Predicting the Surgical Site Infections in Patients Undergoing Lumbar Internal Fixation Surgery: A New Predictive Nomogram is Evelopmenting and Assessmenting

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Abstract

Purpose

The purpose of this research is to develop and validate a nomogram of the risk of surgical site infections in Patients Undergoing lumbar Internal Fixation Surgery.

Patients and methods:

We had collected a total of 1327 patients with lumbar internal fixation surgery, 1273 patients were normal lumbar fixation group and 54 patients in the surgical site infections group. Patients are divided into two echelons of testing and verification, and R software is used as the only statistical analysis. In the training tests, first, single factor logistic regression analysis was used to select potential predictors with significant p-values. Then multivariate logistic regression analysis is used to filter out the predictors which we need. A nomogram was constructed using the coefficients of variable provided by Multivariate logistic regression analysis, the calibration and clinical applicability of the predictive model are evaluated by using the C index, calibration curve, and decision curve. In addition, we use internal verification tests to verify the built model.

Results

This unprecedented nomogram of SSI risk for lumbar Internal Fixation Surgery includes modic status, glucose, Hb, ESR, blood transfusion, sebum thickness. The model shows a good degree of discrimination, with a C index of 0.975 (95% confidence interval: 0.964, 0.987) and good alignment. The decision curve analysis showed that the SSI nomogram is clinically meaningful when the 1% probability threshold of the normal group is used to determine the intervention. The C-index of the validation test was 0.981(95% confidence interval: 0.957, 1.005).

Conclusion

This novel SSI prediction nomogram combines Modic status, glucose, Hb, ESR, blood transfusion, sebum thickness, and can be easily used for individualized SSI probability prediction in lumbar Internal Fixation Surgery patients.

1. Introduction

Surgical site infection (SSI) is defined as infections occurring up to 30 days after surgery (or up to one year after surgery in patients receiving implants) and affecting either the incision or deep tissue at the operation site. Because of SSI is associated with a large number of morbidities and leads to a significant increase in hospitalization costs, although improvements in prevention and drug development have

reduced their percentage, they remain an important clinical issue[1]. Lumbar Internal Fixation Surgery is an established treatment for a range of spinal disorders including: degenerative pathologies, trauma, and neoplasia. Besides, under the consensus of rapid recovery, early identification of the risk factors of postoperative SSI and prevention is more conducive to the recovery of patients after spinal surgery. Previous researches have shown that diabetes, fusion segments, erythrocyte sedimentation rate, protein, whether to use antibiotics preventively, and etc, are directly related to the occurrence of postoperative wound infections[2].

In China, there are many patients who need lumbar internal fixation every year, and the related complications should not be underestimated. The occurrence of complications after surgery often brings additional burdens to patients, including economic, psychological, satisfaction, etc. Among them, Surgical site infection is one of the most serious complications following spinal surgery during the early postoperative stage, and has always been one of the focuses of spine doctors[3]. Many risk factors related to the occurrence of SSI have been found in previous studies, but there was no predictive model that can comprehensively assess the probability of occurrence of SSI before surgery[4-6]. Thus, the purpose of this research is to develop and validate a nomogram of the risk of lumbar postoperative surgery site infection by using the same characteristics.

2. Patients And Methods

2.1 Patients and Research Design.

This study was approved by the institutional review board of our hospital (Approval No. 2021(KY-E-223)). A retrospective study was established, and the subjects were patients who undergoing lumbar internal fixation surgery in single center from May 2016 to February 2021. The data which we collected showed that there were 54 cases in the surgical site infection group and 1273 cases in the lumbar normal fixation group.

The US Centers for Disease Control and Prevention Guidelines for the Prevention of SSI (2018 Edition) are used as the diagnostic criteria for postoperative SSI[7]. Superficial SSI often manifests as redness, tenderness, swelling, fever, and pain in the area. It refers to infections that happen in the skin and subcutaneous tissues only within 30 days after surgery. The signs and symptoms of deep SSI are usually fever, pain, tenderness, continuous drainage or bleeding from wounds, abscesses or nodules, needing surgical debridement or even implant removal. Usually refers to an infection involving the muscle and fascia that occurred within 1 year (the implant remains in place). Determined the SSI case by looking at the information registered on the patient's medical record to determine the signs or symptoms recorded during the hospitalization.

The inclusion criteria for the surgical site infections group include.

(a) Patients who require lumbar internal fixation surgery to be admitted to the hospital from May 2016 to February 2021.

- (b) Posterior lumbar internal fixation surgery, including lumbar spondylolisthesis, lumbar disc herniation, lumbar spinal stenosis, lumbar spinal tumor, lumbar scoliosis correction, etc.
- (c) Before the operation, the skin of the operation area is intact, without ulceration, suppuration, ulcers, plaques, etc.
- (d) Deep tissue necrosis in the operation area, accompanied by chills, high fever, swelling of the operation area, drainage tube drainage of purulent secretions, bacterial culture (+).
- (e) For the first discovery after lumbar internal fixation, and the first debridement for the postoperative incision.

The exclusion criteria for the surgical site infections group included.

- (a) Patients who excluded from inclusion criteria.
- (b) The patient stimulates the incision due to irresistible factors, such as immersion, contamination, premature stitch removal, and the use of toxic liquids.
- (c) Long-segment scoliosis that is not predominantly lumbar curvature, lumbar malignant tumor invasion, lumbar tuberculosis, preoperative skin ulceration and inflammation in the lumbar spine surgery area.
- (d) Patients whom clinical and imaging data were imperfect.

The inclusion criteria for the normal group of lumbar spine fixation include.

Patients who require lumbar internal fixation surgery to be admitted to the hospital from May 2016 to February 2021, including lumbar degenerative diseases, such as lumbar disc herniation, lumbar spinal stenosis, degenerative scoliosis, etc. As well as internal fixation of lumbar fractures, lumbar spinal tumors, etc.

The exclusion criteria for the normal group receiving lumbar spine fixation include.

- (a) Patients who excluded from inclusion criteria.
- (b) Patients whom clinical and imaging data were imperfect.

2.2. Evaluation Variables.

Gender, age, diabetes, modic, ASA, additional antibiotics, operation time, number of vertebral bodies spanned, number of screws, anesthesia time, glucose, WBC, Hb, PLT, albumin, ESR, blood transfusion sebum thickness and skin to lamina thickness of the patients were collected from the His medical system at our Hospital. The indicators collected using the hospital imaging system, including the number of vertebrae spanned and the number of screws.

2.3. Statistical Analysis

The R software (Version 3.6.0: <https://www.R-project.org/>) was used for statistical analysis. The following steps were used to build the prediction model and select the most appropriate SSI predictors. First, Single factor logistic regression analysis was used to select potential predictors with significant p-values. Then multivariate logistic regression analysis is used to filter out the predictors which we need. Finally, a nomogram was constructed using the coefficients of variable provided by Multivariate logistic regression analysis.

Two-sidedness as the main feature of statistical significance level. By introducing and analyzing the statistical significance level of all selected features, the SSI risk prediction model were developed by applying statistically significant predictors and potential features. The calibration of SSI was evaluated by constructing a calibration curve. measuring Harrell C index were to quantify the performance of the SSI fault nomogram. By quantifying the net income of the spinal instrument group under different threshold probabilities, the decision curve analysis is performed to determine the clinical applicability of the SSI nomogram. In the calculation method of net benefit, the proportion of all false positive patients is not included in the proportion of true positive patients, and the relative harm of giving up intervention is weighed against the negative consequences of unnecessary intervention. The readiness of the SSI risk nomogram we constructed was evaluated by using internal verification tests.

3. Results

3.1. Patient Characteristics.

There were 54 patients in the SSI group and 1273 patients in the normal lumbar fixation group. In the experimental group and the validation group, the baseline characteristics of all study patients (SSI and normal groups) are shown in Table 1 and 2 respectively. Typical cases of surgery site infection after lumbar internal fixation surgery were shown in Figure 1.

Table 1

Clinical characteristics of patients with lumbar Internal Fixation Surgery patients in training test.

Characteristics	Yes (N=42)	No (N=1020)	P- value	TRUE (N=1062)
Gender			0.117	
Female	28 (66.7%)	542 (53.1%)		570 (53.7%)
Male	14 (33.3%)	478 (46.9%)		492 (46.3%)
Age			0.391	
Mean (SD)	58.4 (13.9)	56.5 (11.2)		56.6 (11.3)
Median [Min, Max]	60.0 [21.0, 80.0]	56.0 [12.0, 87.0]		56.0 [12.0, 87.0]
Diabetes			1	
No	38 (90.5%)	922 (90.4%)		960 (90.4%)
Yes	4 (9.5%)	98 (9.6%)		102 (9.6%)
Modic			<0.001	
A	0 (0%)	868 (85.1%)		868 (81.7%)
B	15 (35.7%)	109 (10.7%)		124 (11.7%)
C	27 (64.3%)	43 (4.2%)		70 (6.6%)
ASA			0.125	
A	5 (11.9%)	54 (5.3%)		59 (5.6%)
B	29 (69.0%)	812 (79.6%)		841 (79.2%)
C	8 (19.0%)	154 (15.1%)		162 (15.3%)
Antibiotics			0.005	
No	21 (50.0%)	728 (71.4%)		749 (70.5%)
Yes	21 (50.0%)	292 (28.6%)		313 (29.5%)
OP_times			0.471	
Mean (SD)	103 (64.3)	96.1 (49.4)		96.4 (50.1)
Median [Min, Max]	95.4 [14.3, 313]	83.5 [2.00, 339]		84.0 [2.00, 339]

Abbreviations: ASA: American Society of Anesthesiologists; OP times: operation times; AT: Anesthesia time; ESR: erythrocyte sedimentation rate;

Characteristics	Yes (N=42)	No (N=1020)	P-value	TRUE (N=1062)
Number of vertebral bodies spanned			0.167	
Mean (SD)	2.40 (2.39)	1.88 (0.883)		1.90 (0.990)
Median [Min, Max]	2.00 [1.00, 12.0]	2.00 [1.00, 6.00]		2.00 [1.00, 12.0]
Number of screws			0.034	
Mean (SD)	6.26 (3.41)	5.10 (1.59)		5.15 (1.71)
Median [Min, Max]	6.00 [1.00, 20.0]	4.00 [2.00, 12.0]		4.00 [1.00, 20.0]
AT			0.105	
Mean (SD)	97.1 (67.5)	115 (54.9)		114 (55.5)
Median [Min, Max]	80.0 [10.0, 340]	100 [20.0, 379]		100 [10.0, 379]
Glucose			0.032	
Mean (SD)	6.46 (2.33)	5.65 (2.05)		5.68 (2.07)
Median [Min, Max]	5.38 [3.30, 11.5]	5.07 [2.90, 22.0]		5.07 [2.90, 22.0]
WBC			0.018	
Mean (SD)	10.0 (4.00)	8.47 (3.48)		8.53 (3.52)
Median [Min, Max]	9.02 [3.93, 23.0]	7.50 [3.01, 25.8]		7.56 [3.01, 25.8]
Hb			<0.001	
Mean (SD)	105 (19.1)	126 (20.1)		126 (20.5)
Median [Min, Max]	104 [67.8, 143]	128 [50.0, 178]		127 [50.0, 178]
PLT			0.760	
Mean (SD)	262 (118)	257 (97.6)		257 (98.4)
Median [Min, Max]	225 [75.1, 518]	247 [26.7, 2250]		246 [26.7, 2250]
Albumin			<0.001	

Abbreviations: ASA: American Society of Anesthesiologists; OP times: operation times; AT: Anesthesia time; ESR: erythrocyte sedimentation rate;

Characteristics	Yes (N=42)	No (N=1020)	P-value	TRUE (N=1062)
Mean (SD)	36.0 (6.23)	40.1 (4.90)		40.0 (5.02)
Median [Min, Max]	35.9 [24.4, 47.5]	40.1 [22.1, 55.1]		40.0 [22.1, 55.1]
ESR			<0.001	
Mean (SD)	34.2 (26.9)	18.2 (17.7)		18.9 (18.4)
Median [Min, Max]	23.0 [5.00, 103]	13.0 [1.00, 102]		13.0 [1.00, 103]
Blood transfusion			<0.001	
No	27 (64.3%)	933 (91.5%)		960 (90.4%)
Yes	15 (35.7%)	87 (8.5%)		102 (9.6%)
Sebum thickness			0.001	
Mean (SD)	12.7 (9.04)	7.87 (4.02)		8.06 (4.42)
Median [Min, Max]	10.9 [4.12, 41.3]	7.12 [1.45, 48.9]		7.22 [1.45, 48.9]
Skin to lamina thickness			0.302	
Mean (SD)	49.4 (12.2)	47.4 (9.70)		47.5 (9.81)
Median [Min, Max]	47.4 [28.7, 78.1]	46.7 [2.74, 88.3]		46.7 [2.74, 88.3]
Abbreviations: ASA: American Society of Anesthesiologists; OP times: operation times; AT: Anesthesia time; ESR: erythrocyte sedimentation rate;				

Table 2

Clinical characteristics of patients with lumbar Internal Fixation Surgery patients in validation test.

Characteristics	Yes (N=12)	No (N=253)	P- value	TRUE (N=265)
Gender			0.124	
Female	10 (83.3%)	143 (56.5%)		153 (57.7%)
Male	2 (16.7%)	110 (43.5%)		112 (42.3%)
Age			0.134	
Mean (SD)	61.2 (10.6)	56.1 (10.8)		56.4 (10.8)
Median [Min, Max]	62.0 [35.0, 78.0]	57.0 [26.0, 80.0]		57.0 [26.0, 80.0]
Diabetes			1	
No	11 (91.7%)	233 (92.1%)		244 (92.1%)
Yes	1 (8.3%)	20 (7.9%)		21 (7.9%)
Modic			<0.001	
A	0 (0%)	218 (86.2%)		218 (82.3%)
B	3 (25.0%)	26 (10.3%)		29 (10.9%)
C	9 (75.0%)	9 (3.6%)		18 (6.8%)
ASA			0.634	
A	0 (0%)	11 (4.3%)		11 (4.2%)
B	9 (75.0%)	198 (78.3%)		207 (78.1%)
C	3 (25.0%)	44 (17.4%)		47 (17.7%)
Antibiotics			1	
No	9 (75.0%)	182 (71.9%)		191 (72.1%)
Yes	3 (25.0%)	71 (28.1%)		74 (27.9%)
OP times			0.665	
Mean (SD)	87.3 (55.7)	94.6 (45.7)		94.3 (46.1)
Median [Min, Max]	75.7 [28.0, 195]	86.0 [23.0, 269]		85.0 [23.0, 269]

Abbreviations: ASA: American Society of Anesthesiologists; OP times: operation times; AT: Anesthesia time; ESR: erythrocyte sedimentation rate;

Characteristics	Yes (N=12)	No (N=253)	P- value	TRUE (N=265)
Number of vertebral bodies spanned			0.142	
Mean (SD)	2.58 (1.68)	1.81 (0.782)		1.85 (0.853)
Median [Min, Max]	2.00 [1.00, 6.00]	2.00 [1.00, 4.00]		2.00 [1.00, 6.00]
Number of screws			0.173	
Mean (SD)	6.25 (3.02)	4.98 (1.47)		5.03 (1.58)
Median [Min, Max]	5.00 [3.00, 12.0]	4.00 [2.00, 10.0]		4.00 [2.00, 12.0]
AT			0.14	
Mean (SD)	84.7 (63.2)	114 (50.4)		113 (51.2)
Median [Min, Max]	60.0 [26.7, 200]	105 [26.7, 309]		101 [26.7, 309]
Glucose			0.091	
Mean (SD)	6.20 (1.30)	5.48 (1.77)		5.51 (1.75)
Median [Min, Max]	6.26 [4.60, 8.32]	5.01 [3.28, 18.0]		5.04 [3.28, 18.0]
WBC			0.868	
Mean (SD)	8.50 (3.04)	8.35 (3.25)		8.35 (3.23)
Median [Min, Max]	9.29 [4.49, 13.7]	7.43 [3.30, 18.2]		7.43 [3.30, 18.2]
Hb			0.049	
Mean (SD)	113 (21.3)	127 (18.8)		126 (19.1)
Median [Min, Max]	122 [68.0, 132]	128 [71.8, 175]		127 [68.0, 175]
PLT			0.112	
Mean (SD)	217 (86.9)	262 (102)		260 (102)
Median [Min, Max]	224 [45.8, 314]	250 [92.0, 1160]		250 [45.8, 1160]
Albumin			0.355	

Abbreviations: ASA: American Society of Anesthesiologists; OP times: operation times; AT: Anesthesia time; ESR: erythrocyte sedimentation rate;

Characteristics	Yes (N=12)	No (N=253)	P- value	TRUE (N=265)
Mean (SD)	38.2 (6.83)	40.1 (5.24)		40.0 (5.32)
Median [Min, Max]	36.9 [26.3, 46.9]	39.9 [25.1, 52.3]		39.9 [25.1, 52.3]
ESR			0.355	
Mean (SD)	24.4 (22.8)	18.0 (17.8)		18.3 (18.0)
Median [Min, Max]	21.5 [5.00, 92.0]	13.0 [1.00, 98.0]		13.0 [1.00, 98.0]
Blood transfusion			<0.001	
No	6 (50.0%)	233 (92.1%)		239 (90.2%)
Yes	6 (50.0%)	20 (7.9%)		26 (9.8%)
Sebum thickness			0.015	
Mean (SD)	10.7 (3.66)	7.69 (3.69)		7.82 (3.74)
Median [Min, Max]	10.3 [6.24, 17.0]	6.85 [2.10, 26.8]		6.94 [2.10, 26.8]
Skin to lamina thickness			0.763	
Mean (SD)	46.2 (11.2)	47.2 (9.80)		47.2 (9.85)
Median [Min, Max]	48.4 [26.0, 60.3]	46.6 [3.37, 74.9]		46.6 [3.37, 74.9]
Abbreviations: ASA: American Society of Anesthesiologists; OP times: operation times; AT: Anesthesia time; ESR: erythrocyte sedimentation rate;				

3.2. Variables selection

Univariate logistic regression analysis showed that, relative to the normal group, albumin, antibiotics, AT, blood transfusion, ESR, gender, glucose, Hb, modic, number of screws, number of vertebral bodies spanned, sebum thickness, WBC were candidate predictors for the probability of SSI in lumbar Internal Fixation Surgery patients (all $P < 0.05$) (Table 3).

Table 3

Univariate logistic regression of predictive factors for SSI in patients with lumbar Internal Fixation Surgery patients in training test.

Variables	OR	95% CI	P value
Age	1.015	0.988~1.045	0.292
Albumin	0.846	0.792~0.902	<0.001*
Antibiotics	2.493	1.336~4.655	0.003
ASA	0.873	0.430~1.734	0.704
AT	0.993	0.986~0.999	0.046
Blood transfusion	5.958	2.990~11.488	<0.001*
Diabetes	0.990	0.292~2.530	0.985
ESR	1.029	1.017~1.040	<0.001*
Gender	0.567	0.287~1.071	0.088
Glucose	1.133	1.012~1.247	0.015
Hb	0.954	0.940~0.968	<0.001*
Modic	13.142	8.171~22.804	<0.001*
Number of screws	1.313	1.145~1.508	<0.001*
Number of vertebral bodies spanned	1.384	1.112~1.719	0.002
OP times	1.003	0.997~1.008	0.354
PLT	1.000	0.997~1.002	0.714
Sebum thickness	1.120	1.075~1.169	<0.001*
Skin to lamina thickness	1.020	0.989~1.052	0.195
WBC	1.106	1.025~1.186	0.006
Abbreviations: ASA: American Society of Anesthesiologists; OP times: operation times; AT: Anesthesia time; ESR: erythrocyte sedimentation rate;			
*: Statistically significant difference.			

Besides, the multivariate logistic regression analysis is used to approximate the above candidate predictors and select the best subset of predictor variables, which is blood transfusion, glucose, Hb, ESR, modic, sebum thickness. (Table 4)

Table 4
multivariate logistic regression analysis for SSI in patients after
Univariate logistic regression analysis in training test.

Variables	Odds ratio	95% CI	P value
Blood transfusion	1.048	1.009~1.086	0.013
ESR	1.001	1.000~1.001	0.044
Glucose	1.009	1.004~1.013	<0.001*
Hb	0.999	0.9987~0.999	0.027
Modic	1.165	1.143~1.186	<0.001*
Sebum thickness	1.006	1.003~1.008	<0.001*
*: Statistically significant difference.			

3.3. Development of a Personalized Prediction Model.

Following the result of Univariate and multivariate logistic regression analysis, A predictive model is developed and displayed as a nomogram(Figure 2), which includes the above-mentioned features.

3.4. Plotting the ROC curve

In addition, ROC curves were constructed and the AUC of the prediction model was calculated to be 0.976, indicating that the model has a high recognition ability. (Figure 3)

3.5. Apparent performance of the SSI prediction nomogram

Include in the train group and verification group, the calibration curve of the SSI prediction nomogram used to predict the probability of undergoing SSI in lumbar Internal Fixation Surgery patients showed good consistency in this retrospective study (Figure 4(a) and (b)). C index of 0.975 (95% confidence interval: 0.964, 0.987). The C-index of the validation test was 0.981(95% confidence interval: 0.957,1.005), indicating that the model had good predictive accuracy. The area under the curve (AUC) for training and validation tests were 0.976 and 0.982, respectively (Figure 3(a) and 3(b)) implying a good discriminatory power of the model. In the SSI forecast nomogram, the apparent performance shows good forecasting ability.

3.6. Clinical Use

As shown in Figure 5, the constructed decision curve analysis serves as the assessment of the SSI risk nomogram. We can know from the decision curve analysis that when the threshold probability of patients and doctors is within a certain range, using this risk nomogram to predict the risk of SSI will be more

beneficial than existing solutions, and this range is respectively > 1% And <99%. Within this range, based on the risk nomogram, the net benefit was comparable with several overlaps.

4. Discussion

Currently, the nomograms are widely used for cancer or others prognosis, due to these can simplify the statistical prediction model to a single numerical estimate of the probability of an event, such as death or recurrence, and the estimate is tailored to the individual patient's situation[8-11]. In this study, for the first time, the nomogram was used to evaluate the SSI rate of patients undergoing lumbar internal fixation surgery. In clinical practice, especially in surgical operations, poor healing of postoperative incisions often brings great distress to the attending physicians and patients[12, 13]. Many studies have shown that Surgical site infections is closely related to many factors, such as Diabetes or blood sugar level, Serological indicators, inflammatory factors, antibiotics, nutritional status, obesity and etc. [14-18]. In our research, a novel tool was developed and verified for predicting SSI in lumbar Internal Fixation Surgery patients, using six readily available variables. By integrating imaging indicators, serological levels, and intraoperative conditions into the nomogram, the prediction of SSI in lumbar Internal Fixation Surgery patients is personalized and relatively accurate forecasting.

In risk factor analysis, SSI in lumbar Internal Fixation Surgery was associated with modic, glucose, Hb, ESR, blood transfusion, sebum thickness. The nomogram indicates that Lumbar disc mutation, High glucose level, Anemia, High ESR, Intraoperative blood transfusion, and Increased sebum thickness may be the critical factors in the risk of SSI in lumbar Internal Fixation Surgery.

Diabetes has always been the focus of surgeons' attention, and it is also an important factor related to surgery site infection[19-21]. Hyperglycemia affects various pathways of the immune system, leading to decreased phagocytosis and chemotaxis of neutrophils and monocytes, resulting in increased neutrophil apoptosis and decreased monocyte antigen delivery capacity, respectively[22, 23]. Thus, Perioperative blood glucose management is very important for the incision healing of patients after lumbar spine surgery, and the preoperative blood glucose level can also be used as an evaluation indicator for the postoperative incision healing. Low back pain (LBP) is the one of the most disabling conditions worldwide, and is usually associated with modic changes which could be foci of chronic subclinical infection and not mere markers of degeneration, as initially described, by a retrospective analysis[24]. It is well known that the modic1 stage is the inflammatory phase, which is related to the knowledge of postoperative wound infection, due to the localized action of proinflammatory mediators, and more recently low-grade bacterial infection[25]. In our multivariate regression analysis, modic changes have strong statistical significance($p < 0.001$).

In our prediction model, the preoperative hemoglobin value is closely related to the incidence of SSI. In other words, the lower the hemoglobin, the higher the probability of SSI. In existing studies, it has been found that anemia is one of the key factors that cause SSI[26, 27]. In support of this finding, a retrospective study has reported evidence that supports that the change in hemoglobin value is a useful

indicator of the occurrence of related complications after spinal surgery[28]. The healing of the surgical incision is closely related to the blood oxygen saturation of the incision microenvironment, due to the increased demand for reparative processes such as cell proliferation, bacterial defence, angiogenesis and collagen synthesis[29]. Therefore, adequate tissue perfusion and oxygenation is an absolute pre-requisite for a successful repair, and the content of hemoglobin with the ability to carry oxygen determines the prognosis of the incision. Besides, erythrocyte sedimentation rate (ESR), refers to the sedimentation speed of red blood cells under certain conditions. The ESR of healthy people fluctuates in a narrow range, many pathological conditions can significantly increase the ESR and the ESR is the result of the interaction of many factors. Previous studies on surgical procedures have shown that ESR is considered a useful marker for early diagnosis of SSI[4]. In addition, intraoperative blood transfusion is also statistically significant for incision healing. According to a retrospective cohort study, one of the risk factors for postoperative infection in spinal surgery may be intraoperative allogeneic red blood cell infusion[30]. A research had thinks that whether patients undergoing lumbar spine surgery receive allogeneic blood transfusion during or after surgery, the risk of infection at the surgical site, urinary tract infection and overall postoperative infection will increase, except that the risk of pneumonia is not increased[31]. Therefore, based on the current research, whether blood transfusion is required during the perioperative period of lumbar spine surgery, we should follow the blood transfusion principles or guidelines[32].

In lumbar spine surgery, obesity or BMI is mostly a risk factor for incisions infection after lumbar spine surgery, Since BMI may not reflect the composition of specific parts of the body, in a prospective study, Emily Waisbren and others used percent body fat (%BF)($\text{Body fat\%} = (1.20 \times \text{BMI}) + (0.23 \times \text{age}) - (10.8 \times \text{gender}) - 5.4$) as an independent risk factor, and think that unlike the traditional definition of obesity, this type of obesity defined by %BF is associated with a 5-fold increase in the risk of SSI, and this risk also increases with the increase of %BF, which is more sensitive and accurate than BMI SSI risk measurement, but further research is needed to better understand this relationship[33, 34]. In our measurement, the thickness of the sebum in the lumbar spine surgery area is taken as the measurement value of the specific part, this has a better guiding significance for the infection of the incision at the specific surgical site.

In our study, a new predictive model was established to evaluate the probability of SSI after lumbar internal fixation, this is both benefit for spine surgeons and patients after lumbar spine surgery. Before this, there was no comprehensive evaluation system that included imaging, serology, etc. We have carried out internal verification in the existing data, and demonstrated good clinical practicability and effectiveness in both the experimental group and the verification group. Besides, the internal validation of this study shows excellent discriminative and corrective power, especially the interval validation of our satisfactory C-index (0.981) proves that the prediction model can be broadly and accurately applied to the vast majority of cases.

5. Limitations

Our current study also suffers from the following shortcomings. The predictive factors analysis did not include all potential factors affecting the probability of SSI. Some of the potential influences on the probability of SSI, such as number of screws, number of vertebral bodies spanned, etc., were not fully understood. Although our prediction model proved to be robust in internal validation, it lacks externally validated, and thus may be biased if applied to other SSI patients in other regions. These are precisely the issues that need to be addressed in our subsequent study.

6. Conclusion

Clinicians can use a new nomogram to assess the risk of the surgery site infection rate of lumbar Internal Fixation Surgery patients, which is based on a predictive model developed by current research, so as to provide necessary early intervention measures and reasonable postoperative guidance. However, to determine whether intervention of risk factors can effectively reduce the infection rate of the surgical site in patients undergoing lumbar internal fixation surgery, the nomogram still needs extensive external verification.

Abbreviations

SSI
surgery site infection
CI
Confidence interval
AUC
Area under the curve
BMI
body mass index.

Declarations

Ethics approval and consent to participate

We confirm that all subjects and /or their legal guardians provided written informed consent for participation in this study. Written informed consent was obtained from the patient for publication of this research and any accompanying images. Prior approval of the study was obtained from the institutional ethical review board of The First Affiliated Hospital of Guangxi Medical University (No.2021(KY-E-223)). We have determined that all methods are carried out in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated during and analyzed during the current study are not publicly available due to the data involves patient privacy, we do not publish it publicly, but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no financial or other conflicts or interest in relation to this research and its publication.

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Authors' contributions

All authors read and approved the final manuscript.

Tianyou Chen and Zide Zhang: Conceptualization, Methodology, Software. Tuo Liang, Tianyou Chen and Jiarui Chen: Data curation, Writing- Original draft preparation. Jie Jiang, Tianyou Chen and Hao Li: Visualization, Investigation. Chong Liu and Xinli Zhan: Supervision. Hao Guo, Wuhua Chen and Zhen Ye: Software, Validation. Yuanlin Yao and Shian Liao: Writing- Reviewing and Editing.

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Figures

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Figure 1

Typical cases of surgery site infection after lumbar internal fixation surgery.

Figure 2

Construction of a nomogram for surgery site infection after the lumbar internal fixation surgery.

Figure 3

ROC curve analysis for training and validation tests. (a) Training test. (b) Validation test. AUC: area under curve.

Figure 4

Calibration curves for predicting the risk profile of surgery site infection in the cohort for training and validation tests. (a) Training test. (b) Validation test. The x-axis represents the predicted risk of surgery

site infection. The y-axis represents the actual diagnosis of surgery site infection. The diagonal dashed line represents an ideal perfect prediction model. Solid lines represent the performance of the nomogram, where closer proximity to diagonally dashed lines represents better prediction.

Figure 5

Decision curve analysis of the SSI prediction nomogram. Note: y-axis measures the net benefit. The dashed line indicates SSI prediction nomogram. The thin solid line indices assumption that all patients underwent SSI. Thin thick solid line represents the hypothesis that no patients underwent SSI. The decision curve showed that if the threshold probability of a patient and a doctor is >1% and <99%,

respectively, using this SSI prediction nomogram in the currstudy to predict SSI risk adds more benefit than the intervention-all-patients scheme or the intervention-none.