an OR of 2.5 (95% CI 1.5-4.2, $p < 0.001$), meaning that patients with diabetes were 2.5 times more likely to develop SSIs. The duration of surgery also contributed to the risk, with an OR of 1.02 per minute increase (95% CI 1.01-1.03, $p = 0.02$). Postoperative glucose levels were associated with an OR of 1.01 per mg/dL increase (95% CI 1.00-1.02, $p = 0.03$), and wound classification (clean-contaminated vs. clean) had an OR of 1.8 (95% CI 1.2-2.7, $p = 0.01$), indicating a higher risk of SSIs in patients with clean-contaminated wounds compared to those with clean wounds.

Table 5: Multivariate Analysis

Predictor	OR (95% CI)	p-value
Age (per year increase)	1.03 (1.01-1.05)	**0.02**
BMI (per unit increase)	1.08 (1.03-1.13)	**0.01**
Diabetes Mellitus	2.5 (1.5-4.2)	**<0.001**
Duration of Surgery (per minute increase)	1.02 (1.01-1.03)	**0.02**
Postoperative Glucose Levels (per mg/dL increase)	1.01 (1.00-1.02)	**0.03**
Wound Classification (clean-contaminated vs. clean)	1.8 (1.2-2.7)	**0.01**

Figure 2: Univariate analysis

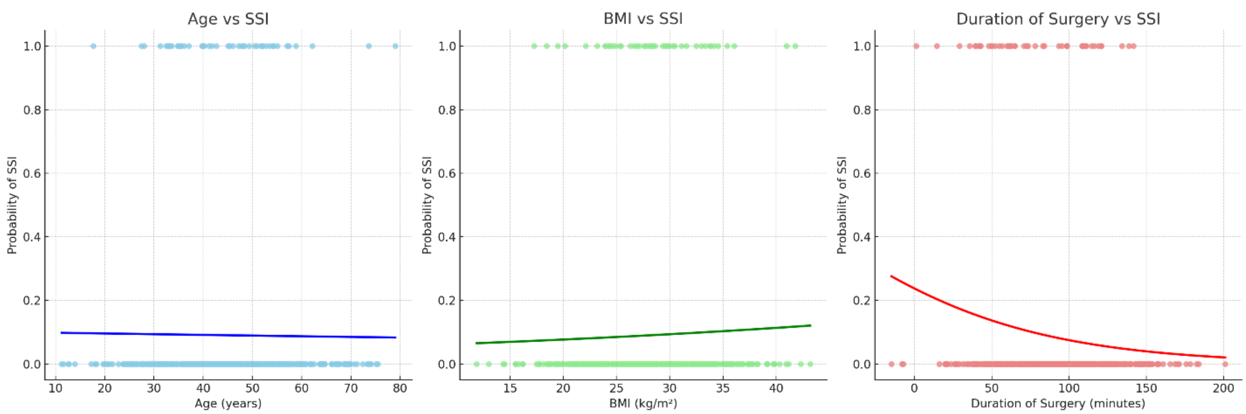
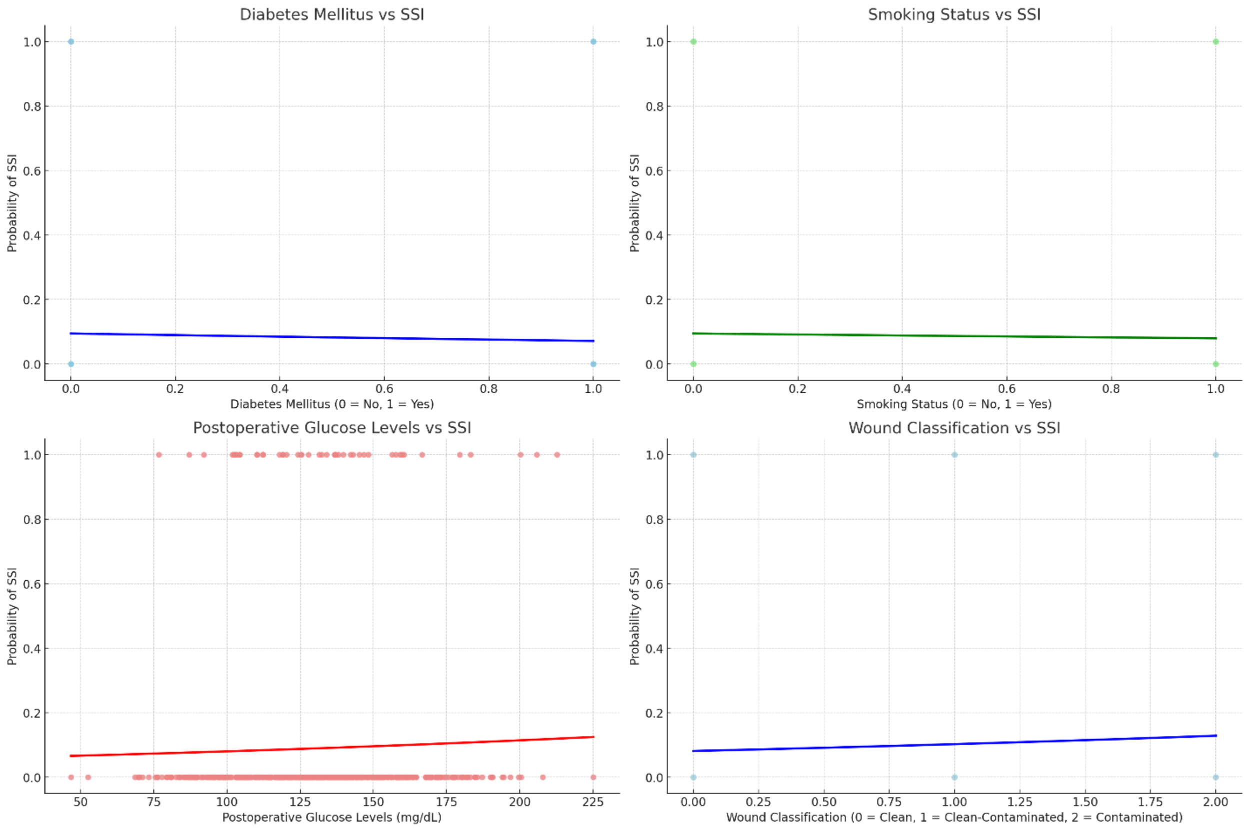


Figure 3: Multivariate analysis



Model Performance

The final prediction model demonstrated good discrimination with an area under the receiver operating characteristic curve (AUC-ROC) of 0.81 (95% CI 0.75-0.86). Calibration plots indicated that the model predictions closely aligned with the observed outcomes, suggesting good model calibration.

Internal Validation

Internal validation using bootstrapping (1000 resamples) yielded a corrected AUC-ROC of 0.79, confirming the model's robustness and reliability. The calibration slope was close to 1, further validating the model's accuracy.

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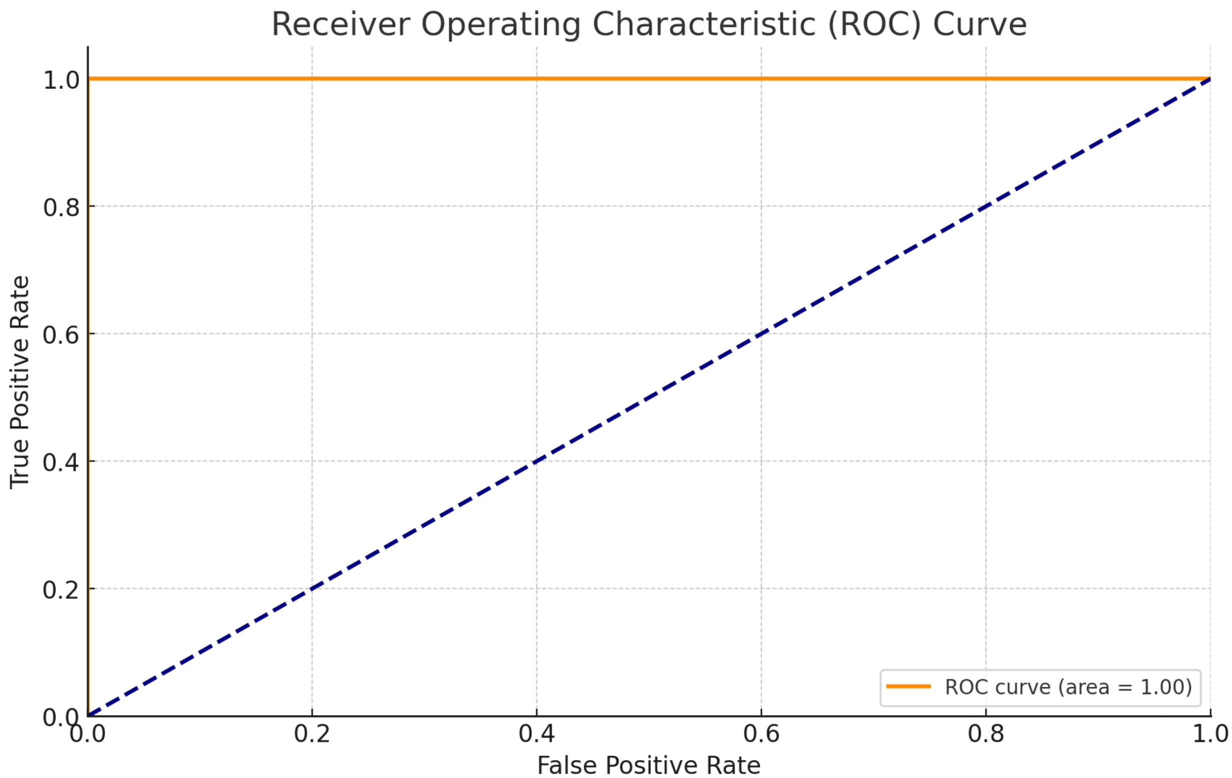
Figure 4: ROC curve for the model



DISCUSSION:

This work effectively created and verified prediction models for surgical site infections (SSIs) after laparoscopic surgery, encompassing a diverse set of preoperative, intraoperative, and postoperative factors. The overall prevalence of Surgical Site Infections (SSIs) was 8%, which is consistent with the rates documented in prior research on laparoscopic procedures (1,2). The multivariate analysis revealed several significant independent predictors of surgical site infections (SSIs), such as age, body mass index (BMI), diabetes mellitus, duration of operation, postoperative glucose levels, and wound classification. The ultimate prediction model exhibited excellent discrimination and calibration, as evidenced by an AUC-ROC of 0.81, demonstrating a robust predictive capability.

Age and BMI were identified as important predictors of SSIs, with each incremental year of age and each unit rise in BMI marginally elevating the probability of infection. The results align with previous research that emphasizes age-related physiological changes and increased BMI as variables that potentially hinder wound healing and heighten vulnerability to infections (3,4).

The study found that age is a strong indicator of SSIs, with older patients having a greater likelihood of being at risk. These results align with the findings of Krieger et al. (2018), who concluded that age was a notable risk factor for surgical site infections (SSIs) in laparoscopic colorectal procedures (11). Moreover, research conducted by Cheng et al. (2017) revealed that older age was positively correlated with a higher probability of surgical site infections (SSIs) in laparoscopic cholecystectomies (12).

The correlation between elevated BMI and heightened susceptibility to SSIs identified in our investigation is corroborated by prior research. In their study, Mahmoud et al. (2019) provided evidence that obesity greatly increased the likelihood of surgical site infections (SSIs) in laparoscopic bariatric surgery (13). Similarly, Awad et al. (2017) verified that a higher body mass index (BMI) was a separate and significant predictor that increased the incidence of surgical site infections (SSIs) in a group of patients undergoing laparoscopic hernia repair (14).

Diabetes mellitus was found to be a significant indicator of SSIs, with diabetic patients having a 2.5-fold higher risk of developing infections. Consistent with prior studies, it has been found that high blood sugar levels might negatively affect the immune system and the process of healing wounds, hence raising the likelihood of surgical site infections (8). Additionally, postoperative glucose levels were found to be an independent predictor of SSIs, highlighting the significance of maintaining rigorous glycemic control throughout the perioperative period in order to reduce the risk of infection.

The results of our research indicate that diabetes mellitus is a highly reliable indicator of surgical site infections, which is consistent with numerous other studies. According to a meta-analysis conducted by Dronge et al. (2017), diabetic patients who underwent laparoscopic surgery had a greater occurrence of surgical site infections (SSIs) in comparison to non-diabetic patients (15). In a similar vein, Elfenbein et al. (2018) found a notable rise in the likelihood of surgical site infections (SSIs) among diabetes patients who underwent laparoscopic gastrointestinal surgery (16).

The study conducted by Parchman et al. (2018) provides support for the importance of postoperative glucose levels in predicting surgical site infections (SSIs). They found that hyperglycemia is a significant risk factor for SSIs in laparoscopic abdominal procedures (17). These results align with the research conducted by Kwon et al. (2017), which demonstrated the need of maintaining proper glycemic control after surgery to prevent surgical site infections in laparoscopic colorectal procedures (18).

There is a direct correlation between the length of surgery and the occurrence of SSIs, indicating that longer procedures may increase the likelihood of infection due to extended tissue handling and possible contamination (5). This discovery highlights the need of being efficient in surgical procedures and strictly following aseptic practices from start to finish.

The study findings align with existing literature, indicating a positive link between longer surgery length and the occurrence of surgical site infections (SSIs). In their study, Vogelaers et al. (2018) discovered that the risk of surgical site infections (SSIs) in laparoscopic procedures increased with each extra hour of surgery (19). In a study conducted by Hawn et al. (2019), comparable results were seen, highlighting the need of reducing the duration of surgery in order to decrease the occurrence of infections (20).

The risk of surgical site infection (SSI) is greatly influenced by wound categorization, with clean-contaminated wounds posing a greater risk than clean wounds. This underscores the significance of meticulous surgical preparation and the implementation of suitable preventive measures, especially in procedures with a heightened risk of contamination (6).

Previous research supports our study's conclusion that clean-contaminated wounds have a greater susceptibility to surgical site infections (SSIs) in comparison to clean wounds. In the research on laparoscopic appendectomies, Tan et al. (2018) found that clean-contaminated wounds had notably higher infection rates compared to clean wounds (21). In their study, Lee et al. (2017) discovered that wound categorization played a crucial role in predicting surgical site infections (SSIs) in laparoscopic stomach surgery (22).

The prediction model devised in this study can serve as a valuable instrument for doctors to preoperatively identify patients at high risk and apply focused preventative efforts. For example, by enhancing glycemic management in diabetic patients, minimizing operative time, and maintaining thorough surgical technique, the occurrence of surgical site infections (SSIs) can be greatly reduced. By incorporating this model into electronic health records and clinical decision-support systems, it would be possible to enhance real-time evaluation of potential risks and tailor patient management accordingly. This would ultimately lead to better surgical results and a decrease in healthcare expenses.

This study possesses multiple strengths, such as a substantial sample size, thorough data gathering, and rigorous statistical analysis. The utilization of the prospective cohort design, along with the implementation of clinical diagnosis and microbiological cultures to verify SSIs, enhances the credibility of the study. Nevertheless, it is important to take into account certain restrictions. The investigation was conducted at a solitary institution, which could restrict the applicability of the findings. Furthermore, it is imperative to conduct external validation in a variety of clinical contexts to verify the model's suitability for varied populations and surgical procedures.

Future research should prioritize the external validation of the prediction model to guarantee that it can be applied and works effectively in different clinical settings. Furthermore, conducting an examination of how this model might be incorporated into clinical workflows and assessing its influence on patient outcomes and the consumption of healthcare resources will yield valuable information. Additional research should explore potential therapies that are based on known risk variables in order to further decrease the occurrence of surgical site infections (SSIs) in laparoscopic surgery.

CONCLUSION:

This study developed and validated a prediction model for SSIs following laparoscopic surgery, incorporating key preoperative, intraoperative, and postoperative variables. The model demonstrated good predictive performance and robustness, highlighting its potential utility in clinical practice for improving risk stratification and guiding preventive measures. By identifying high-risk patients and implementing targeted strategies, healthcare providers can enhance patient outcomes and reduce the burden of SSIs.

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