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Development and validation of a predictive nomogram for surgical site infection among general surgery patients in Amhara region Ethiopia

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Surgical site infections (SSIs) remain a significant cause of morbidity, prolonged hospital stays, and increased healthcare costs, particularly in low-resource settings such as Ethiopia. While SSIs are widely recognized as preventable, the burden of these infections remains high, especially in sub-Saharan Africa, where healthcare resources are limited, and surgical care may not consistently meet recommended standards. In Ethiopia, as in many similar settings, the lack of robust, context-specific predictive tools limits the ability of healthcare providers to proactively manage SSI risks. Current predictive models and nomograms for SSI risk are generally developed in high-resource settings and may not accurately capture the unique risk factors in Ethiopia. The aim of this study was Development and validation of nomogram for Surgical Site Infection Prediction Among General Surgery Patients in Amhara. A prospective follow-up study was conducted involving general surgery patients at referral hospitals in the Amhara region. Predictors of SSIs were identified through logistic regression analysis, and a nomogram was constructed based on these predictors. The model was internally validated using bootstrapping techniques to assess the accuracy and reliability of the risk estimates. Model performance was evaluated in terms of discrimination, measured by the area under the receiver operating characteristic (ROC) curve (AUC), and calibration, using calibration plots. The incidence of SSI was 39.6%. The key prognostic predictors of this model were: sex, age, diabetes mellitus (DM), wound classification, wound care, American Society of Anesthesiologists (ASA) score, residence, surgery duration, preoperative hospital stays, alcohol consumption, and prior surgical history. The model's discrimination power was 90.1% with 95% CI (87-93%) and its calibration is well fitted with 45 degrees. The bootstrapped model produced consistent β coefficients, supporting the stability and robustness of the model. The nomogram was developed with key predictors of SSI and demonstrated excellent discrimination ability, with an AUC of 0.87 (95% CI: 0.84–0.91). Calibration plots showed a strong agreement between predicted and observed probabilities, indicating the model is well-calibrated. The incidence of SSI was notably high. American Society of Anesthesiologists (ASA) score, sex, age, diabetes mellitus (DM), wound classification, wound care practices, patient residence, surgery duration, preoperative hospital stay, alcohol use, and history of previous surgeries were key prognostic predictors. The validated model had an excellent discrimination power with well fitted calibration. The developed nomogram accurately predicts the risk of SSIs among general surgery patients. It might serve as a practical tool for identifying high-risk patients, enabling healthcare providers to implement targeted preventive measures, improving patient outcomes and reducing the burden of SSIs in Ethiopian healthcare settings. Further external validation is recommended to confirm the model's applicability across different settings.

Keywords Surgical site infection, Nomogram, Predictive model, General surgery, Ethiopia, Amhara region

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SSI is an infection occurring within 30 days after the operative procedure. Its m be superficial deep soft tissue and any part of the anatomy, organs and spaces other than the incision that was opened or manipulated during an operation caused by bacteria that get in through incisions[1–3]. It threatens the lives of millions of patients each year and contribute to the spread of antibiotic resistance. In low- and middle-income countries, 11% of patients who undergo surgery are infected in the process[2].

Surgical site infections remain one of the most common complications following surgical procedures and are associated with increased morbidity, prolonged hospital stays, and higher healthcare costs globally[2]. The World Health Organization (WHO) estimates that SSIs account for up to 20% of healthcare-associated infections in low- and middle-income countries (LMICs), significantly impacting surgical outcomes and patient recovery[4] .SSI not only increases the risk of revision surgery and prolongs the hospital stay, but also brings huge economic burden to patients, families and society[5,6].

Morbidity and mortality that are attributed to surgical site infections is still remains to be very high and is even increasing throughout the world. SSI is associated with a mortality rate of 3% and 75% of SSI-associated deaths are directly attributable to the SSI[7].

In countries with limited resources, SSIs affecting up to 66% of operated patients[8]. In LMICs, the incidence of SSI was 12 per 100 surgical patients. In Africa, SSIs were the leading infections in hospitals which ranges from 2.5 to 30.9%. Most cited risk factors in the continent were long duration of surgery and wound contamination class[9].

In Ethiopia, SSIs are a major public health concern due to limited healthcare infrastructure, scarcity of essential surgical supplies, and infection control challenges[10]. The Amhara region, being one of the largest administrative regions in Ethiopia, faces a high burden of SSIs among general surgery patients, with reported rates significantly above global averages[11]. Despite these challenges, there is limited predictive research on SSIs in Ethiopia's healthcare settings, which restricts the ability of healthcare professionals to stratify patients by risk and implement targeted preventive measures. Nomograms are predictive models that have shown significant utility in estimating the probability of clinical events, including SSIs, by incorporating various patient and clinical factors[12]. These tools offer a visual and quantifiable method to personalize patient care, improve clinical decision-making, and optimize resource allocation in surgical units. However, such predictive models specific to the Ethiopian context and tailored for the Amhara region's patient population are lacking. Therefore, this study aims to develop and validate a nomogram for the prediction of SSIs among general surgery patients in referral hospitals in the Amhara region. By identifying patient and clinical variables that significantly contribute to the risk of SSI, this research seeks to provide a reliable tool for clinicians to stratify patients according to their infection risk, ultimately improving surgical outcomes and patient care.

Methods asd materials

Study designs and study setting

This study employs a prospective cohort design to develop and validate a nomogram for predicting surgical site infections (SSIs) among general surgery patients. The research was conducted in selected referral hospitals within the Amhara region of Ethiopia, which serve as primary centers for complex surgical procedures and receive patients from various districts. These hospitals are equipped with surgical wards, infection control units, and laboratory facilities necessary for diagnosing SSIs. It was conducted Frome March 8 to April 28, 2023 GC.

Source and study population

All adult patients (aged ≥ 18 years) who underwent general surgical procedures in the selected referral hospitals within the Amhara region from March 8 to April 28, 2023 GC were the study population. General surgery encompasses a wide range of procedures, including abdominal, hernia, colorectal, and thyroid surgeries. All patients with age ≥ 18 years who underwent elective or emergency, clean and clean contaminated surgery were included in the study. whereas, Patients undergoing emergency surgeries, immunocompromised individuals, patients whose wounds were not primarily closed in the operation room, and those with incomplete medical records were excluded from the study to ensure data integrity and homogeneity.

Sample size determination

The sample size was determined using the rule of thumb that requires a minimum of 10 events per predictor variable to ensure reliable model estimates. Based on an SSI incidence rate of 19% and considering 15 potential predictor variables, the minimum required sample size was 789 patients. However, only 463 patients underwent surgery during the study period; therefore, all eligible participants were included. Data were collected retrospectively from patient medical records using a standardized abstraction form and prospectively through patient surveys during follow-up, including telephone interviews. To ensure accuracy and consistency, data collectors received training on the abstraction process. A pilot test involving 5% of the sample was conducted to refine the data collection tool, and any discrepancies were resolved through consensus or consultation with the principal investigator.

Variables included in the data abstraction form.

1. *Socio-Demographic Characteristics*: age, sex, marital status, educational status, Occupational status, & Residence.
2. Behavioral related factors: alcohols consumption, & cigar ate smoking.
3. *Patient and surgical wound related factors*: History of Previous Surgery, Preoperative Blood Transfusion, Surgical Wound Class, ASA Score, Body Mass Index, & Length of Pre-Operative Hospital Stay.
4. Comorbidity: (DM, HIV/AIDS, HTN ….)

5. *Hospital and surgical Related factors*: Grade of the Surgeon Who Performed the Surgery, Antibiotic Given? If yes, the time antibiotic Given, & Number of Professionals in the OR while the Surgery was Performed.
6. Procedure Related Factor: duration of surgery, drainage, wound care, type of antibiotic given.
7. *Type of surgical Procedures*: Large Bowel Surgery, Appendix surgery, Gastric Surgery.
8. *Sign and symptoms*: discharge from their wound, pain, wound breakdown, Redness of the wound.

Variable definitions

Surgical Site infection (SSI) An infection that occurs within 30 days after the operative procedure and involves the skin, subcutaneous tissue, or deeper soft tissues of the incision[13].

Comorbidities Presence of chronic conditions such as diabetes mellitus, hypertension, cardiovascular diseases, and others as documented in patient records.

Antibiotic Prophylaxis Administration of antibiotics within one hour before the surgical incision and continued as per standard protocols.

Data processing and analysis

Data were interred into EPI DATA, version 3.02; and exported to R for analysis. Descriptive statistics **such as** demographic and clinical characteristics of the study population were summarized using frequencies and percentages for categorical variables and means with standard deviations for continuous variables. Bivariable logistic regression was done to asses association of Potential predictors with SSI. Variables with a p-value < 0.25 in Bivariable analysis were included in a multivariable logistic regression model to identify independent predictors of SSI. Variables with p value < 0.05 were taken into a nomogram using the rms package in R to calculate the probability of SSI based on individual patient characteristics. An internal validation technique using the bootstrap method with 1,000 resamples was employed to evaluate the stability and reliability of the model. The area under the receiver operating characteristic curve (AUC-ROC) was calculated to assess the model's ability to distinguish between patients who develop SSIs and those who do not. Calibration plots, along with the Hosmer-Lemeshow goodness-of-fit test, were used to evaluate the agreement between predicted and observed SSI probabilities. Additionally, decision curve analysis was performed to assess the clinical utility of the nomogram by quantifying the net benefit across different threshold probabilities.

Ethical considerations

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Bahir Dar University under protocol ID CMHS/IRB 008. Additionally, a formal letter was submitted, and permission was secured from the research and quality offices of UoGCSH, FHCSH, and TGSTH before initiating data collection. Informed consent was obtained from all participants prior to their inclusion in the study. The principal investigators ensured that all participants fully understood the research process and voluntarily agreed to participate. Participants were assured of the anonymity and confidentiality of the data collected. Patients who developed surgical site infections (SSIs) during post-discharge follow-up were linked to appropriate healthcare facilities for treatment. For patients residing in rural areas, they were referred to the nearest health center. For those residing in the cities where the study hospitals are located, they were referred to the respective study hospitals where their surgeries were performed and treated according to the hospital protocols.

Result

Socio-demographic characteristics

A total of 463 patients were recruited and 441 of them were included in the final analysis. The median length of hospital stay (LOS) was 6 days (95% CI: 6, 7) days. Two hundred twenty-five (51%) of the patients was in the age group of 41-60years old and more than two-fourth 230 (52.1%) of patients were male. Two hundred twenty-six (50.7%) of study participants were in the rural dwellers (Table 1).

Comorbidities asd patient related characteristics

About 56 (12.7%) patients have Diabetes Mellitus, while 44 (10%) patients have HIV/AIDS. The majority of patients (85.6%) do not drink alcohol. Nearly nine-tenths of participants (89.4%) were Never smokers while only about 17 (3.9%) were Current Smokers (Table 2). The mean body mass index (BMI) was 22.34 ± 2.7 kg/m^2, six patients (1.4%) with BMI >= 30 Kg/m^2. Seventy-one (16%) of patients reported as having a history of previous surgery and 38 (8.8%) patients were given a pre-operative blood transfusion. The majority, 344 (78%) were Clean-contaminated and, of those 40.4%, 26.4% and 1.4% of participants were belongs to ASA score I II, and IV respectively. Antibiotic Prophylaxis was given for 428 (97%) patients and of those, (83.5%) were given 30 min before the surgery. Drainage was inserted for 23 (5.2. %) of procedures and wound care was performed for 402 (91.1%) of post-operative patients (Table 2).

Type of surgical procedures

Large Bowel Surgery 176 (39.9%) was the leading procedure followed by other abdominal Procedures 87 (19.7%), Appendix surgery 61 (13.8%), Gastric Surgery 43 (9.7%), Gallbladder surgery 32 (7.2%), Herniorrhaphy 22 (5.0%), and Breast surgery 20 (4.5%)Incidence of SSI.

One hundred seventy-five patients (39.6%) developed surgical site infections (SSI). Among them, 128 cases (73.1%) were superficial SSIs, 42 cases (24%) were deep soft tissue SSIs, and 5 cases (2.9%) were organ/space SSIs.

We included 14 candidate prognostic predictors from the bivariable analysis into the initial multivariable model. After refinement, key prognostic predictors such as age, sex, wound care, wound class, ASA score, diabetes mellitus (DM), alcohol consumption, residence, preoperative hospital stay, and duration of surgery

Variables	Category	Total	
		Frequency	Percent
Age category	<=20	12	2.7
	23–40	153	34.7
	41–60	225	51.0
	> 60	46	10.4
Sex	Female	206	47.9
	Male	230	52.1
Educational status	College and above	46	10.4
	Secondary school	105	23.8
	Primary school	124	28.1
	Able to read and write only	42	9.5
	Unable to read and write	119	27.0
Residence	Urban resident	235	48.8
	Rural resident	226	51.2

Table 1. Socio-demographic characteristics of patients undergone general surgery at referral hospitals in Amhara region, between march - April, 2023.

Variables	Category	Frequency	Percent
Diabetes mellitus?	No	385	87.3
	Yes	56	12.7
HIVAIDS?	No	394	89.3
	Yes	47	10.7
Alcohol drinking?	No	373	84.6
	Yes	68	15.4
History of previous surgery	No	365	83.7
	Yes	71	16.3
The grade of the surgeon	Consultant surgeon	70	16.1
	Surgeon	330	75.7
	Resident	36	8.3
Pre-operative blood transfusion	No	398	91.3
	Yes	38	8.7
ASA score	ASA I	176	40.4
	ASA II	115	26.4
	ASA III	99	22.7
	ASA IV	40	9.2
	ASA V	6	1.4
Surgical wound class	Clean	92	23.1
	Clean-Contaminated	344	78.9
Antibiotic prophylaxis	Yes given	423	97.0
	No prophylaxis required	13	3
Time antibiotic given	Less than 30 min before the surgery	353	83.5
	30 min to 1 h before the surgery	70	16.5
Wound care	Yes	397	91.1
	No	39	8.9

Table 2. Comorbidity, behavioral characteristics of patients undergone general surgery at referral hospitals in Amhara region, north-west Ethiopia, march-April, 2023 ($n = 441$).

remained in the reduced model. Based on the results of this reduced model, we developed a prediction model and a corresponding nomogram (Table 3).

Model discrimination and calibration

The area under the receiver operating characteristics curve (AUC) of the original model was 90.3% with 95% confidence interval of (87.1% to 93.1) (Fig). Based on the default 0.5 cut off probability, the original model has accuracy (ACC) of 90.3% with sensitivity (S) 0.78, specificity (SP) 0.90, positive predictive value (PV+) 0.83,

Prognostic determinants	Multivariate analysis	
	Original β	Bootstrap β
	β (95%CI)	β (95%CI)
Sex	1.46 (0.72, 2.08)	1.51 (0.81, 2.37)
Residence	0.36 (– 0.12 ,1.080	0.38 (– 0.22, 0.960
DM	1.02 (0.41, 2.500)	1.04 (0.08, 2.1517735
Alcohol	– 0.14 (– 1.05, 0.66)	– 0.12 (– 1.03, 0.77)
ASA	2.9 (1.82, 3.28)	3.07 (2.29, 3.93)
History of Surgery	1.28 (0.23, 1.93)	1.34 (0.53, 2.13)
Wound class	– 0.47 (– 1.32, 0.20)	– 0.49 (– 1.26, 0.22)
Wound Care	– 2.04 (– 3.54, – 0.24	– 2.24 (– 3.96, – 0.63)
Age 1	15.18 (– 55.62, – 55.43)	6.92 (5.05, 8.59)
Age2	15.40 (– 55.400, – 55.32)	7.15 (5.30, 8.92)
Age3	14.99 (– 51.42, – 51.00)	6.74 (4.37,8.89)
Duration of surgery	– 0.83 (– 2.38, – 0.23)	– 0.84 (– 1.85, 0.29)
Preoperative hospital stays	1.73 (2.97, 10.79)	1.84 (1.10 ,2.67)

Table 3. Bivariate regression analysis to develop and validate a prediction model for SSIs.

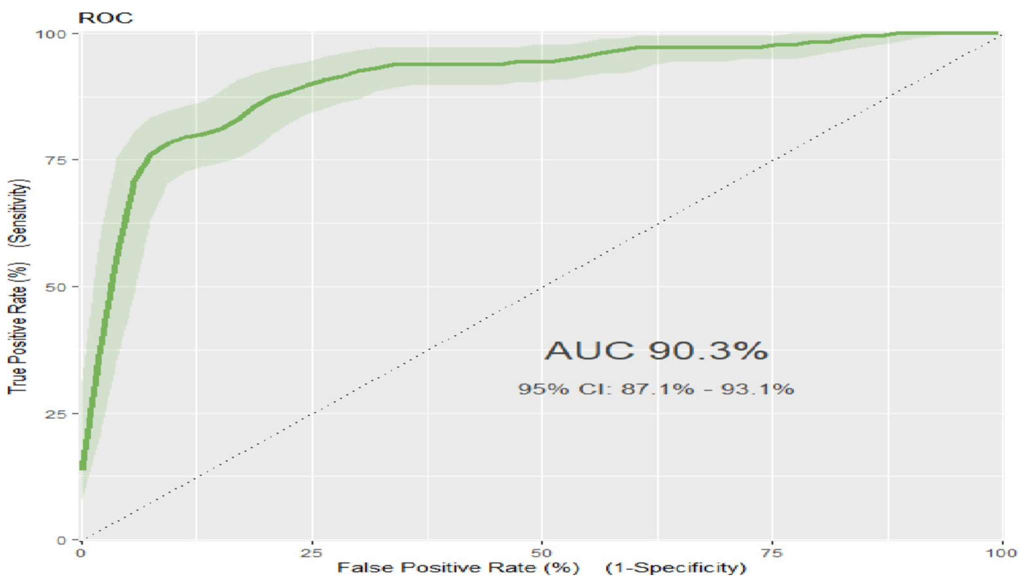

Fig. 1. Receiver operating characteristics curve for prediction model of the original model.

and negative predictive value (PV-) 0.86(Fig. 1). However, based on the optimal cut of point (Youden index), 0.51 probability, the model has accuracy (ACC) of 0.87% with 95% CI (0.82.0.88), sensitivity(S) 0.78,95%CI (0.71, 0.84), specificity (SP) 0.90,95% CI (0.86, 0.93), positive predictive value (PV+) 0.83,95%CI (0.77, 0.89), and negative predictive value (PV-) 0.86, 95%CI (0.81, 0.90). It appears that at a 0.5 cutoff, specificity is highest, and accuracy is maximized. Whereas, at 0.51 cutoff, corresponding to the Youden Index (a point that optimizes both sensitivity and specificity), provides balanced performance across sensitivity, specificity, accuracy, PPV, and NPV (Table 4).

Model calibration

The calibration plot for the model indicated, predicted probabilities are quite close to the red line, meaning that the model's predicted probabilities are generally well-calibrated across the range of observed probabilities. The model does a good job of matching predicted outcomes with actual outcomes. The p vale is 0.366; Therefore, given an excellent calibration, the model might perform well in a new sample (Fig. 2).

The density plot showed the distribution of predicted probabilities for developing surgical site infections (SSI) across 441 patients, with color coding for actual outcomes (ground truth). Red represents patients without SSI (negative cases, 60.3%), while blue represents patients with SSI (positive cases, 39.7%). The plot showed some overlap in the model, revealing, it isn't 100% perfect (Fig. 3).

To avoid over-interpretation and minimize too optimistic results from the original model; we used a bootstrapping technique using rms package to validate our model. This study used 1000 bootstrap samples with

Cut of point	Sensitivity	Specificity	Accuracy	PV+	PV-
0.2	91	71	79	67	92
0.3	86	81	83	75	90
0.4	80	84	83	77	86
0.5	79	90	86	85	90
0.51 (yode index)	80	84	83	77	86

Table 4. Sensitivity, (specificity), positive predictive value and negative predictive value of the model at different cut of point.

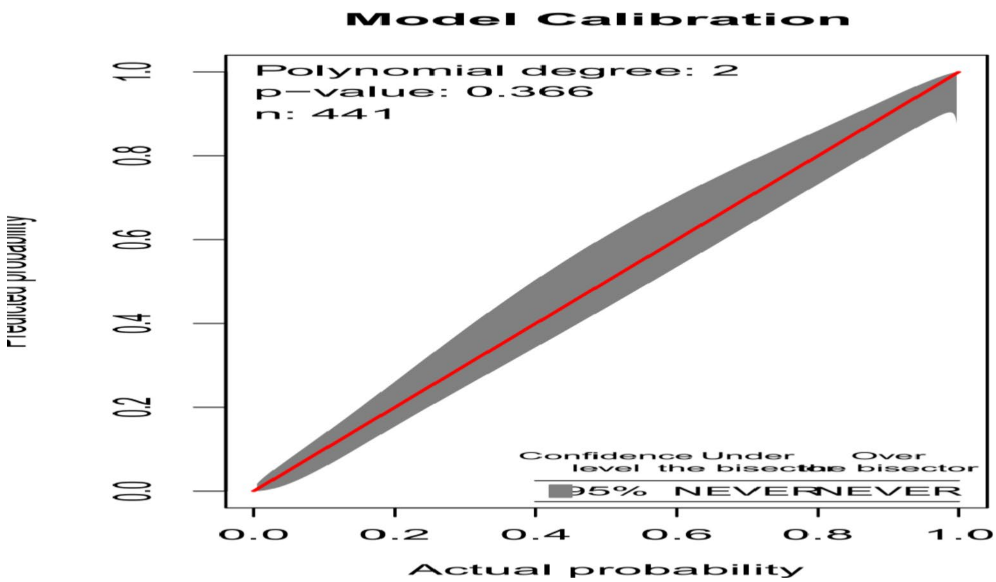

Fig. 2. Calibration belt for the original model: predicted probability versus observed probability of SSI.

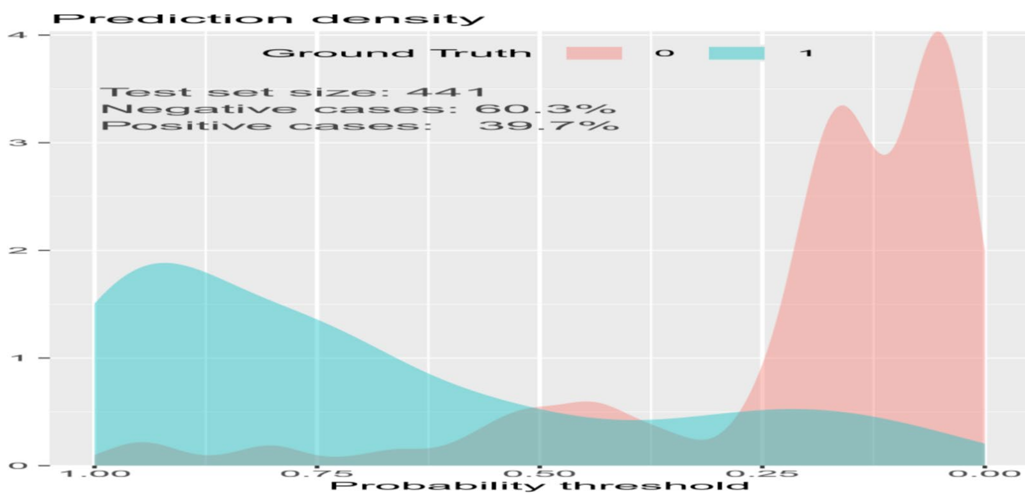

Fig. 3. Prediction density plot for surgical site infection risk: probability threshold distribution ($n = 441$).

replacement; the corrected AUC was 87%, 95%CI (84%, 91%) and the optimism coefficient for the validated model was 0.0856. The β coefficients of the bootstrapped model were almost the same as the original β coefficients.

The calibration plot for the validated model indicated predicted probabilities are quite close to the observed probabilities. The calibration curve is close to the ideal line, indicates that the model is well-calibrated and performs reliably across different risk levels, predicting the probability of SSI accurately. A well-calibrated model, as suggested by this plot, means that the predicted probabilities (from the nomogram) correspond well

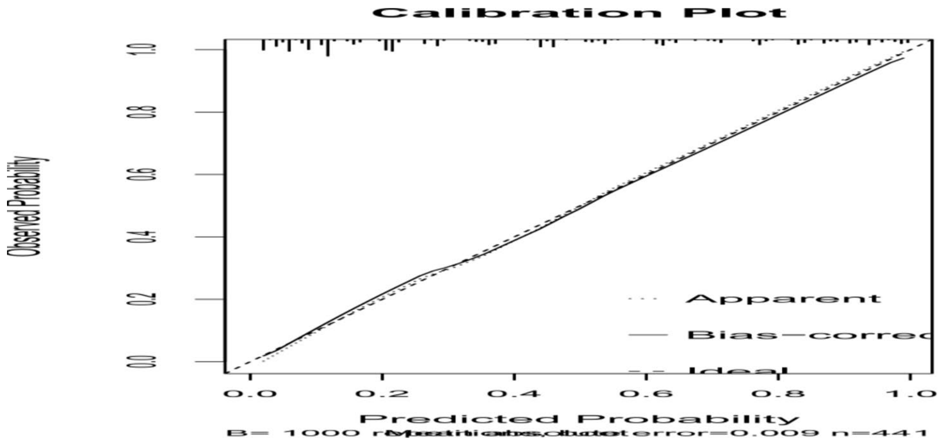

Fig. 4. Calibration plot of the validated model: predicted probability versus actual probability of SSI.

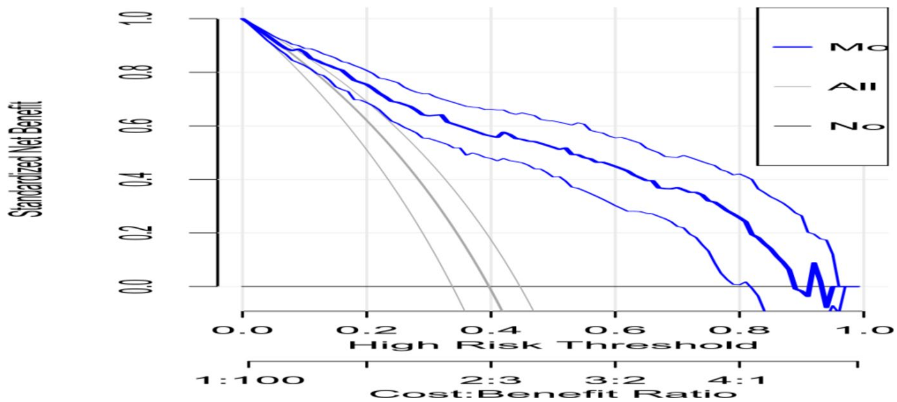

Fig. 5. A plot of decision curve showing the net benefit of the model against threshold probability and corresponding cost-benefit ratio of SSI.

with the actual probabilities observed in the dataset, making it a potentially useful tool for clinical decision-making (Fig. 4).

Model summery

These ratios indicate that after optimism correction, the model retains about 82.6% of its original Dxy value and about 61.2% of its original R^2 value, suggesting a moderate degree of optimism bias, especially in the R2 metric.

	Index. orig	Training	Test	Optimism	Index. corrected
Dxy	0.4922	0.5403	0.4546	0.0856	0.4065
R2	0.2268	0.2736	0.1855	0.0881	0.1387

Decision curve

The model has a higher standardized net benefit across a range of risk thresholds. The findings indicate that the model provides the best balance of benefit versus harm within the threshold range of approximately **0.1 to 0.6**, after which its net benefit declines. For clinical or decision-making purposes, this model would be most useful within this risk threshold range. This implies that our model has the highest clinical and public health importance. Therefore, decisions made using the model such as safely discharging patients with some medications or keeping them for more intensive care in the hospitals has a higher net benefit (Fig. 5).

Simplified nomogram development for SSIs

A **nomogram** is a graphical calculating device or chart that represents a mathematical relationship between independent with the outcome variables. It is often used in medical fields to predict the probability of a particular outcome based on several predictor variables. It allows clinicians or decision makers to quickly estimate the risk or prognosis for individual patients without needing complex statistical calculations. The

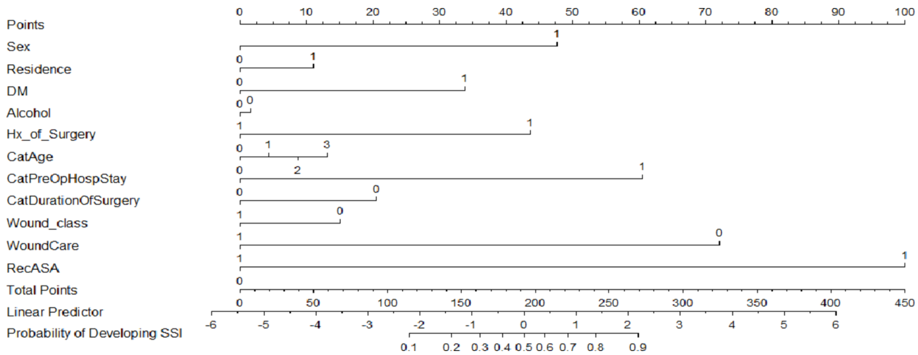

Fig. 6. Nomogram for predicting the probability of developing surgical site infections (SSIs).

nomogram was developed from: sex, age, preoperative hospital stays, history of surgery, duration of surgery, alcohol consumption, residence, DM, ASA, wound care, and wound class. It consists of elven parallel lines or scales that represent different predictor variables. Each variable is assigned a point value, and the total risk is estimated by summing these points and referring to a final scale. To use this nomogram, a clinician or user plots the value of each predictor variable on the respective scales (top point scale), sums the points, and then reads the corresponding risk estimate from a final scale (total points scale), then read down to the SSI (Fig. 6).

For example, if patient is male, wound care, and ASA, the point for each variable is 49, 75, and 100 respectively. when we sum up the result is 224, then we go down to the total pint scale and point the result to SSI (probability of the outcome) and point on the scale. Therefore, for the above variable the probability of SSI is 0.6 (60%). To predict an individual estimated risk of SSI from patients who undergone surgery based on linear predictors of validated regression coefficients as: the probability of SSI = 1/1 + exp-(-17.25 + 1.46*sex + 0.36*residence + 6.92*age[1] + 0.15*age2 + 6.4*age3 + 1.84*preoperative hospital stay + -0.84*duration of surgery + 1.34*history of surgery +-0.12*alcohol + 1.04*DM + 3.07*ASA+-0.49*wound class+-2.24*wound care.

Discussion

The World Health Organization (WHO) and UNICEF have developed comprehensive global guidelines for preventing and managing surgical site infections (SSIs), a major issue in surgical care. These guidelines advocate for a multi-dimensional strategy to lower SSI rates, with particular emphasis on low- and middle-income countries (LMICs), where SSIs contribute significantly to healthcare burdens[1,14]. Notably, SSIs are the most common postoperative complication following colorectal surgery, causing significant pain and suffering for patients. Additionally, SSIs are linked to adverse economic consequences, higher morbidity, prolonged hospital stays, increased readmission rates, sepsis, and mortality[15–17].Central to these recommendations is the use of precise risk-stratification tools and predictive models to support clinical and public health decision-making in healthcare settings. In line with these guidelines, we developed a prediction model and nomogram specifically for assessing SSI risk.

In this study, 441 patients were included, revealing a surgical site infection (SSI) incidence of 39.6%. Most infections (73.1%) were superficial, affecting only the skin and subcutaneous tissue, which is consistent with prior research findings[18]. Remarkably, our observed SSI rate is higher than rates reported in other studies conducted in Ethiopia[19], Tanzania[20], Uganda[21] and various regions in Asia[3]. This discrepancy may stem from variations in healthcare infrastructure, patient management practices, and the specific characteristics of study populations. Additionally, differences in resources available for infection control, surgical protocols, and follow-up care may contribute to the increased SSI rate seen in this study.

We predicted the likelihood of surgical site infections (SSIs) using key prognostic determinants included in our reduced model, such as sex, age, diabetes mellitus (DM), wound classification, wound care, American Society of Anesthesiologists (ASA) score, residence, surgery duration, preoperative hospital stays, alcohol consumption, and prior surgical history. Identifying and understanding these SSI incidence and risk factors is essential for optimizing patient care and improving surgical outcomes. This study found significant association between longer preoperative stays and higher rate of SSIs. This is in line with the others findings[22,23]. This is due to longer preoperative stays could increase the risk of exposure to hospital-acquired infections. Similarly, this study identified diabetes mellitus (DM) as a significant predictor for surgical site infections (SSI), this finding is consistent with previous studies[24–26].The heightened susceptibility to SSI in individuals with diabetes might be attributed to various physiological factors, including impaired wound healing and compromised immune function. The findings of this study revealed that preoperative alcohol consumption significantly increased the risk of surgical site infections (SSIs), a conclusion supported by various research studies[27–29]. This may be attributed to chronic alcohol use suppressing the immune system, particularly impairing the function of white blood cells such as neutrophils and macrophages, which are essential for combating infections. Additionally, alcohol disrupts angiogenesis, the formation of new blood vessels at the wound site, which is critical for effective wound healing. It also revealed that the history of surgical interventions significantly influences the incidence of surgical site infections (SSIs), this finding is in line with previous research findings[30,31]. This may be due to the formation of scar tissue from prior surgeries, which can impair wound healing and increase susceptibility to infections. So, understanding past practices and advancements in surgical techniques provides insight for prevention of SSIs. Similarly, this study revealed that wound care, and the duration of surgery significantly influence the occurrence of surgical site infections. The duration of surgery has been consistently identified as a significant risk factor for surgical site infections (SSIs) across various surgical specialties[32–35]. This suggest that surgical teams should be aware of the risks associated with prolonged surgeries and consider strategies to minimize duration where possible.

The findings of this study's model performance is better than other study[36]. This revealed that our model has produced discrimination performance of AUC 90.3% (95% CI 87.10–93.10%) with calibration p-value of 0.367; the calibration curve is almost in 45 degrees, showing a wonderful agreement between predicted and the observed probabilities. A bootstrapping technique was employed to make internal validation to minimize too optimistic results in the original model. The adjusted AUC was 88%, 95%CI (84%, 91%) and optimism for the validated model was 0. 085.The bootstrapped model produced identical β coefficients to the original model, and the calibration plot for the validated model demonstrates a good fit across the range of predicted probabilities, indicating excellent calibration. This suggests the model may perform well in future samples. Bootstrapping simulates multiple samples, which enhances coefficient stability and reduces overfitting, making the model applicable in real-world settings. The high AUC value reflects the model's strong discriminatory power, demonstrating that it can accurately distinguish between patients who are likely to develop an SSI and those who are not. Additionally, calibration assessments further confirm that the model's predictions align closely with actual patient outcomes, bolstering confidence in its clinical application.

The nomogram identifies several risk factors for SSI, such as Sex, Residence, Diabetes Mellitus (DM), Alcohol use, History of Prior Surgery, Age, Preoperative Hospital Stay, Duration of Surgery, Wound Classification, Wound Care, and ASA scores. Each factor was chosen based on clinical relevance and empirical associations with infection risk. Diabetes and prolonged preoperative hospital stays are well-documented risk enhancers due to their impact on immune function and potential exposure to hospital pathogens. Similarly, ASA score reflects overall patient health and its role in postoperative outcomes, while factors like wound classification and care are crucial for managing surgical contamination and recovery. It offers a visual, straightforward scoring system where clinicians can input patient-specific values for each variable, generating a cumulative risk score for SSI. This risk score, then converted to a probability estimate, enables healthcare providers to identify high-risk patients. This model not only aids in determining immediate care priorities but also contributes to long-term quality improvement by standardizing SSI risk assessment practices across different institutions. So, this validated nomogram equips Ethiopian healthcare providers with a locally developed, evidence-based tool for early SSI risk identification and intervention planning. By addressing factors such as wound care and comorbidities preemptively, the model supports individualized patient care while contributing to the broader goal of SSI prevention. This tool is particularly valuable in settings with limited resources, where personalized risk assessments enable the efficient allocation of preventive measures, ultimately improving surgical outcomes and reducing healthcare costs associated with SSI management. Though the model's predictive power and accuracy are optimistic, its application is currently limited to the study population. Future research could focus on external validation in diverse Ethiopian hospitals or similar low-resource settings to ensure generalizability. Additionally, updating the model periodically with new data may help maintain its accuracy as patient demographics and healthcare practices evolve.

Conclusion

The incidence of SSI was notably high. American Society of Anesthesiologists (ASA) score, sex, age, diabetes mellitus (DM), wound classification, wound care practices, patient residence, surgery duration, preoperative hospital stay, alcohol use, and history of previous surgeries were the key prognostic predictors. The developed model was well-calibrated with an excellent discrimination performance for surgical site infections (SSI). Our model includes 11 prognostic predictors that can be readily obtained from each patient's medical chart. These predictors allow for a straightforward assessment of SSI risk, making the model practical for clinical use. The nomogram we developed can aid clinical decision-making by distinguishing between patients at low risk for SSI, who may be discharged with standard medications, and those at high risk, who require more intensive management. This prediction model facilitates personalized risk assessment, guiding preventive strategies and enhancing SSI outcomes. By identifying high-risk patients prior to surgery, healthcare providers can implement targeted interventions, including enhanced wound care, optimized glycemic control, and shortened preoperative hospital stays.

Data availability

The datasets used and/or analyzed during the current study are available here with as Supplementary material.

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Author contributions
KM wrote the main manuscript textMA & ZA editing & approving the manuscriptAll authors reviewed the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

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