

Predicting Infection Risk in Acute Compartment Syndrome: A Nomogram Model Based on Admission Blood Indicators

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Purpose: Acute compartment syndrome (ACS) is a serious complication after tibial fracture and it commonly needs fasciotomy, which may affect 20.4% of patients. However, the predictors of infection remain debated. Our purpose aims to explore the role of admission blood indicators in infection in ACS patients.

Methods: We collected clinical data on ACS patients between Jan. 2015 and Jan 2025. According to whether ACS patients suffer from infection or not, they were divided into two groups. We copy with these data by R language software.

Results: Based on univariate analysis, we found that time from injury to admission, time from injury to surgery, and numerous admission blood indicators were relevant to ACS, but logistic regression analysis showed that neutrophil (NEU), white blood cell (WBC), C-reactive protein (CRP) and time from injury to surgery (all $p < 0.0001$) were predictors for infection in ACS patients. Our nomogram prediction model with 0.995 in AUC with good consistency and good clinical practicality.

Conclusion: We found that the levels of NEU, WBC, CRP and time from injury to surgery were predictors for infection in ACS patients. Our nomogram prediction model can efficiently predict infection in ACS patients.

Keywords: acute compartment syndrome, infection, admission blood indicators, nomogram prediction model, ACS

Introduction

Tibial fracture is one of the most common traumas of lower limbs caused by various injuries.¹ Acute compartment syndrome (ACS), as a severe complication after tibial fractures, usually occurs in 2–9% of patients who have suffered high-energy injuries.¹ The growing pressure within the compartment can rapidly reduce capillary blood flow, which may cause muscle necrosis or even amputation.^{2,3} Currently, fasciotomy has been considered to be the most effective therapeutic method for ACS patients because it can quickly reduce intra-compartmental pressure and restore blood flow.^{4,5} However, fasciotomy can lead to 20.8–36% of patients suffering from surgical site infection (SSI), which brings a huge economic and psychological burden to the families.^{6–9}

Ongoing articles have reported the predictors of SSI in ACS patients receiving fasciotomy. Yang found that open fractures, BMI, and smoking history were closely associated with SSI,⁹ but Yang did not establish the predictive model of SSI in ACS patients. Moldovan¹⁰ found the close relationship between serum biomarkers and Periprosthetic joint infection. To our knowledge, little research has focused on the predictors of SSI in ACS patients, let alone the crucial role of admission blood indicators in the diagnosis of SSI in ACS patients. Therefore, we aim to observe the role of admission blood indicators to predict SSI and then assess its potential biomarkers.

Patients and Methods

Ethics Statement

Our research was obtained by the institutional review boards of Affiliated Hospital of Hebei University of Engineering (2024-020-1) and exemption from informed consent as this is a retrospective study.

Patients

Data on ACS patients after fasciotomy in our hospital from Jan 2015 to Jan 2025. Based on whether ACS patients suffer from infection or not, they were separated into infection group (IG) and non-infection groups (NG). Diagnosis of infection is mainly based on the results of bacterial culture. The inclusion criteria were: 1) tibial fractures patients with ACS (ACS was defined as $\Delta P < 30$ mmHg (ΔP = diastolic arterial pressure-intra-compartmental pressure); 2) age ≥ 18 years; 3) ACS patients received fasciotomy. The exclusion criteria were: 1) patients with vascular injury; 2) patients without tibial fractures; 3) patients with insufficient data.

In our study, the patient characteristics, comorbidities, and admission laboratory results were obtained. The derived inflammatory indicators were included, such as NLR (neutrophils [NEU] count/lymphocytes count), MLR (monocytes count/lymphocytes count), PLR (platelets count/lymphocytes count), SII (platelets count \times NEU count)/lymphocytes count), and SIRI (monocyte count \times NEU count)/lymphocytes count)

Statistics

We used SPSS (version 27.0 SPSS Inc., Chicago, IL) to analyze the data with significance levels of $p < 0.05$. When the continuous variables met normality criteria, we chose *t*-test, but if it did not meet normality criteria, we used Mann-Whitney *U*-test. Regarding count data, we used the chi-square test. We used univariate and logistic regression analyses to analyze data. The cut-off values for continuous variables were used by the maximum Youden index (sensitivity + specificity - 1) in the ROC curve analysis. Finally, we used R language software to establish the nomogram prediction model for SSI. Calibration curve and decision curve were used to assess the predicted probabilities and clinical application value, respectively.

Results

A total of 219 tibial fracture patients with ACS, including 38 with infection and 181 without infection, were included in this study. After selection based on the inclusion criteria and exclusion criteria, 14 patients with infection and 77 patients without infection were excluded (Figure 1). Finally, 24 patients with infection and 104 patients without infection were included in our study.

Table 1 showed that there is no difference in age, gender, BMI, mechanism of injury, open injury, blister, and muscle necrosis, as well as a history of smoking, alcohol, heart disease, hypertension, diabetes, and cerebral infarction in two groups (all $p > 0.05$). However, we found that time from injury to admission ($p < 0.0001$) and time from injury to surgery ($p < 0.0001$) were closely related to SSI.

Table 2 showed that there is no difference in the levels of hemoglobin (HGB), lymphocyte (LYM), platelet (PLT), red blood cell (RBC), PLR, and MLR in two groups (all $p > 0.05$). However, we found that monocyte (MON, $p < 0.0001$), NEU ($p < 0.0001$), white blood cell (WBC, $p < 0.0001$), total protein (TP, $p < 0.0001$), C-reactive protein (CRP, $p < 0.0001$), NLR ($p < 0.0001$), SII ($p < 0.0001$) and SIRI ($p < 0.0001$) were closely related to SSI.

Furthermore, we performed logistic regression analysis and found that the levels of NEU [$p < 0.0001$, OR = 2.301, 95% CI (1.231, 4.353)], WBC [$p < 0.0001$, OR = 1.669, 95% CI (1.069, 2.214)], CRP [$p < 0.0001$, OR = 1.543, 95% CI (1.181, 2.103)] and time from injury to surgery [$p < 0.0001$, OR = 1.213, 95% CI (1.077, 1.403)] were independent risk factors for ACS (Table 3).

We establish a nomogram prediction model according the findings of logistic regression analysis (Figure 2). ROC curve implies good discrimination ability [AUC = 0.995, 95% CI (0.990, 1.000), Figure 3] and the calibration curve shows well calibrated ($p > 0.05$, Figure 4). Decision curve analysis indicates our prediction model with good clinical benefits (Figure 5).

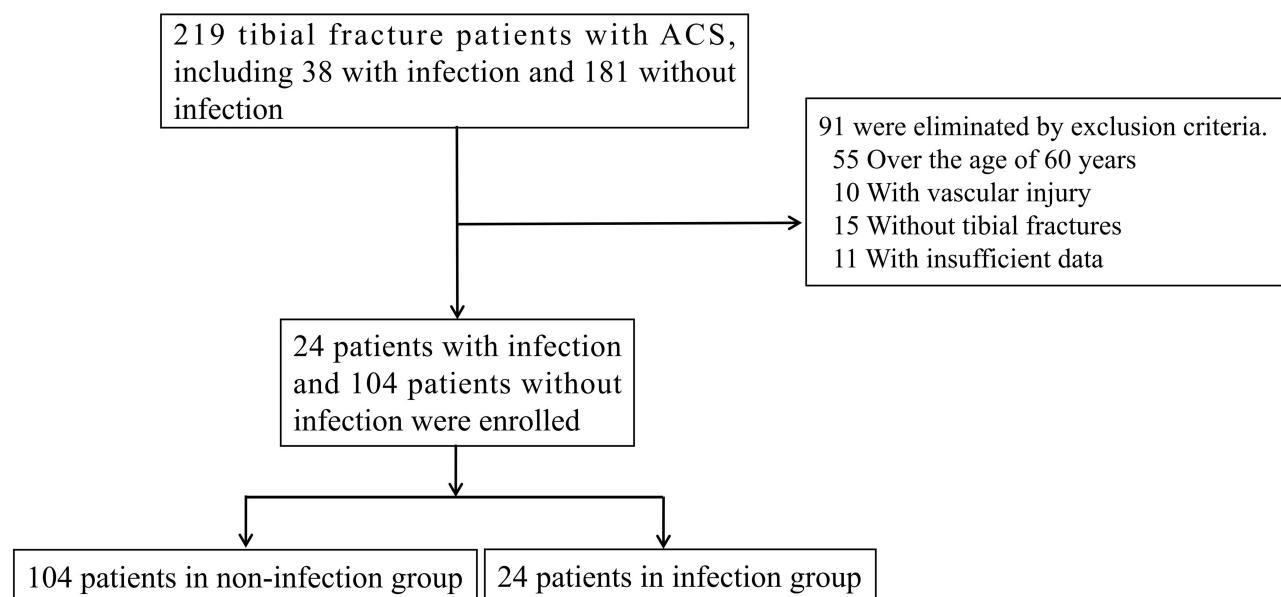


Figure 1 Flow diagram of included patients.

Discussion

ACS, a common complication after tibial fractures, can result in tissue ischemia because of increased intra-compartment pressure, which may cause infection, amputation, or muscle necrosis.¹⁻³ Recently, limited articles reported the incidence and predictors of infection in ACS patients. A previous study has reported that open fractures, BMI, and smoking history

Table 1 Comparison of Characteristics of ACS Patients in Two Groups

Variables	Infection Group (n = 24)	Non-Infection Group (n = 104)	p
Age, years	39.0 (37.0~42.0)	39.0 (36.0~41.0)	0.488
Gender			
Male	15	61	0.729
Female	9	43	
Body mass index (kg/m²)	24.0 (21.5~26.0)	24.0 (22.0~27.0)	0.752
Mechanism of injury			0.999
Car crash injury (yes)	5	23	
Fall injury (yes)	5	22	
Crush injury (yes)	7	29	
Hurt by a crashing object (yes)	7	30	
Time from injury to admission (hours)	8.0 (7.0~8.0)	5.0 (4.0~6.8)	<0.0001
Time from injury to surgery (hours)	10.0 (10.0~11.0)	8.0 (7.0~8.0)	<0.0001
Open injury (yes)	5	21	1.000
Blister (yes)	7	34	0.739
Muscle necrosis (yes)	8	41	0.580
Smoking (yes)	8	39	0.703
Alcohol (yes)	7	35	0.673
Comorbidities			
Heart disease (yes)	1	5	1.000
Hypertension (yes)	2	7	0.676
Diabetes (yes)	1	4	1.000
Cerebral Infarction (yes)	1	5	1.000

Table 2 Admission Laboratory Variables Associated with Infection in ACS Patients

Laboratory variables	Infection Group (n = 24)	Non-Infection Group (n = 104)	p
Hemoglobin (HGB, g/L)	130.6±8.94	130.1±7.91	0.795
Lymphocyte (LYM, 10 ⁹ /L)	1.50(1.15~1.80)	1.40(1.10~1.70)	0.468
Monocyte (MON, 10 ⁹ /L)	0.90(0.75~1.00)	0.70(0.60~0.80)	<0.0001
Neutrophil (NEU, 10 ⁹ /L)	12.5(11.45~13.95)	7.3(6.8~8.35)	<0.0001
Platelet (PLT, 10 ⁹ /L)	230.0(220.00~241.00)	227.5(220.00~240.00)	0.831
Red blood cell (RBC, 10 ¹² /L)	4.9(3.7~5.25)	4.7(4.15~5.2)	0.973
White blood cell (WBC, 10 ⁹ /L)	13.95(11.65~15.2)	6.9(6.1~7.65)	<0.0001
Total protein (TP, g/L)	53.3(48.25~54.6)	56.85(54.05~59.1)	<0.0001
C-reactive protein (CRP, mg/L)	21.4±3.54	5.06±1.47	<0.0001
NLR	8.03(6.48~10.15)	5.45(4.24~6.93)	<0.0001
PLR	153.0(127.94~199.7)	161.74(131.76~209.09)	0.542
MLR	0.58(0.47~0.73)	0.50(0.40~0.64)	0.107
SII	1717.33(1538.10~2624.68)	1272.97(939.80~1599.19)	<0.0001
SIRI	6.97(5.02~9.63)	3.80(2.93~4.89)	<0.0001

Abbreviations: NLR, Neutrophil to Lymphocyte Ratio; MLR, Monocyte-to-lymphocyte ratio; PLR, Platelet-to-lymphocyte ratio; SII, systemic immune-inflammation index; SIRI, system inflammation response index.

Table 3 Logistic Regression Analysis of Laboratory Variables Associated with Infection in ACS Patients

Variables	OR	95% CI		P value
		Lower Limit	Upper Limit	
Neutrophil	2.301	1.231	4.353	<0.001
White blood cell	1.669	1.069	2.214	<0.001
C-reactive protein	1.543	1.181	2.103	<0.001
Time from injury to surgery	1.213	1.077	1.403	<0.001

were relevant to SSI,⁹ but it did not use the predictive model to observe the risk factors of SSI in ACS patients. Moldovan¹⁰ found the close relationship between serum biomarkers and Periprosthetic joint infection. As far as we know, few research has focused on the predictors of SSI in ACS patients, and ignored the important role of admission blood indicators in the diagnosis of SSI in ACS patients. Thus, the purpose of this article is to investigate whether admission blood indicators can predict SSI or not. In the current study, we found that various laboratory elements were related to SSI in ACS patients by univariate analysis. Furthermore, NEU, WBC, CRP and time from injury to surgery were closely related to SSI by logistic regression analysis. Our prediction model implies good discrimination ability and good clinical benefits.

NEU is the most common type of WBC in our body and plays a crucial role in the innate immune system.¹¹ LYM contributes to the adaptive immune system, including antibody production and cell-mediated immunity.¹² MON can release pro-inflammatory and pro-oxidative cytokines against pathogens.¹³ PLT is mainly responsible for regulating NEU

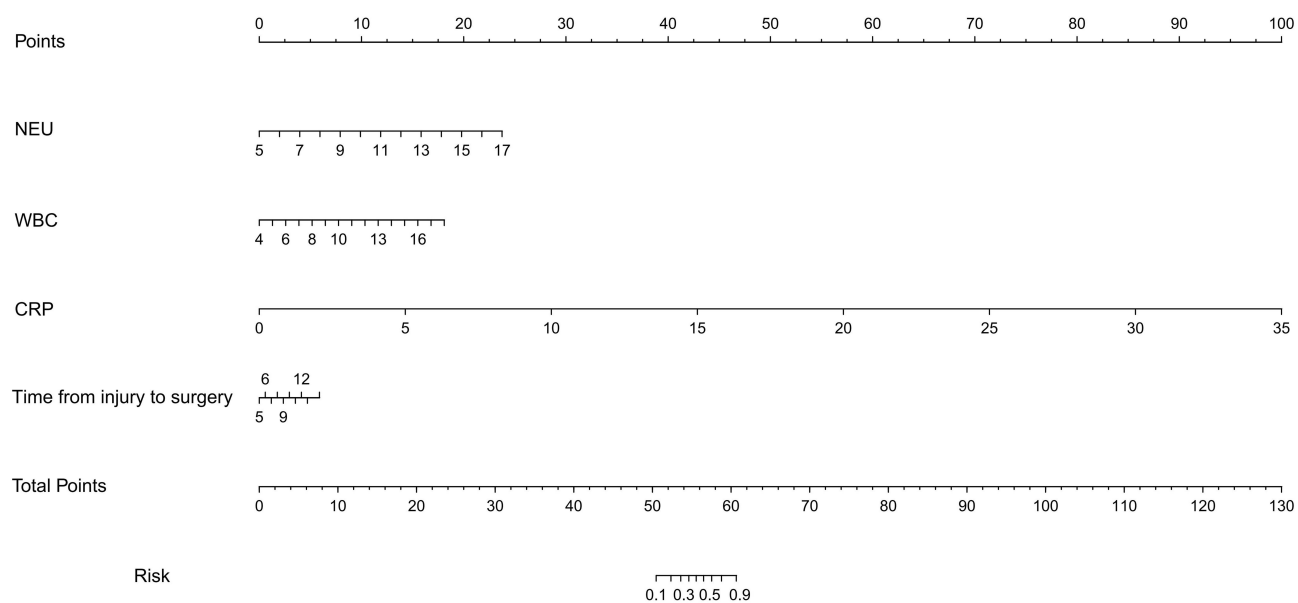


Figure 2 The nomogram prediction model for ACS.

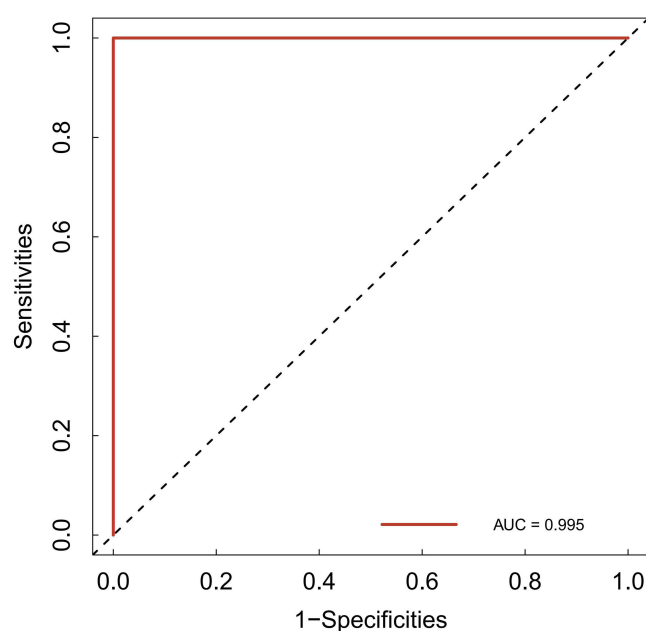


Figure 3 The receiver operating characteristic curves of the nomogram.

and macrophage recruitment.¹⁴ Recently, inflammation ratios have been increasingly studied, including NLR, MLR, and PLR. These indicators have some advantages, such as whole blood count, low-cost, and routine clinical examinations.¹⁵ SII, stems from NEU, LYM, and PLT, can accurately reflect the immune and inflammatory levels of the body, which has been studied in the topic on predictors for inflammation diseases.¹⁶ SIRI, derived from NUE, LYM, and MON peripheral counts, can also represent inflammation.¹⁷ To our knowledge, the relationship between these indexes and SSI in ACS patients has not been studied.

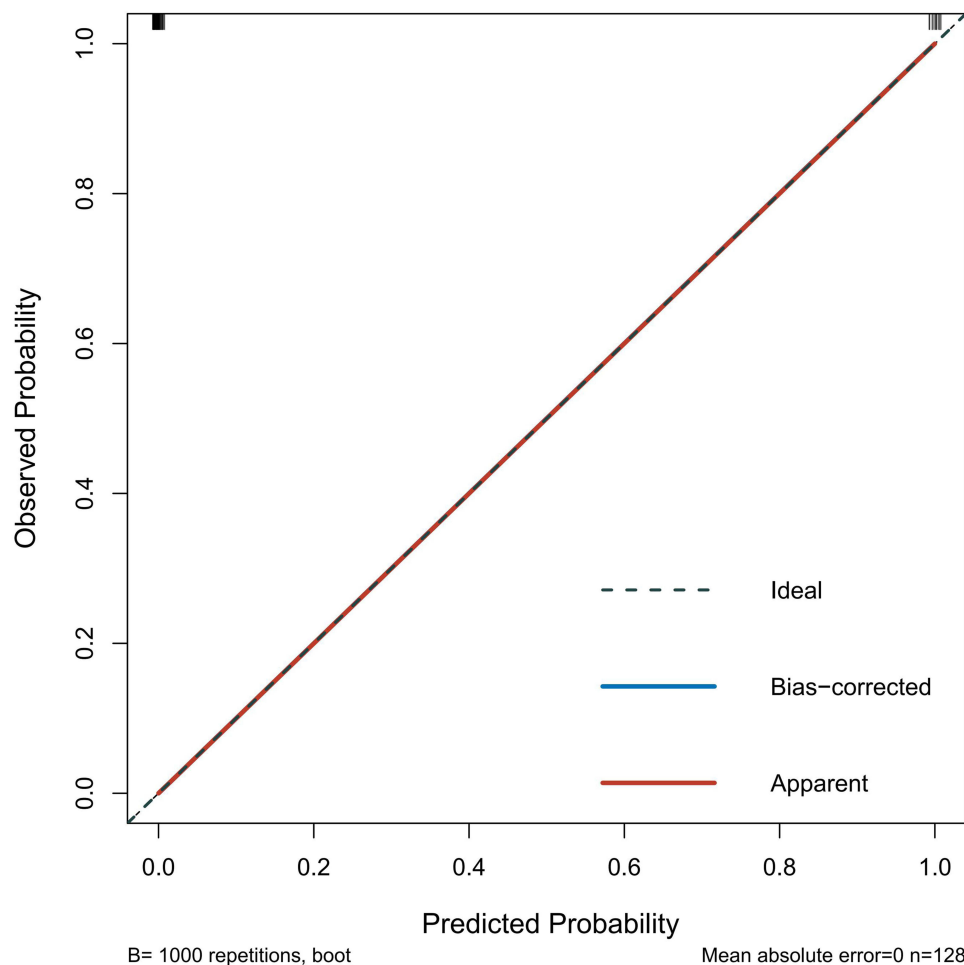


Figure 4 The calibration curve of the nomogram.

In this study, our findings indicated that the levels of MON, NEU, WBC, TP, CRP, NLR, SII, and SIRI were associated with SSI in univariate analysis. Furthermore, logistic regression analysis indicated that the levels of NEU, WBC, and CRP were independent risk factors for SSI. Yang⁹ found, a significant correlation between NEU and SSI in univariate analysis, but in multivariate analysis, no significant correlation was found, which is inconsistent with our results and may be due to differences between samples. Therefore, we need large sample data for further research in future studies. As we know, CRP is an important indicator of inflammation levels in the body. Our study found that patients with elevated CRP have a 1.543 times higher risk of SSI after fasciotomy compared to patients with normal CRP levels.

Previous studies have demonstrated that smoking and high BMI were risk factors for SSI. Yang⁹ also found that these two factors are closely related to SSI, but our study did not find such results. We consider that this may still be related to the differences in the samples. We also investigated the correlation time from injury to admission, time from injury to surgery, and SSI. The results of univariate analysis showed that both were related to SSI, but the results of multivariate analysis only found a significant correlation between injury to surgery time and SSI. As is well known, 6–8 hours after injury is the early stage of treatment. When ACS occurs, high pressure in the compartment leads to tissue ischemia, and delayed treatment can cause muscle necrosis or even amputation. Therefore, the longer the time from injury to surgery, the longer the tissue ischemia time, and the higher the risk of natural tissue necrosis and infection.

Our prediction model to evaluate SSI in ACS patients. The ROC curve suggested good discrimination ability, and the calibration curve showed well calibrated. Decision curve analysis showed our nomogram prediction model with good clinical benefits. Although our study provides some innovative findings, a few limitations should be noted. First, single-center

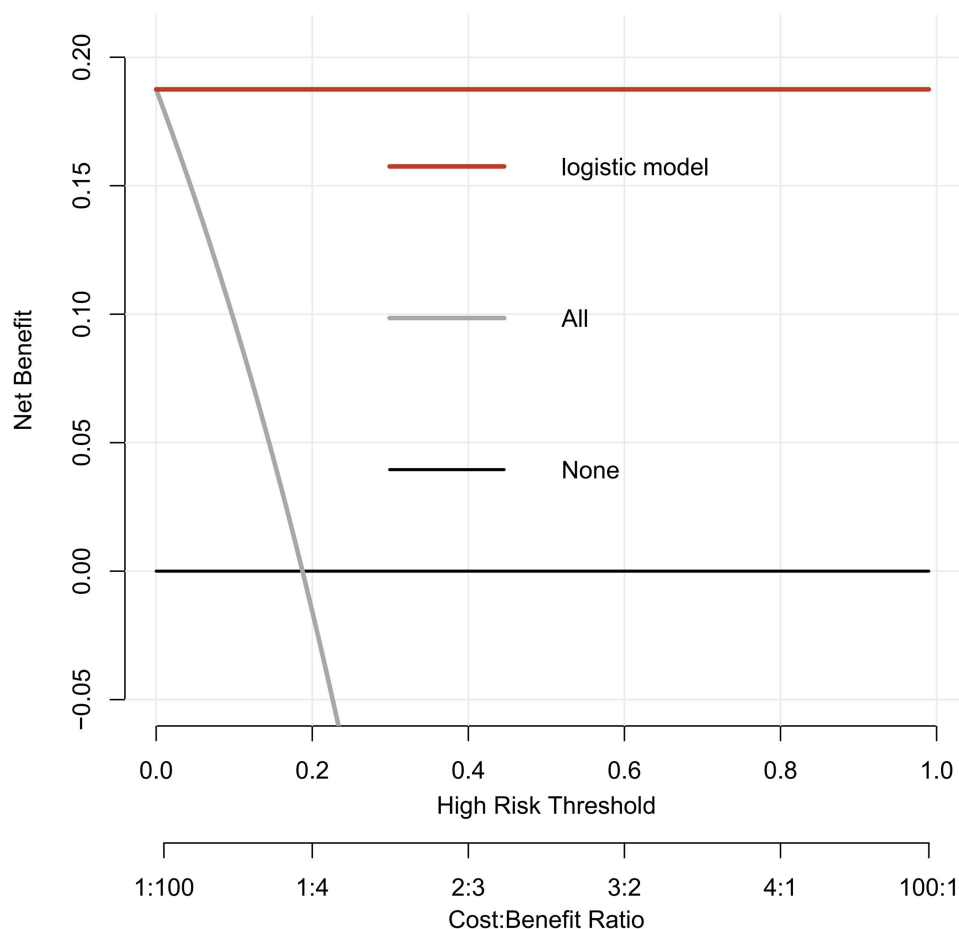


Figure 5 The decision curve analysis of the nomogram.

research and limited samples make it difficult to perform a subgroup analysis, which inevitably affects the reliability of the findings. Therefore, a multicenter, randomized controlled study with a larger sample size is required. Second, the inherent boundedness of data collection caused by a retrospective study causes some important inflammatory markers.

In conclusion, We found that the levels of NEU, WBC, CRP and time from injury to surgery were predictors for infection in ACS patients. Our nomogram prediction model can efficiently predict infection in ACS patients.

Data Sharing Statement

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

Before data collection, this study was approved by the institutional review boards of Affiliated Hospital of Hebei University of Engineering (2024-020-1) in compliance with the Helsinki and an exemption from the informed consent was obtained. All data were anonymized before the analysis to safeguard patient privacy.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no competing interests in this work.

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