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Development and validation of a prediction nomogram for sleep disorders in hospitalized patients with acute myocardial infarction

Jing Huang[1†], Miao Li[1†], Xiu-Wen Zeng[1], Guang-Su Qu[1], Lu Lin[2] and Xu-Min Xin[1*]

Abstract

Purpose Sleep disorders are becoming more prevalent in hospitalized patients with acute myocardial infarction (AMI). We aimed to investigate the risk factors for sleep disorders in hospitalized patients with AMI, then develop and validate a prediction nomogram for the risk of sleep disorders.

Methods Clinical data were collected from patients with AMI hospitalized in our hospital from January 2020 to June 2023. All patients were divided into the training group and the validation group with a ratio of 7:3 in sequential order. The LASSO regression analysis and multivariate logistic regression analysis were used to screen potential risk factors for sleep disorders. The concordance index (C-index), calibration curves, and decision curve analysis (DCA) were plotted.

Results A total of 256 hospitalized patients with AMI were enrolled. Patients were divided into the training group (180) and the validation group (76) according to a scale of 7:3. Of the 256 patients, 90 patients (35.16%) suffered from sleep disorders, and 33 patients (12.89%) needed hypnotics. The variables screened by LASSO regression included age, smoking, NYHA class, anxiety status at admission, depression status at admission, and strangeness of environment. A nomogram model was established by incorporating the risk factors selected. The C-index, calibration curve, and DCA showed good predictive performance.

Conclusions We identified six clinical characteristics as predictors of sleep disorders in hospitalized patients with AMI. It helps nurses make appropriate decisions in clinical practice.

Keywords Prediction nomogram, Risk factors, Sleep disorders, Acute myocardial infarction

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Background

As a common cardiac emergency, acute myocardial infarction (AMI) is characterized by coronary artery stenosis or occlusion leading to severe myocardial cell hypoxia and necrosis, and then resulting in heart dysfunction or heart failure [1]. There are two subclasses of AMI based on the presence or absence of ST-segment elevation in the ECG trace. According to the China PEACE-retrospective AMI study, the number of cases of coronary heart disease (CHD) and AMI increased fourfold in China from 2001 to 2011 [2]. AMI has an acute onset, rapid progress, and easily develops into cardiogenic shock or acute heart failure without timely treatment, which brings a heavy economic burden to families and the health-care system.

Sleep disorders are symptoms of abnormal amount, time, rhythm, cycle, or pattern of sleep, which are common in hospitalized patients with AMI. Numerous studies have confirmed that there exists a link between sleep disorders and cardiovascular diseases involving atherosclerosis, stroke, cardiac arrhythmias, etc. [3, 4] Meanwhile, sleep disorders can also reduce effective sleep, aggravate daytime fatigue symptoms, and seriously affect the recovery of AMI patients [5]. Early screening of risk factors leading to sleep disorders in hospitalized patients with AMI is of great significance for the prevention of sleep disorders. Risk factors for sleep disorders in hospitalized patients have been reported in previous literature [6]. However, there is a lack of comprehensive and systematic risk assessment tools to guide clinicians and nurses to conduct early, individualized assessments of sleep disorders in hospitalized patients with AMI.

The use of clinical characteristics and functional scores as the basis helps guide further interventions in clinical practice. Nomograms provide the probability of individual clinical prognosis, which is more intuitive, accurate, and widely accepted by clinicians and nurses [7]. Therefore, the purpose of this study is to construct a risk prediction nomogram to help clinicians and nurses identify patients who are at high risk of sleep disorders in hospitalized patients with AMI.

Subjects and methods

Patients

We retrospectively enrolled consecutive patients with AMI hospitalized in our hospital (a Grade A tertiary hospital located in southwest China) from January 2020 to June 2023 in the present study. All patients were divided into the training group and the validation group with a ratio of 7:3 in sequential order. The manuscript was written according to the TRIPOD+AI statement for reporting clinical prediction models (Supplementary Table S1). This study obtained approval from the ethics committee of the Second Affiliated Hospital of Chongqing Medical University (Ethical Number: 2023 Scientific Ethics Review No. 62). All participants included in this study understood and provided a verbal informed consent. The ethics committee exempted the requirement for written informed consent due to the retrospective nature of the study design.

Inclusion criteria: (1) AMI diagnosis met ST-segment elevation myocardial infarction (STEMI) criteria with typical history and electrocardiogram (ECG) changes. (2) The clinical data, laboratory tests, and radiological findings of each patient were complete.

Exclusion criteria: (1) patients with comorbidities of malignant tumors, severe liver, and kidney disease; (2) patients with previously diagnosed psychiatric conditions, prior treatment with psychotherapies, or taking sleep medications over long periods; (3) patients who were diagnosed with sleep disorders before hospitalization.

Risk factors

Risk factors related to AMI were determined based on evidence from previous literature combined with the results of the experts' analysis and discussion. Relevant information was obtained by reviewing the patient's clinical medical records and nursing data. A total of 21 indicators of risk factors were collected, including: (1) basic information: gender, age, marital status, medical insurance, degree of education, accompanying personnel, smoking, alcohol, and BMI. (2) comorbidity: hypertension, diabetes mellitus, hyperlipidemia, pulmonary infection, urinary tract infection. (3) clinical information: New York Heart Function Assessment (NYHA) class, physical training, anxiety status at admission, depression status at admission, strangeness of environment, chronic pain, surgical treatment. Adequate physical training was defined as more than twice a week. The self-rating anxiety scale (SAS) was used to evaluate the anxiety status of patients at admission, and SAS scores ≥ 50 were defined as anxiety status. The self-rating depression scale (SDS) was applied to evaluate the depression of patients at admission. SDS scores ≥ 53 were classified as depression states. Strangeness of environment was carried out by verbally asking patients: whether they could not adapt to pillows or beds; whether they could not adapt to the light, smell, or temperature of the ward; whether they were disturbed by nearby patients, nursing workers, and doctors. Chronic pain was defined as pain lasting more than 3 months, which was evaluated by the numerical rating scale (NRS).

Diagnostic criteria for sleep disorders

The Pittsburgh Sleep Quality Index (PSQI) was applied to evaluate sleep quality [8]. The scale has a total score of 0 to 21, with a total score >7 indicating sleep disorders.

Data collection

In order to prevent errors during data collection, risk factors were independently assessed by two researchers. All assessment scales were conducted by the senior investigators. We discussed the differences to determine whether to utilize them.

Statistical analyses

SPSS 25.0 and R 4.0 software were used for statistical analysis. Continuous data were transformed into categorical variables using clinically meaningful cutoffs. Categorical variables were expressed in terms of frequency. Comparisons between the two groups were tested using the chi-square test. Firstly, we used the least absolute shrinkage and selection operator (LASSO) to select the variables with the best predictive value from all the collected risk factors. The principle of the LASSO analysis is that relatively unimportant variables can be shrunk to almost zero by tuning parameter lambda. Secondly, the selected variables were examined by multivariate logistic regression analyses. Then, a nomogram was constructed to intuitively score the individual risk probability of sleep disorders. The nomogram showed a visual graphical result of these risk factors. Each risk factor was corresponding to a score. Then, the total scores were summed, and probability of the outcome event could be calculated by a transformation function between score and probability. The concordance index (C-index), calibration curves, and decision curve analysis (DCA) were plotted to assess the predictive accuracy of the present model. Statistical significance was considered as $P<0.05$.

Results

Patient characteristics

There were 322 patients identified through the hospital database searching between the period from January 2020 to June 2023. After excluding ineligible patients, a total of 256 hospitalized patients with AMI were enrolled during the study period (see Fig. 1). There were 207 male patients and 49 female patients, and the age range was 29–95 years. Patients were divided into the training group (180) and the validation group (76) according to a scale of 7:3. Of the 256 patients, 90 patients (35.16%) suffered from sleep disorders, and 33 patients (12.89%)

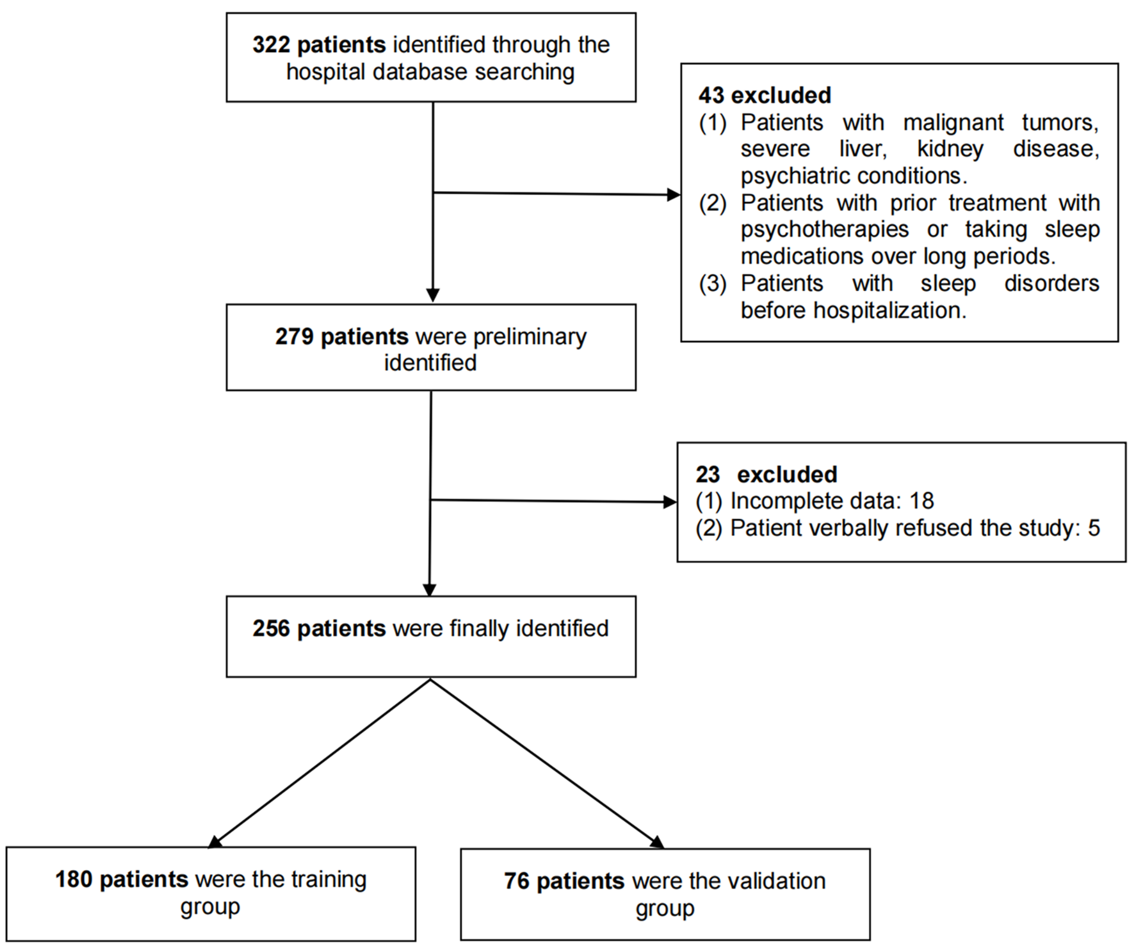

Fig. 1 Flow diagram of the patient cohort

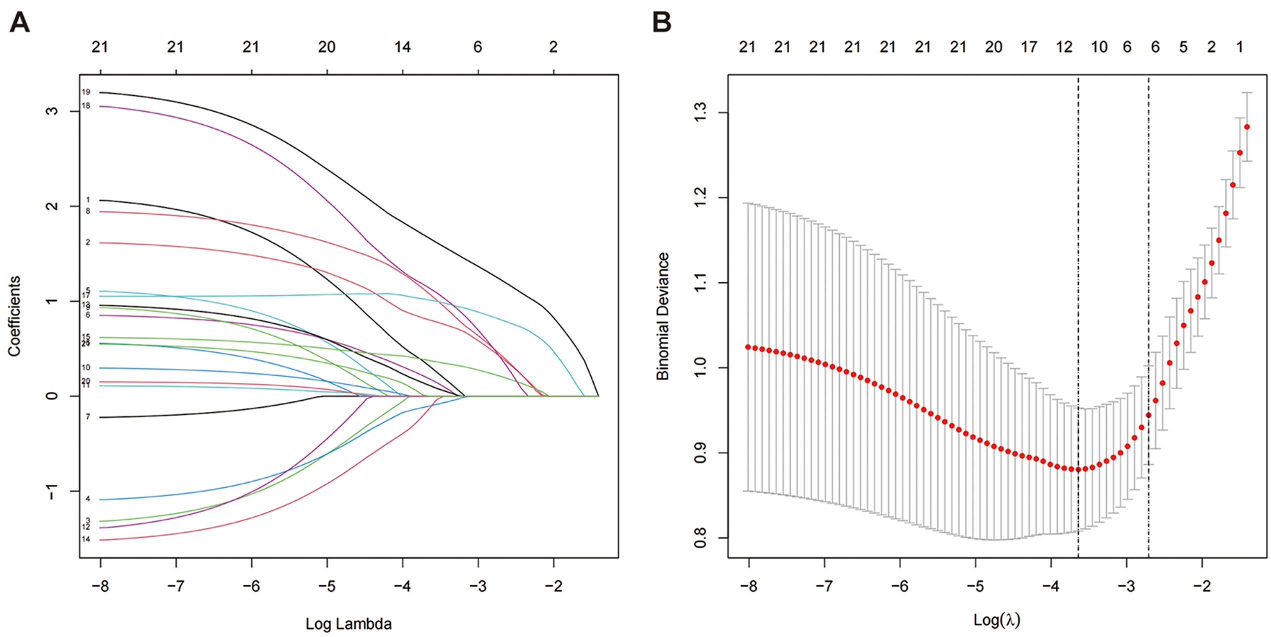

Fig. 2 The potential risk factors selected using the least absolute shrinkage and selection operator (LASSO) regression. (**A**) Plot showing the variation characteristics of the coefficients of variables. (**B**) The optimal parameter (lambda) selection resulted in six features with nonzero coefficients in the LASSO model using five-fold cross-validation via the minimum criteria

Table 1 Multivariate Logistic Regression Analysis in the training group ($n = 180$)

	P-Value	OR	95% CI
Age	0.005	3.867	1.506, 9.929
Smoking	< 0.001	5.045	1.949, 13.060
NYHA	0.03	1.792	1.059, 3.031
Anxiety status	0.028	3.632	1.150, 11.470
Depression status	0.008	7.934	1.708, 36.858
Strangeness of environment	< 0.001	7.958	3.008, 21.055

OR, odds ratio; CI, confidence interval; NYHA, New York Heart Function Assessment (NYHA) class

needed hypnotics. Characteristics of patient characteristics are listed in Supplementary Table S2.

Predictive model development through the training cohort

Based on the basic information, comorbidity, and clinical information, 21 candidate parameters were entered into the LASSO regression analysis in the training group (Fig. 2). Six predictive variables were screened, including age, smoking, NYHA class, anxiety status at admission, depression status at admission, and strangeness of environment. We then included the above variables in the multivariate logistic regression analysis. The results showed that age (odds ratio (OR), 3.867 [95% confidence interval [CI], 1.506–9.929]), smoking (OR, 5.045 [95% CI, 1.949–13.060]), NYHA class (OR, 1.792 [95% CI, 1.059–3.031]), anxiety status at admission (OR, 3.632 [95% CI, 1.150–11.470]), depressive status at admission (OR, 7.934 [95% CI, 1.708–36.858]), and strangeness of environment (OR, 7.958 [95% CI, 3.008–21.055]) were all independently associated with sleep disorders in hospitalized patients with AMI (Table 1). We further developed a predictive nomogram model based on the independent predictor (Fig. 3). The nomogram estimated the probability of sleep disorders by calculating the total scores of independent predictor variables.

Validation of the nomogram

For the prediction nomogram, the C-index was 0.902 (95% CI, 0.800–1) in the training cohort and 0.938 (95% CI, 0.838–1) in the validation cohort, suggesting good discrimination power. Meanwhile, the calibration curve using the Hosmer-Lemeshow test indicated that the model had satisfied predictive performance (Fig. 4). We applied the DCA curve to evaluate the clinical usefulness of the nomogram. In the DCA study, the predictive nomogram had a high net benefit in predicting sleep disorders in hospitalized patients with AMI when the threshold probability was between 2% and 85% in the training cohort or between 5% and 92% in the validation cohort (Fig. 5).

Discussion

Sleep disorders are frequent in hospitalized patients and harmful to the health. A meta-analysis of 47 articles suggested that the incidence of sleep disorders in the elderly over 60 years old was 35.9% (95% CI: 30.6–41.2%) in the Chinese population [9]. According to the results of this study, the incidence of sleep disorders in AMI patients

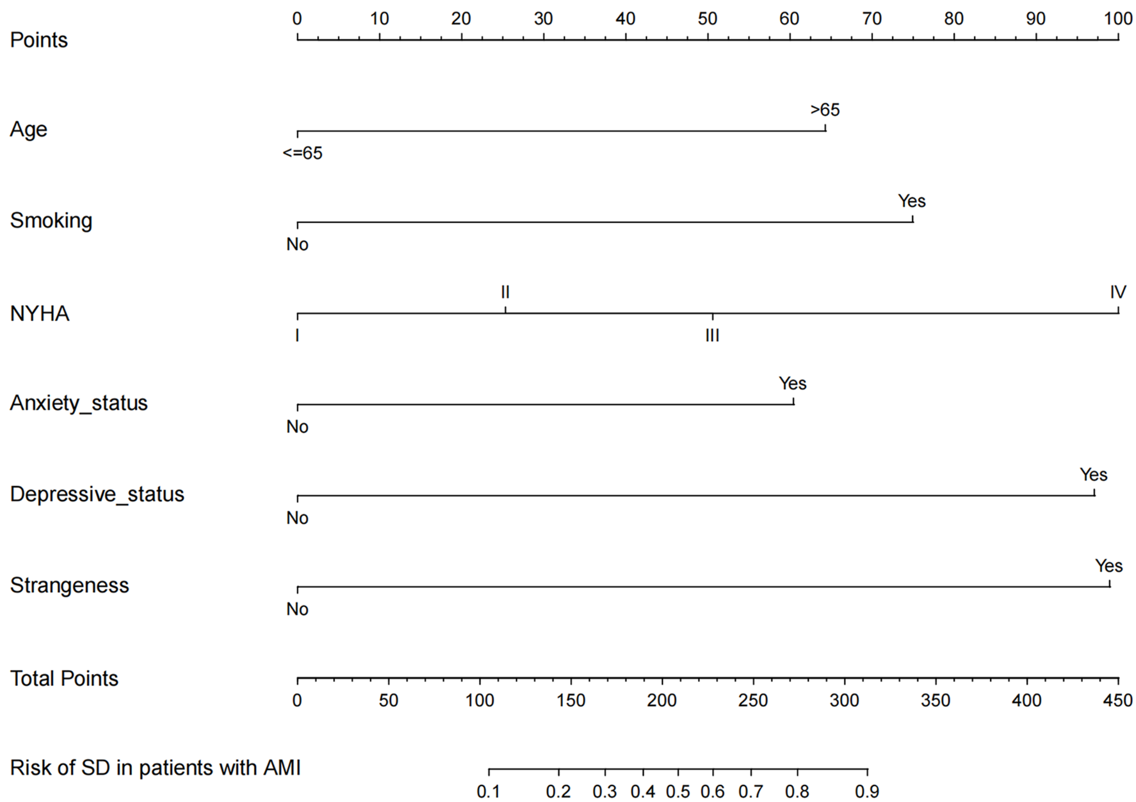

Fig. 3 Nomogram to predict sleep disorders (SD) in hospitalized patients with acute myocardial infarction (AMI). Six variables selected were applied to develop this nomogram

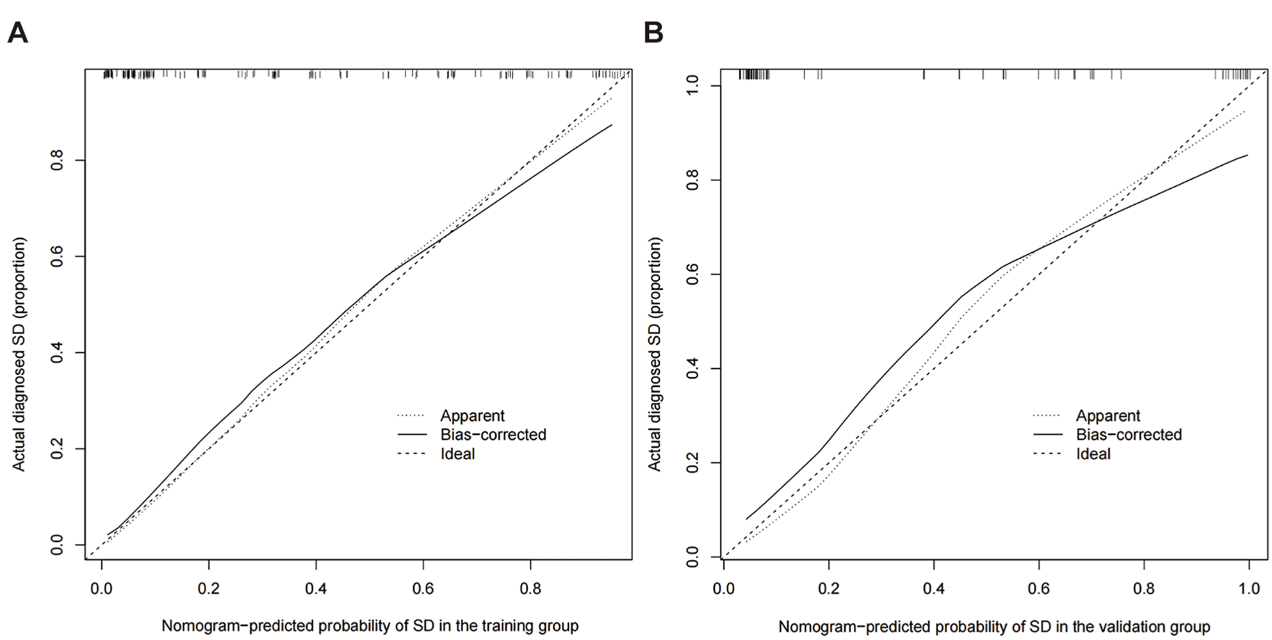

Fig. 4 The calibration curve of the nomogram in the training cohort (**A**) and the validation cohort (**B**). The y-axis represents actual diagnosed cases of sleep disorders (SD), the x-axis represents the predicted risk of SD

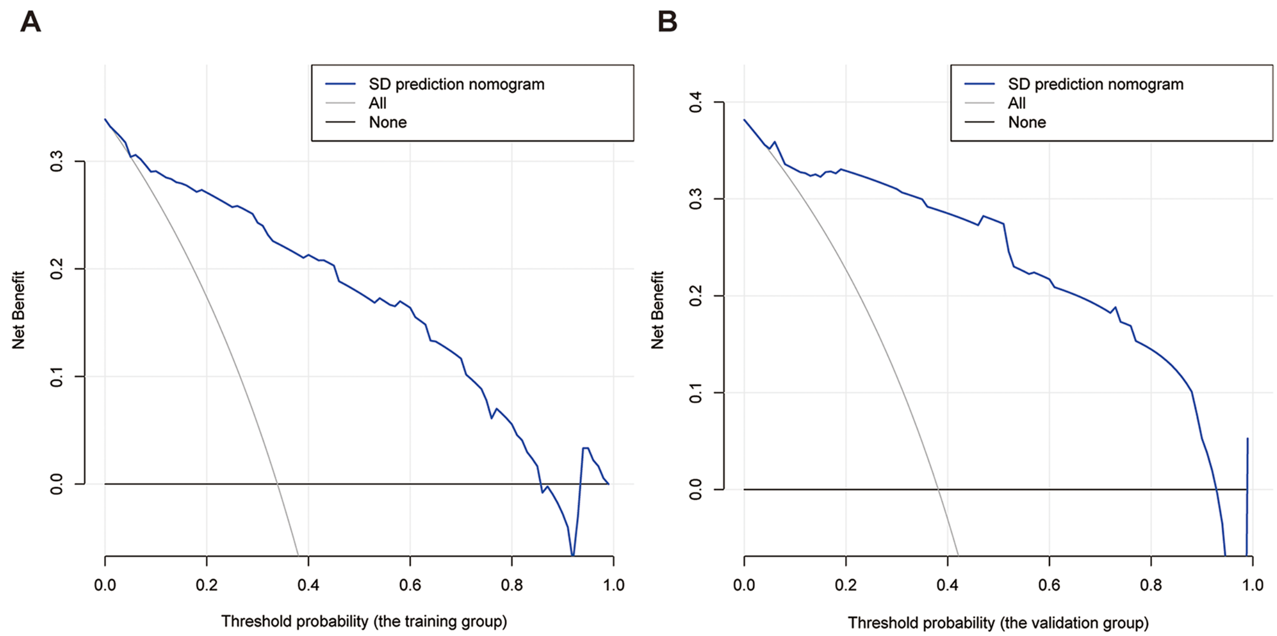

Fig. 5 The decision curve analysis (DCA) for the nomogram in the training cohort (**A**) and the validation cohort (**B**). The solid line represents the assumption that no patients suffer from sleep disorders (SD). The thin, solid line represents the assumption that all patients suffer from SD. The blue line indicates the SD risk nomogram

during hospitalization was 35.16%. Meanwhile, the use rate of sleeping pills was 12.89%. We conducted a retrospective study to explore the independent risk factors of sleep disorders in patients with AMI during hospitalization and construct a related risk prediction model in order to achieve early identification and intervention of high-risk patients. Our study found that age, smoking, NYHA class, anxiety or depression status at admission, and strangeness of environment were the independent risk factors for sleep disorders in AMI patients during hospitalization. Our study identified depression status at admission (OR=7.934) and strangeness of environment (OR=7.958) as the most significant risk factors for sleep disorders. More importantly, this study constructed a nomogram model of predictive variables. The nomogram model, combining six selected predictors, could be easily assessed within a few hours after admission. In addition, C-index, calibration curve, DCA, and clinical practicability show good predictive performance. To guarantee practical convenience in clinical practice, we used the routine variables, which could provide an effective basis for early identification of AMI.

This study confirmed that age and smoking are independent risk factors for sleep disorders in patients with AMI during hospitalization. Previous studies have shown that sleep becomes more fragmented and lighter as the number of arousals and awakenings increases during the natural aging process of the human body [10, 11]. Meanwhile, the elderly's immune system function is degraded, accompanied by a variety of chronic diseases and increased drug use, which will further contribute to sleep disorders [12]. Smoking is associated with an increased risk of hypertension, coronary heart disease, and peripheral vascular disease. A cross-sectional study of 189,970 participants applied urinary cotinine to verify smoking intensity and demonstrated that smoking was associated with sleep problems [13]. Another analysis indicated a relationship between sleep disturbance and both active and passive exposure to high levels of tobacco smoke [14]. Smoking cessation is recommended for patients with AMI.

The analysis found a relationship between sleep disorders and the NYHA class in AMI patients. Heart failure is usually characterized by progressive worsening and recurrent symptoms such as dyspnea, limitation of activity, and fluid retention. Patients with heart failure are more likely to have sleep-disordered breathing [15]. Nasir et al. defined PSQI>5 as sleep disorders, and reported that nearly 92.5% of patients with chronic heart failure had sleep quality problems [16]. Patients with heart failure are prone to sleep disruption and arterial oxyhemoglobin desaturation [17], which can easily lead to the occurrence of anxiety and depression. Therefore, sleep intervention is necessary for patients with a high NYHA class. A previous study suggested that raising the head of the bed and oxygen therapy could relieve the symptoms of respiratory disorders and therefore improve sleep quality [18]. Left ventricular ejection fraction (LVEF) and B-type natriuretic peptide (BNP) serve as the important objective items for diagnosing heart failure in clinical practice. A decline in LVEF or an increase in BNP may be related to sleep disorders in patients with AMI. Meanwhile, myocardial enzymes and troponin are indeed the core indicators for diagnosing and assessing the severity of AMI [2]. Therefore, it is necessary to conduct echocardiographic screening and relevant serological tests at admission.

Anxiety manifests as restlessness, panic, and somatic manifestations such as nausea and palpitations. Depression was characterized by a depressed mood, delayed thinking, and changes in sleep habits. In this study, anxiety status and depression status were the important risk factors for sleep disorders. Patients with anxiety or depression often have decreased appetite, which increases the risk of malnutrition and immunodeficiency [19]. Meanwhile, patients with sleep disorders experience daytime fatigue and decreased physical strength, which further aggravates the occurrence of negative emotions. Luo et al. showed that insomnia symptoms could increase the risk of depression and anxiety one year later [20]. There are bidirectional associations between sleep disorders and anxiety/depression status. Nurses should evaluate the psychological status of anxiety and depression in hospitalized patients with AMI, relieve their anxiety and depression status individually, and intervene in sleep disorders. Additionally, this analysis suggested that environmental strangeness was a risk factor for sleep disorders in patients with AMI. Noise, smell, humidity, and bed may make patients feel unfamiliar. Therefore, nurses need to pay attention to the psychological counselling and increase the patient's ability to accept the new environment.

To our knowledge, this report represents the first such comprehensive study to develop and validate a prediction nomogram for sleep disorders in hospitalized patients with AMI. This analysis demonstrated a good overall performance in prediction and could help achieve the goals of early diagnosis and early treatment in clinical nursing practice. However, our study had some limitations. Firstly, this analysis was a retrospective study from a single institution. Future research should focus on updating the model by expanding the sample size and conducting external validation using a multi-center patient population. Secondly, the outcome indicator was obtained during the short-term hospitalization period, and there was a lack of long-term follow-up with patients. Thirdly, we did not include different laboratory data at admission that may indicate an association with sleep disorders. It is necessary to incorporate relevant serum biomarkers, including creatine kinase (CK), Troponin (cTnI or cTnT), and BNP, in order to further improve the prediction nomogram in the future research.

Conclusion

The present study shows that age, smoking, NYHA class, anxiety status, depression status, and strangeness of environment were the independent risk factors for sleep disorders in hospitalized patients with AMI. The prediction model has good predictive power and high specificity, and it helps nurses make appropriate decisions in clinical practice.

Abbreviations

AMI	Acute Myocardial Infarction
CHD	Coronary Heart Disease
STEMI	ST-Segment Elevation Myocardial Infarction
ECG	Electrocardiogram
NYHA	New York Heart Function Assessment
SAS	Self-Rating Anxiety Scale
SDS	Self-Rating Depression Scale
NRS	Numerical Rating Scale
PSQI	Pittsburgh Sleep Quality Index
LASSO	Least Absolute Shrinkage And Selection Operator
DCA	Decision Curve Analysis
OR	Odds Ratio
CI	Confidence Interval
LVEF	Left Ventricular Ejection Fraction
CK	Creatine Kinase
BNP	B-Type Natriuretic Peptide

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12872-024-04074-9.

Supplementary Material 1

Supplementary Material 2

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Not applicable.

Author contributions

Conception and design: Jing Huang, Xu-Min Xin, Miao Li. Collection of the clinical data: Jing Huang, Miao Li, Xiu-Wen Zeng. Statistical analysis: Xu-Min Xin, Lu Lin. Investigation and the relevant literature review: Xiu-Wen Zeng, Guang-Su Qu. Manuscript writing: Jing Huang, Miao Li. Revision of the paper: Xu-Min Xin, Guang-Su Qu. All authors read and approved the final manuscript.

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Data availability

The data that support the findings of this study are available on request to the authors.

Declarations

Ethical approval

The studies involving human participants were reviewed and approved by the Ethics Committee of the Second Affiliated Hospital of Chongqing Medical University.

Consent for publication

All authors agreed to publish the paper.

Informed consent

Written informed consent was obtained from all enrolled patients before study inclusion.

Competing interests
The authors declare no competing interests.

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