BMC Neurology

RESEARCH

Open Access

Influencing factors and predictive models of early post-stroke depression in patients with acute ischemic stroke

AiNi Xiao[1], RuiYang Wang[2], CongJie Liu[1] and XiangYu Wang[1*]

Abstract

Background Post-stroke depression (PSD) refers to a depressive state that appears after stroke onset and is one of the most common complications in ischemic stroke patients. The occurrence of PSD exacerbates the risk of disability and increases the mortality of patients. Current diagnosis of PSD is severely underdiagnosed.

Methods Patients hospitalized for acute ischemic stroke between December 2019 and November 2022 in the Department of Neurology of Sinopharm Gezhouba Central Hospital were retrospectively collected. Patients' basic clinical information, test data and related questionnaire scores were collected. They were divided into PSD group and NPSD group. Multivariate regression was used to analyze the risk factors of post-stroke depression and establish a risk prediction model to draw nomograms. Receiver Operating Characteristic Curve (ROC), Calibration curve and Decision Curve Analysis (DCA) decision curve were drawn using R language to assess the clinical efficacy and clinical utility of the model.

Results Post-stroke depression in Acute Ischemic Stroke (AIS) patients was associated with single factors such as hypertension, living alone, education level, homocysteine level, National Institute of Health Stroke Scale (NIHSS) score, lymphocyte count, neutrophil count ($P < 0.05$). Among them, living alone, CRP level, hypertension, homocysteine level, education level, systemic immune inflammation index (SII), and NIHSS score were independent risk factors for post-stroke depression in AIS patients ($P < 0.05$). The seven selected variables were used to construct a risk prediction model, nomograms were drawn, and ROC curves were used to assess model discrimination, AUROC = 0.881. Calibration curve is used to evaluate the consistency of the model, DCA decision curve is used to evaluate the practicability of the model, and this model has good discrimination ability, calibration and clinical practicability.

Conclusion The probability of PSD in AIS patients in this study was 26.51%. Independent risk factors for developing PSD, including CRP level, living alone, history of hypertension, homocysteine level, education level, SII, NIHSS score to establish risk prediction model and draw nomograms. The model was demonstrated to have good discrimination, calibration and clinical utility by internal validation.

Keywords Peripheral blood leukocyte derived related markers, Acute ischemic stroke, Risk prediction model, Post-stroke depression

*Correspondence:
XiangYu Wang
371531036@qq.com

[1]Neurology Department, Third Clinical Medical College of China Three Gorges University, (Sinopharm Gezhouba Central Hospital), Yichang, China
[2]Orthopedics Department, the First College of Clinical Medical Science, China Three Gorges University, Yichang, China

Introduction

Post-stroke depression (PSD) usually refers to the depressive state after stroke onset, which is a common complication of ischemic stroke and is mainly characterized by loss of pleasure, depressed mood, reduced interest and feelings of worthlessness [1]. PSD was first proposed by psychiatrists more than 100 years ago [2]. In recent years, with an increasing number of post-stroke survivors, the total number of patients with PSD has grown substantially, and approximately one-third of stroke survivors suffer from PSD [3]. At present, the diagnosis of PSD is difficult in clinical practice, only 5% of stroke patients are diagnosed with PSD and treated, and active screening of symptoms in post-stroke patients is required to avoid missed diagnosis of PSD [4, 5]. In this study, we analyzed the course of disease and peripheral blood leukocyte-derived related markers in patients with acute ischemic stroke, sought the related influencing factors of early post-stroke depression and constructed a risk prediction model in order to provide more judgment basis for the diagnosis of post-stroke depression and clinical prognosis evaluation.

Subjects and methods

Study population

This study was a retrospective case-control study. Patients with acute ischemic stroke who presented to the Department of Neurology, the Third Clinical Medical College of China Three Gorges University (Sinopharm Gezhouba Central Hospital) between October 2019 and October 2022 were retrospectively collected.

Inclusion criteria:

(1) No previous history of stroke.
(2) Patients with acute ischemic stroke who meet the diagnostic criteria of the Chinese Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke 2018 will be verified by computed tomography (CT) or magnetic resonance imaging (MRI) results within 24 h after admission.
(3) All participants completed the relevant scale assessment at 2 weeks after onset.
(4) All participants were informed about the study content.

Exclusion criteria:

(1) Patients with a previous history of psychosis.
(2) Patients diagnosed with depression or other psychological diseases before stroke.
(3) Patients with dementia or significant cognitive impairment and decreased level of consciousness.
(4) Severe aphasia, visual or auditory disorders.
(5) Combined with other metabolic abnormalities, tumors, severe acute inflammatory diseases and hematological diseases.
(6) Cases in which relevant medical history collection could not be perfected.

Observation index

(1) Collect the basic information of patients: gender, age, education level, whether living alone, smoking and drinking history, previous relevant medical history, such as hypertension, diabetes, hyperlipidemia, etc.
(2) Disease assessment: National Institute of Health Stroke Scale (NIHSS) and Hamilton Depression Scale (HAMD-17) scores were completed at 2 weeks. The degree of depression was evaluated according to the Depression Scale (HAMD-17), where a score value > 7 was judged as PSD.
(3) Laboratory tests: All patients were required to collect venous blood samples from the emergency department or ward of our hospital within 24 h of admission, and white blood cell count, platelet count, lymphocyte count, and neutrophil count in peripheral blood were collected to calculate Neutrophil to Lymphocyte Ratio (NLR), Platelet to Lymphocyte Ratio (PLR), Monocyte to Lymphocyte Ratio (MLR), and Systemic Immune Inflammation Index (SII).

Study group

Patients diagnosed with acute ischemic stroke by CT or MRI were collected. Screening was performed by inclusion and exclusion criteria. Patients were divided into groups according to whether they were diagnosed with post-stroke depression: post-stroke depression group (group A) and non-post-stroke depression group (group B). A total of 342 patients with acute ischemic stroke were screened for this study. According to the exclusion criteria, 10 patients were excluded (Fig. 1).

Statistical analysis

All data were analyzed using SPSS 26.0 software. The normal distribution of measurement data was expressed as the mean ± standard deviation ($\bar{x}\pm s$), the skewed distribution was expressed as the median and interquartile range, and the enumeration data were expressed as frequency and percentage. Independent sample t-test or rank sum test was used for comparison between groups, and chi-square test was used for comparison of enumeration data. $P<0.05$ was considered statistically significant. Logistic regression analysis was performed for factors that were statistically significant in univariate analysis. $P<0.05$ was considered statistically significant, and $P<0.01$ was considered highly significant. Statistical

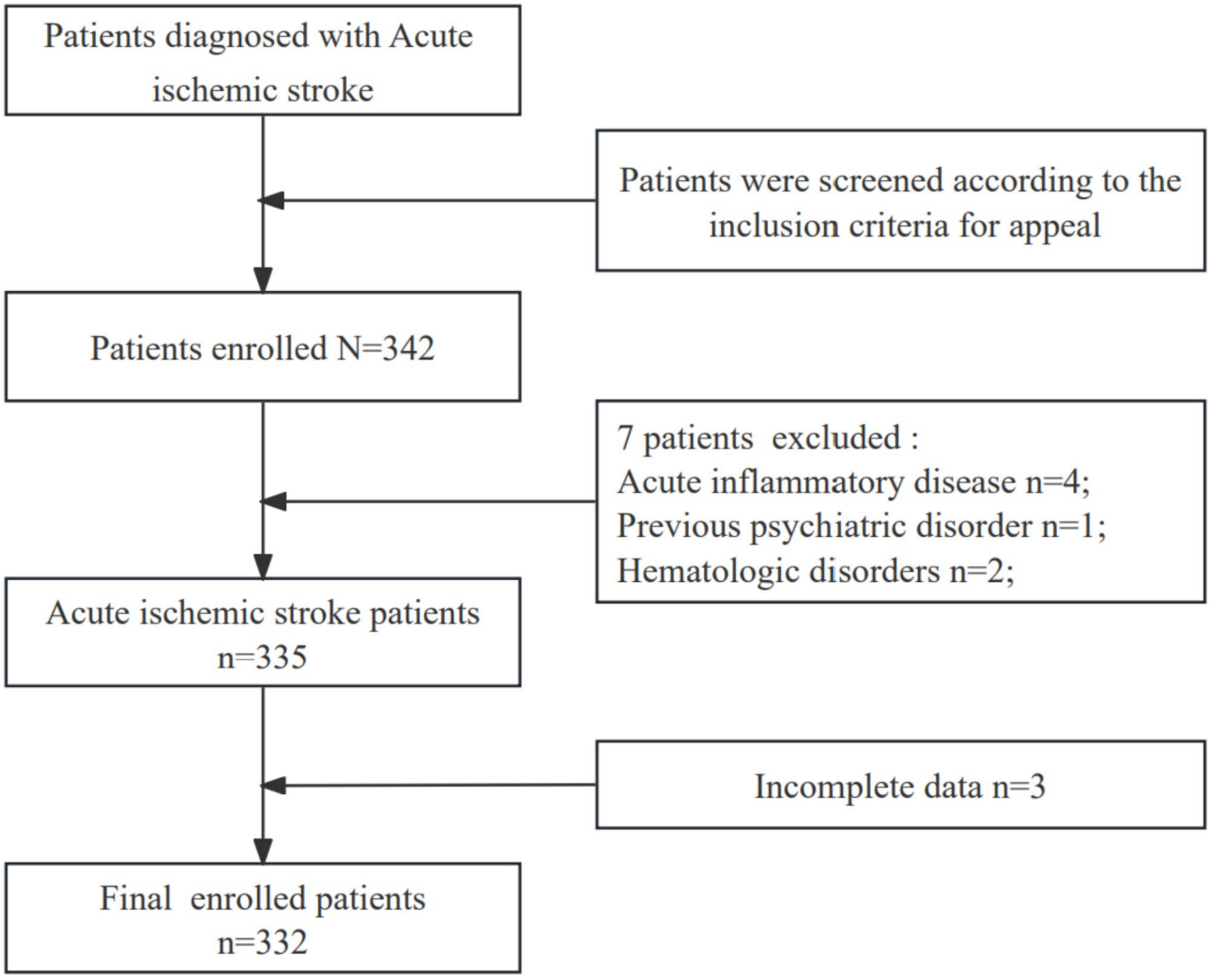

Fig. 1 Enrollment Flow Chart for Study Subjects

analysis was performed using R statistical software (version 4.3.2, R Foundation for Statistical Computing), and significant multivariate factors in binary logistic regression equations were included to establish risk prediction models and construct nomograms. Bootstrap resampling was used to plot Calibration curves and Decision Curve Analysis (DCA) decision curves.

Results

Baseline patient characteristics

A total of 332 patients were finally included during the study period, and all stroke patients were divided into PSD group and NPSD group according to the evaluation results of the HAMD-17 Depression Scale. In this study, 88 patients were in the PSD group and 244 patients were in the NPSD group. The prevalence of PSD was 26.5% (Table 1).

Univariate analysis of the occurrence of PSD in patients with AIS

By univariate analysis, Hypertension, living alone, education level, homocysteine, NIHSS score, lymphocyte count, neutrophil count, CRP, NLR, PLR, MLR and SII were statistically different ($P<0.05$). Among them, Hypertension, living alone, education level, homocysteine, NIHSS score, lymphocyte count, neutrophil count, CRP, NLR, PLR and SII were highly significant ($P<0.01$) (Table 2).

Univariate analysis of the occurrence of PSD in patients with AIS

Factors that were highly significant ($P<0.01$) in the univariate analysis were included in the binary logistic regression equation. The results showed that CRP, living alone, combined hypertension, homocysteine level, education level, SII, and NIHSS score had a statistically significant higher risk of early PSD in AIS patients ($P<0.05$)

Table 1 Clinical characteristics of AIS patients

Variables		Overall [*n* = 332]
Gender	Male	155(46.70)
	Female	177(53.30)
Age (years)		63.12 ± 7.25
Drinking[n(%)]		87(26.20)
Smoking[n(%)]		84(25.30)
BMI (kg/m^2)		23.41 ± 3.28
Hypertension [n(%)]		190(57.20)
Diabetes [n(%)]		104(31.30)
Hyperlipidemia [n(%)]		134(40.40)
Living alone [n(%)]		74(22.30)
Education Level [n(%)]	Illiteracy	26(7.80)
	Primary school	107(32.20)
	Junior high school	149(44.90)
	High school	41(12.30)
	University	9(2.70)
TOAST typing [n(%)]	Large artery atherosclerosis	217(65.36)
	Small vessel occlusion	42(12.65)
	Cardioembolic	73(21.99)
Homocysteine [μmol/l, $\bar{x}$±s]		15.41 ± 2.78
NIHSS score [M(P_{25},P_{75})]		2(2,4)
PLT [(10^9/L), $\bar{x}$±s]		185.76 ± 20.76
Lym [(10^9/L), M(P_{25},P_{75})]		1.33(1.24,1.40)
Mono [(10^9/L), M(P_{25},P_{75})]		0.42(0.37,0.49)
Neu [(10^9/L), M(P_{25},P_{75})]		3.16(2.88,3.69)
CRP [mg/L, M(P_{25},P_{75})]		3.62(3.35,3.89)
NLR [M(P_{25},P_{75})]		2.41(2.21,2.80)
PLR [$\bar{x}$±s]		142.18 ± 21.26
MLR [M(P_{25},P_{75})]		0.32(0.28,0.37)
SII [M(P_{25},P_{75})]		449.71(390.10,518.06)

(Table 3). Forest plots were drawn to visualize the results of the multivariate regression analysis (Fig. 2).

Establishment of nomogram prediction model for PSD occurrence in patients with AIS

The significant factors obtained from the above analysis included " NIHSS score, SII, education level, homocysteine, hypertension, living alone and CRP " were integrated to establish a logistic regression equation: $P = 1/(1 + e\text{-}Y)$, e is the base of the natural logarithm, Y=0.616×CRP+0.882×Living alone+1.366×Hypertension +0.159×Education level+0.007×SII+0.434×NIHSS score-13.232. They were plotted as nomograms using R language and seven predictors were assigned accordingly. A vertical line is drawn upwards at the specific score value of the patient predictor, and the score corresponding to the intersection of the line and the Point line segment is the specific score of this variable. By analogy, the scores corresponding to the intersection of the seven predictors and the Point line segment are added to the total score of the patient model prediction, and a vertical line is drawn downwards at the point corresponding to the total score found at the Total Points, and the value corresponding to the intersection of this line and the Risk point is the risk of the patient experiencing the outcome event (Fig. 3).

For example, a AIS patient with admission education level of junior high school, having hypertension, CRP level of 4 mg/L, NIHSS score of 3, homocysteine level of 15, SII of 500 and living alone. The nomogram model constructed in this study predicts their risk of developing early PSD. The patient's education level was 23 points on the nomogram corresponding to junior high school; 26 points corresponding to a history of hypertension; 18 points corresponding to a CRP level of 4 mg/L; 26 points corresponding to a NIHSS score of 3; 21 points corresponding to a homocysteine level of 15; 40 points corresponding to an SII of 500; and 18 points corresponding to living alone. Total score 23 + 26 + 18 + 26 + 21 + 40 + 18 = 172. The predicted risk of PSD occurrence segment corresponding to a total score of 172 points showed 51%. The probability of early PSD in this AIS patient is therefore 51%.

Discrimination evaluation in using a risk prediction model

ROC curves were plotted to evaluate the discriminatory power of the model, and the results showed that AUROC = 0.881, 95% CI: 0.843–0.918. The area under the ROC curve is greater than 0.7, indicating that the model has good discrimination. The optimal cut-off point of this prediction model was 0.635, when the sensitivity was 0.852 and the specificity was 0.783 (Fig. 4).

Consistency assessment of predictive models in PSD occurring after AIS

Calibration curves were used to visualize the results of the Hosmer-Lemeshow test to evaluate measures of the accuracy of the model in predicting the probability of an outcome event, reflecting the degree of agreement between the model-predicted risk and the actual risk. Bootstrap resampling (1000 resamplings) was used to plot Calibration curves to assess the calibration of this prediction model. The prediction curve in this study is close to the diagonal line, and the H-L goodness of fit test in this study is $P = 0.612 > 0.05$. The consistency between the probability of predicting the occurrence of outcome events and the probability of the true occurrence of events is good, and the fitting of this model is good (Fig. 5).

DCA decision curve for predictive model

In this study, DCA decision curves were used to test the clinical utility of the model. According to this decision curve, when the threshold of the model is set in the range of 2–90%, the decision curve is located above the None

Table 2 Risk factors associated with early PSD in AIS patients

Risk factors		PSD($n=88$)	NPSD($n=244$)	Correlation coefficient	*P*
Gender	Male	34 (38.60)	121(49.60)	3.118	0.077
	Female	54 (61.40)	123(50.40)		
Age (years)		64.35 ± 6.98	62.67 ± 7.31	1.870	0.062
Drinking[n(%)]	Yes	18 (20.50)	69 (28.30)	2.047	0.152
	No	70 (79.50)	175(71.70)		
Smoking[n(%)]	Yes	20(22.70)	64(26.20)	0.420	0.517
	No	68 (77.30)	180(73.80)		
BMI [(kg/m^2), $\bar{x}\pm s$]		23.05 ± 3.09	23.54 ± 3.34	-1.196	0.232
Hypertension [n(%)]	Yes	71 (80.70)	119(48.80)	26.907	<0.001
	No	17 (19.30)	125(51.20)		
Diabetes [n(%)]	Yes	23 (26.10)	81(33.20)	1.499	0.221
	No	65 (73.90)	163(66.80)		
Hyperlipidemia [n(%)]	Yes	38 (43.20)	96 (39.30)	0.396	0.529
	No	50 (56.80)	148(60.70)		
Living alone [n(%)]	Yes	38 (43.20)	23 (14.80)	30.175	<0.001
	No	50 (56.80)	208(85.20)		
Education Level [n(%)]	Illiteracy	6(6.80)	20(8.20)	15.654	0.003
	Primary school	18(20.50)	89(36.50)		
	Junior high school	41(46.60)	108(44.30)		
	High school	18(20.50)	23(9.40)		
	University	5(5.70)	4(1.60)		
TOAST typing [n(%)]	Large artery atherosclerosis	56 (63.64)	161 (65.98)	2.271	0.321
	Small vessel occlusion	15 (17.04)	27 (11.07)		
	Cardioembolic	17 (19.32)	56 (22.95)		
Homocysteine [μmol/l, $\bar{x}\pm s$]		16.48 ± 2.33	15.03 ± 2.838	4.713	<0.001
NIHSS score [M(P_{25},P_{75})]		3 (2,6)	2(1,4)	-6.039	<0.001
PLT [(10^9/L), $\bar{x}\pm s$]		189.16 ± 18.20	184.53 ± 21.51	1.800	0.073
Lym [(10^9/L), M(P_{25},P_{75})]		1.27(1.18,1.38)	1.34(1.26,1.40)	-3.239	0.001
Mono [(10^9/L), M(P_{25},P_{75})]		0.45(0.38,0.51)	0.41(0.37,0.49)	-1.175	0.240
Neu [(10^9/L), M(P_{25},P_{75})]		3.61(3.05,4.00)	3.08(2.84,3.49)	-5.406	<0.001
CRP [mg/L, M(P_{25},P_{75})]		3.89(3.69,4.05)	3.48(3.31,3.79)	-6.682	<0.001
NLR [M(P_{25},P_{75})]		2.81(2.44,3.07)	2.34(2.13,2.68)	-6.868	<0.001
PLR [$\bar{x}\pm s$]		149.23 ± 21.65	139.64 ± 20.57	3.698	<0.001
MLR [M(P_{25},P_{75})]		0.35(0.29,0.39)	0.31(0.28,0.36)	-2.343	0.019
SII [M(P_{25},P_{75})]		525.21(454.85,584.32)	432.17(371.92,478.84)	-6.963	<0.001

Table 3 Multivariate logistic regression analysis of early PSD in AIS patients

Risk factors	β	SE	Wald	OR	95% CI for Exp (B)		*P*
					Lower part	Upper part	
CRP	0.616	0.273	5.097	1.851	1.085	3.158	0.024
Living alone	0.882	0.365	5.848	2.415	1.182	4.937	0.016
Hypertension	1.366	0.360	14.405	3.920	1.936	7.938	<0.001
Homocysteine	0.159	0.062	6.539	1.172	1.038	1.324	0.011
Education levels	0.596	0.179	11.045	1.816	1.277	2.581	0.001
SII	0.007	0.002	13.718	1.007	1.003	1.010	<0.001
NIHSS scores	0.434	0.087	25.003	1.544	1.302	1.831	<0.001

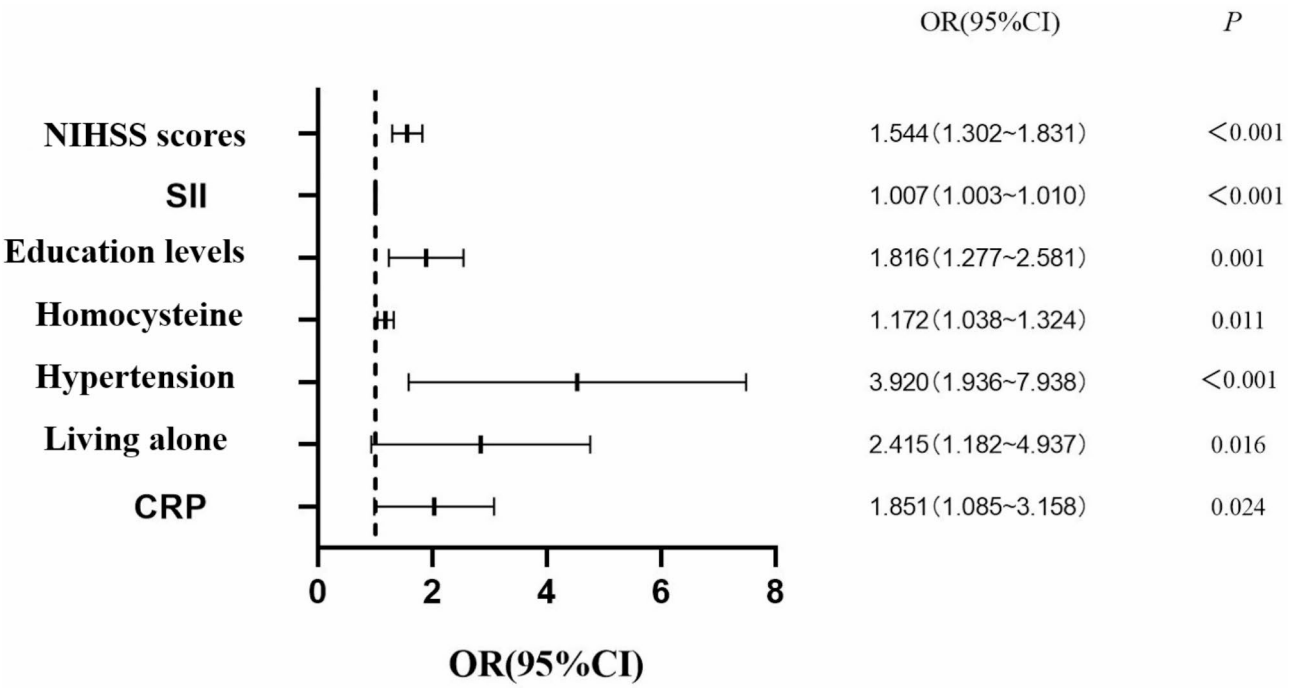

Fig. 2 Forest plot visualizing binary logistic regression for early PSD in AIS patients

line and the All line, within which the model is clinically useful (Fig. 6).

Discussion

The incidence of PSD

PSD is the most common neuropsychological disorder in post-stroke patients and is characterized by persistent emotional decline and decreased interest [6]. The pathophysiological mechanism of post-stroke depression (PSD) involves multifactorial interactions, including neurotransmitter disturbances, resulting in insufficient secretion of 5-HT and NE; neuroinflammation activation, pro-inflammatory factors impairing limbic system function; and brain-derived neurotrophic factor reduction leading to decreased synaptic plasticity. These mechanisms together contribute to the development of depressive symptoms [5]. PSD can occur at different stages after stroke, including acute (within 1 month), intermediate (1–6 months), and convalescent (>6 months) phases. Early PSD refers to patients who exhibit depression within 2 weeks of acute stroke onset [7, 8]. PSD occurs mostly within one year of stroke, especially within 3 months of stroke, but some studies have found the highest incidence of depression after one year of stroke [9]. Previous data have reported that the incidence of PSD fluctuates between 18% and 33% [5, 10]. A total of 332 patients were included in this study, 88 in the PSD group and 244 in the NPSD group. The incidence of PSD was 26.51%, which is consistent with the above reports.

Risk factors for PSD

There are many factors that influence the development of PSD in AIS patients. This study showed that having hypertension, living alone, education level, homocysteine level, NIHSS score, lymphocyte count, neutrophil count, CRP level, NLR, PLR, and SII were independent risk factors for developing PSD. Seven clinical predictors (CRP level, homocysteine level, living alone, history of hypertension, education level, NIHSS score, and SII) were included in this study to construct a simple and easy-to-use nomogram as a new predictive tool for assessing and predicting the risk of post-stroke depression.

C-reactive protein (CRP) has traditionally been classified as a biomarker of peripheral and central inflammation. Previous studies have found that higher levels of CRP have some correlation with depressive symptoms and prognosis after stroke [11–14]. Patients with AIS often have a systemic inflammatory response, and the level of CRP in the blood rises within the first few days after stroke onset [11, 15].CRP plays an important role in regulating and amplifying inflammatory processes, leading to neuroinflammation, which is a critical process in the pathogenesis of PSD [16]. Because systemic inflammation following stroke may be a potential therapeutic target, it is clinically important to better understand the relationship between peripheral inflammation and depression.

Homocysteine (Hcy), as a sulfur-containing amino acid, may aggravate the degree of depression by altering neurotransmitters causing abnormalities in

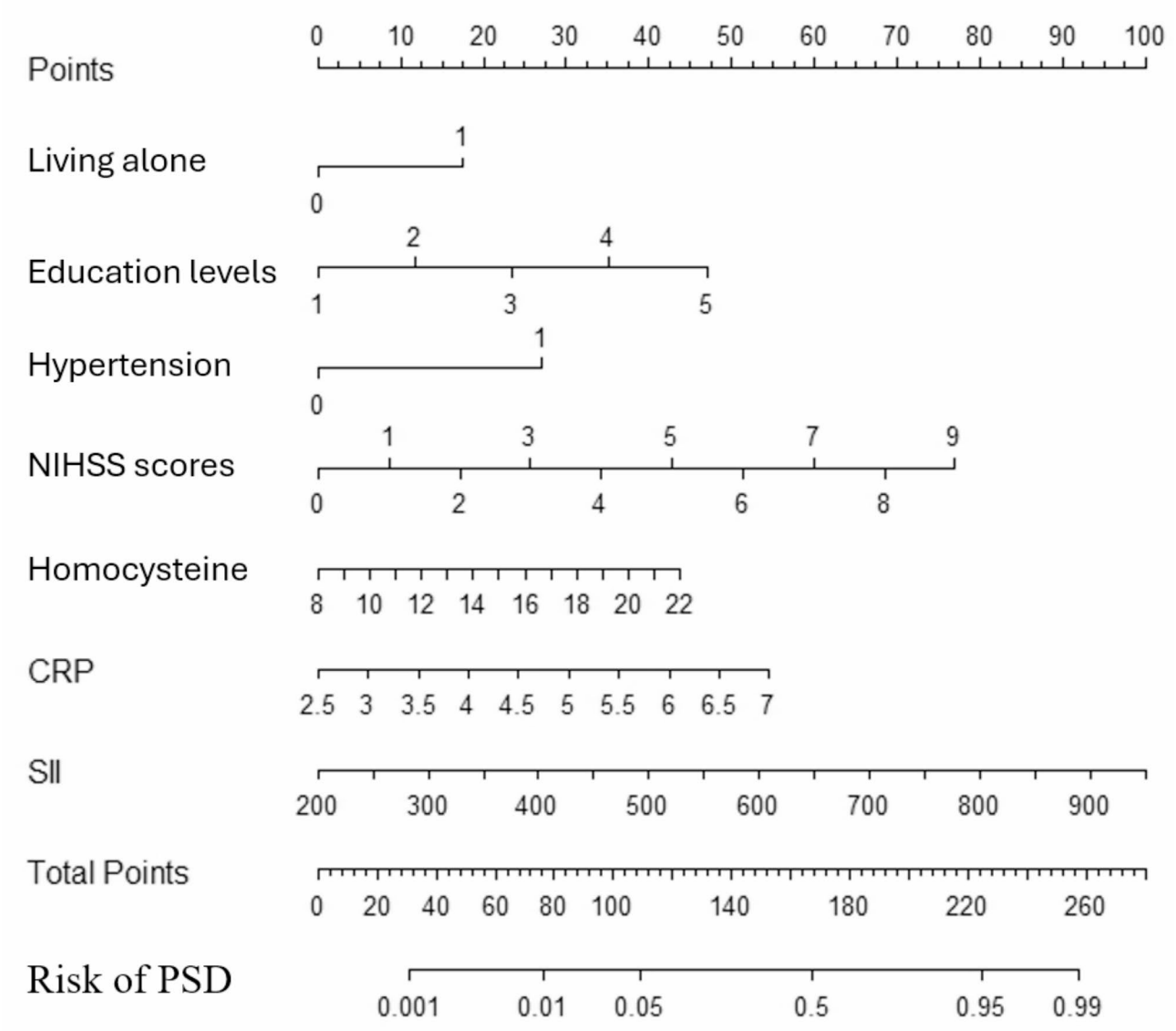

Fig. 3 Nomogram for predicting early PSD in AIS patients

central monoamine neurotransmitters and HPA axes [17]. Homocysteine has been shown to be associated with depression [17–19]. Homocysteine (OR = 1.172, 95% CI: 1.038–1.324, $P = 0.011$) was an important potential predictor of PSD in this study. Hcy is also considered as an evaluation of stroke improvement [20]. Hcy can be reduced by vitamin B12 during the methionine cycle, and increased Hcy levels may lead to depletion of vitamin B12, which is a coenzyme for serotonin (5-HT) metabolism [21]. At the same time, 5-HT reduction has been shown to be one of the pathogenesis of depression [22, 23]. This indirectly suggests that improvement in depression may be achieved by lowering Hcy. Therefore, ischemic stroke patients with elevated Hcy levels should be treated early with Hcy lowering drugs. At the same time, higher Hcy levels can return to normal by changing lifestyle, such as eating more folate-rich foods, quitting alcohol, and smoking.

In this study, patients living alone are more likely to develop PSD, marital relationship and cohabitation are important components of mental health in later life, whether living alone is closely related to the well-being of the elderly, the happiness index of the elderly living alone will be significantly reduced, accompanied by related mental health diseases, and living alone itself is closely related to depression [24].

Previous studies have found that hypertension has important predictive value for the development of PSD [25–27]. Previous hypertension was highly associated with the development of PSD in this study. Hypertension is not only closely associated with the risk of stroke, but also with the severity of stroke. In addition, hypertension

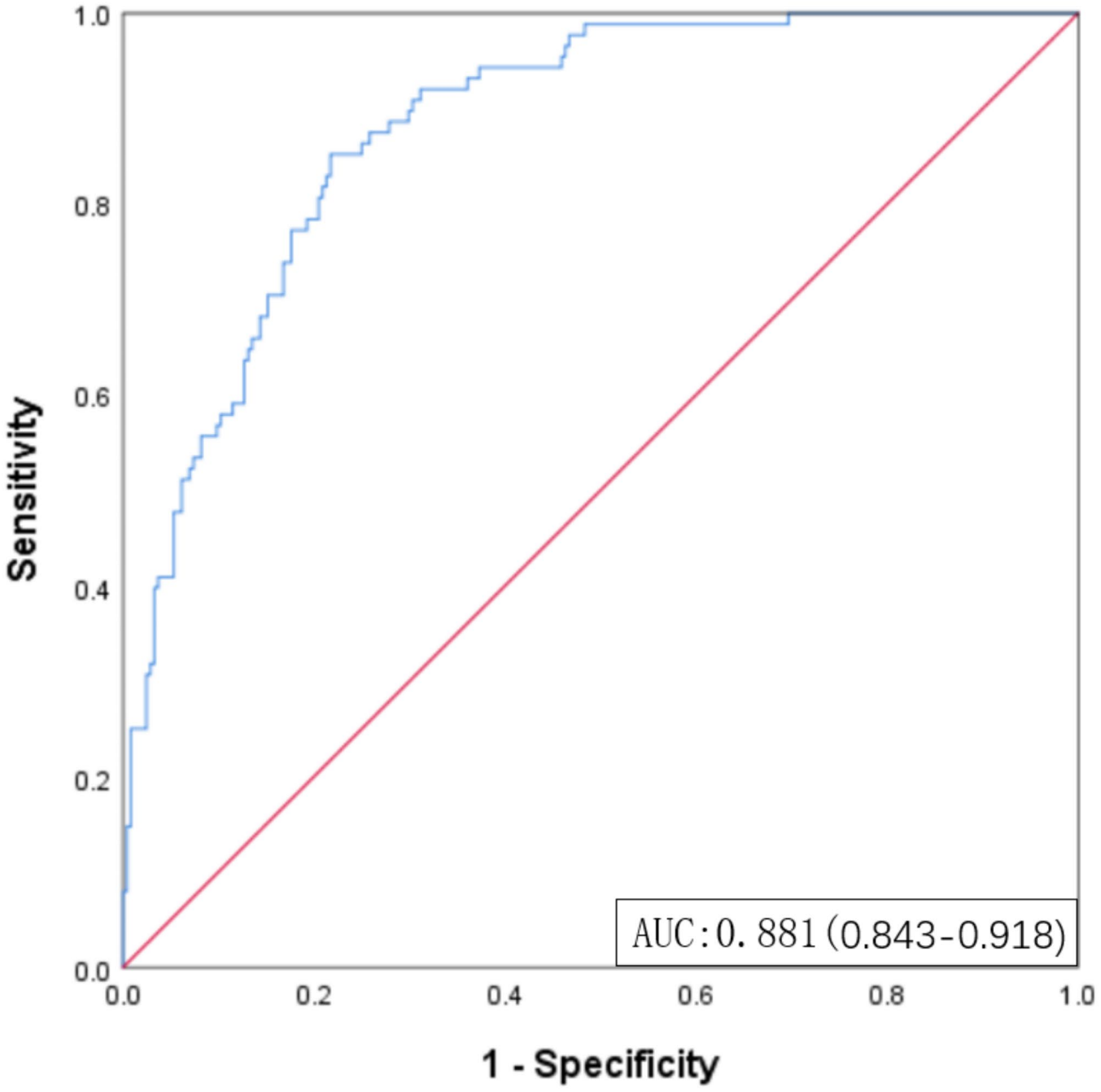

Fig. 4 ROC curve analysis of prediction model

may further increase the risk of post-stroke depression by promoting the development of small-vessel brain disease [28, 29].

Most scholars have found that higher educational level is a risk factor for developing PSD [30]. This is consistent with the results of this study. Reasons for analysis may be because it is associated with better functional cognitive reserve [31, 32]. University education has previously been found to be a significant predictor of PSD. The risk of PSD increases as education increases [33–35]. Higher education is associated with faster and more successful coping with new situations, but factors such as lifestyle or the complexity of culturally influenced roles and responsibilities may predispose stroke patients with higher education to depression.

A large number of previous scholars have found that stroke severity is closely related to PSD [26, 36–41]. Because of the large vessel involvement in patients with carotid artery stenosis, it predisposes to severe stroke, while previous studies have found that carotid artery stenosis often induces large vessel infarction and higher NIHSS scores [42]. This supports the relationship between NIHSS score and early onset PSD. Therefore, NIHSS score is abnormally important for the assessment

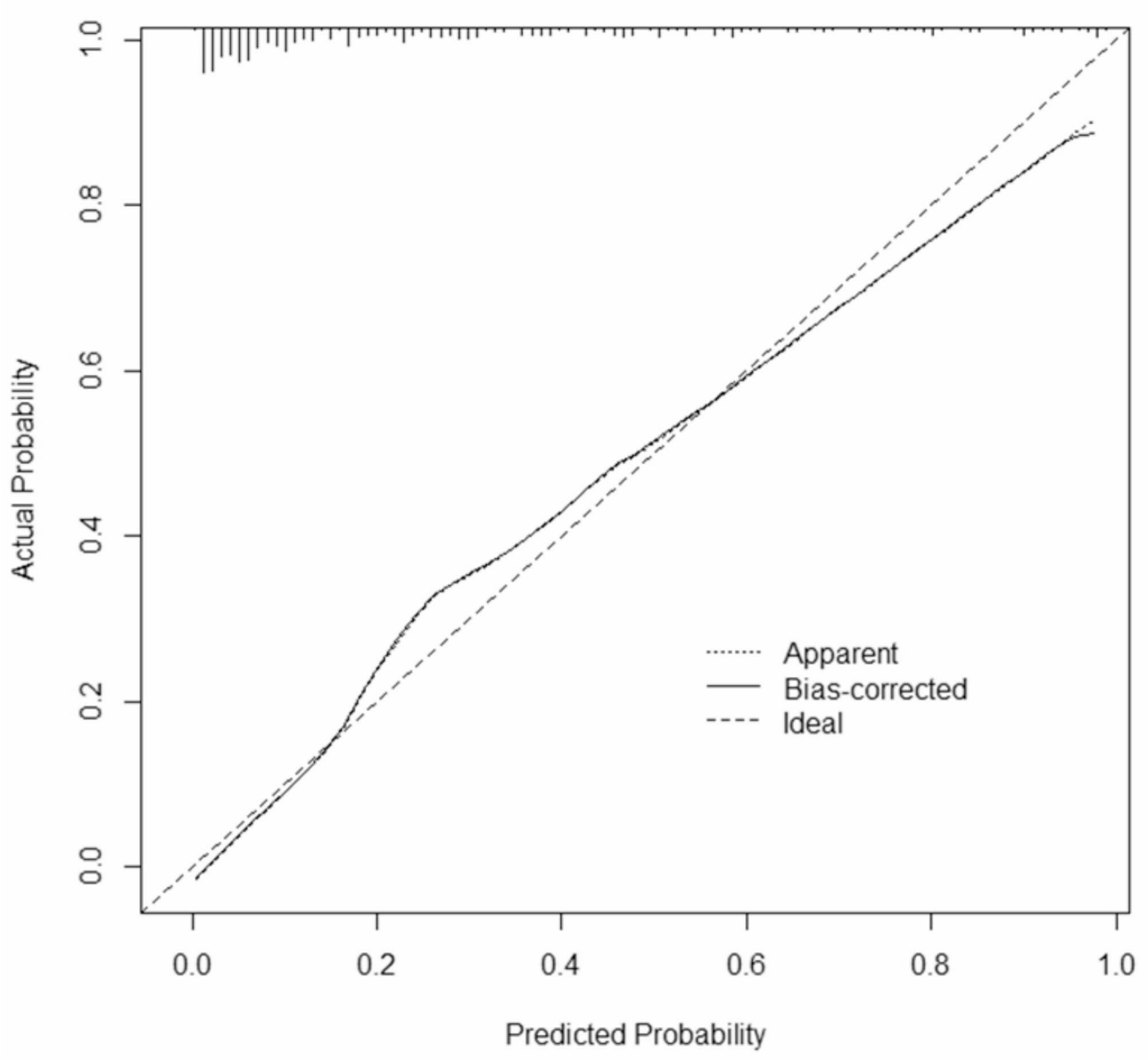

Fig. 5 Calibration curves for predictive models in PSD Occurring After AIS

of post-stroke depression and is of great value for whether stroke patients develop PSD in clinical work.

Systemic immune inflammatory index (SII) is a relatively new immune biomarker that combines platelets and neutrophil-to-lymphocyte ratio (NLR). It was initially used as a prognostic biomarker in patients with hepatocellular carcinoma [43]. Some studies point to SII as an important predictor of AIS [44, 45]. In this study, AIS patients with higher SII were found to have a statistically significant higher risk of PSD. As a comprehensive index, SII combines the values of neutrophils, lymphocytes and platelets and can more comprehensively reflect the situation of inflammation and thrombosis. Compared with NLR and PLR, SII has more advantages in reliability and representativeness. Moreover, SII has the advantages of easy availability and rapidity and does not require patients to pay additional costs.

Predictive model of PSD

In recent years, the incidence of AIS has risen dramatically, seriously endangering the lives of middle-aged and elderly people. The occurrence of PSD can have a strong negative impact on the prognosis of stroke patients. There are currently few direct and effective treatments for PSD in clinical practice. Many scholars have investigated the factors associated with predicting PSD in AIS patients. In this study, we used R software to draw nomograms to predict the risk of PSD in AIS patients.

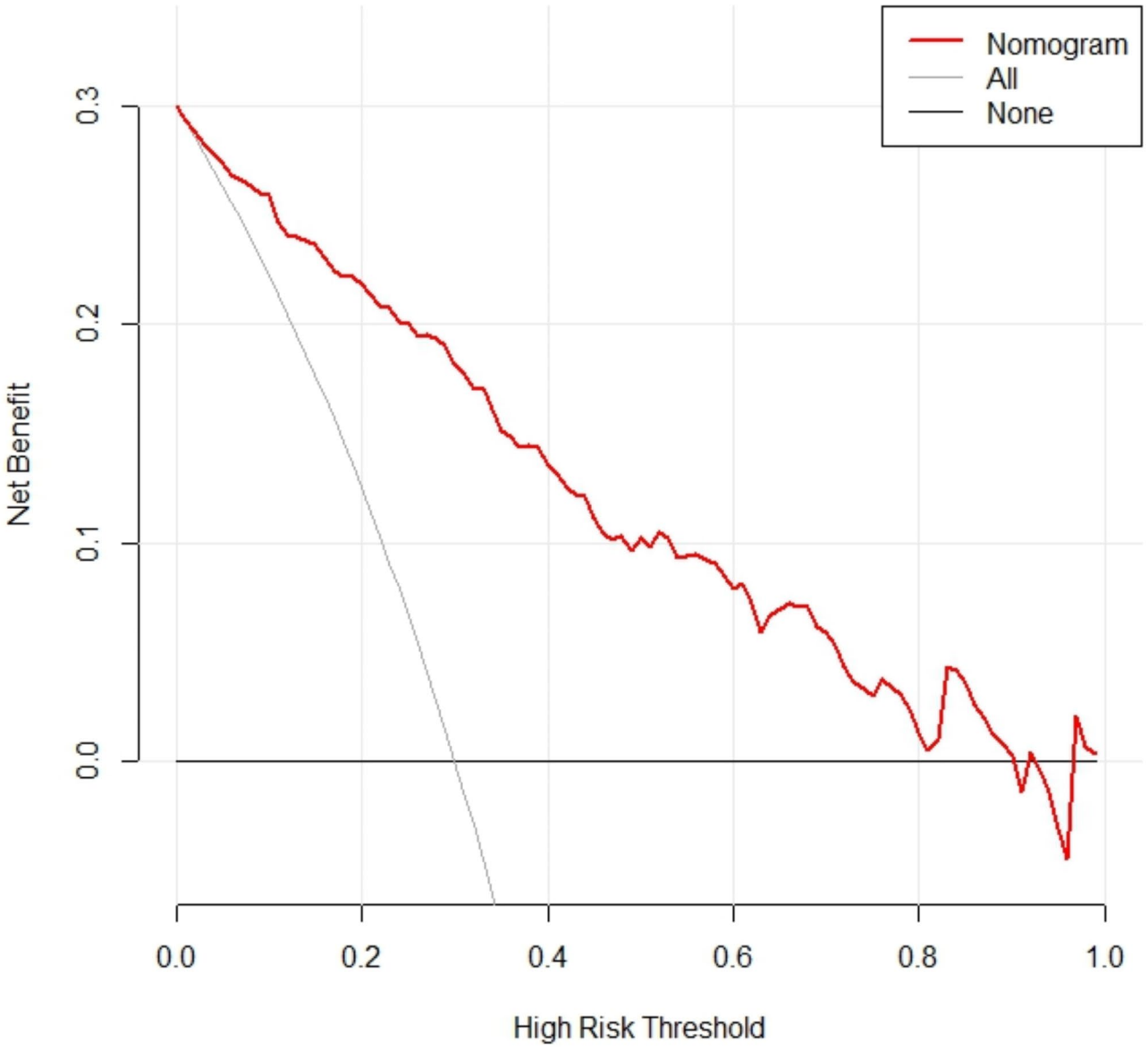

Fig. 6 DCA Decision Curve for Study Model

The AUROC of the predictive model for PSD was 0.881, which was greater than 0.7. Therefore, the modeling in this study has good discrimination. The calibration curve for building the model is close to the diagonal dashed line of Ideal. It is proved that this prediction model has a high consistency between the probability of predicting the occurrence of outcome events and the probability of the occurrence of real events. The DCA decision curve is suitable for assessing the clinical value and clinical utility of the model. Based on the DCA decision curve drawn in this study, it can be concluded that the model constructed in this study has good clinical practical value.

In this study, univariate analysis and binary logistic regression equations were used to screen significant factors and construct a risk prediction model as a new predictive tool for assessing and predicting the risk of post-stroke depression. Accurate risk assessment can help physicians understand the prognosis of patients early and take timely interventions. The prediction model of PSD based on clinical factors of patients has high clinical value, which is helpful for clinicians to diagnose early PSD, reduce the missed diagnosis rate of PSD, and timely treat it, greatly improving the prognosis of stroke patients. Therefore, the risk prediction model constructed in this study can accurately and efficiently predict the probability of PSD in AIS patients and has some value of clinical promotion.

Limitations

There are also some limitations in this paper. First, this is a single-center case-control study with a small sample size and some limitations. We will then conduct a multicenter study to further validate the efficacy of this study model. Second, considering the genetic and ethnic variability of depression, the results of this study are valid in Chinese ethnicity, and the results of this study may have some selection bias.

Conclusion

The probability of PSD in AIS patients in this study was 26.51%. Having hypertension, living alone, education level, homocysteine level, NIHSS score, lymphocyte count, neutrophil count, CRP level, NLR, PLR, and SII were independent risk factors for developing PSD. Including CRP level, living alone, history of hypertension, homocysteine level, education level, SII, NIHSS score to establish risk prediction model and draw nomograms. The model was demonstrated to have good discrimination, calibration and clinical utility by internal validation.

Abbreviations

PSD	Post-stroke depression
AIS	Acute Ischemic Stroke
NIHSS	National Institute of Health Stroke Scale
ROC	Receiver Operating Characteristic Curve
MRI	Magnetic resonance imaging
HAMD	Hamilton Depression Scale
NLR	Neutrophil to lymphocyte ratio
PLR	Platelet to lymphocyte ratio
MLR	Monocyte to lymphocyte ratio
SII	Systemic immune inflammation index
DCA	Decision Curve Analysis
CRP	C-reactive protein
BMI	Body mass index

Acknowledgements

Not applicable.

Author contributions

XAN: data acquisition, literature search, manuscript preparation, and was a major contributor in writing the manuscript. WXY: revised and reviewed the manuscript for the final publication. WRY: made charts and analyzed the data. LCJ: literature search and interpreted the data. All authors read and approved the final manuscript.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data availability

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

Declarations

Ethics approval

This study involving human participants were reviewed and approved by Ethics Committee of the Third Clinical Medical College of China Three Gorges University (Sinopharm Gezhouba Central Hospital). No. 2023018. All methods were performed in accordance with the Declaration of Helsinki and the relevant guidelines and regulations.

Consent to participate

Informed consent to participate was waived by the Ethics Committee of the Third Clinical Medical College of China Three Gorges University due to the retrospective nature of the study design.

Competing interests

The authors declare no competing interests.

Received: 6 May 2024 / Accepted: 17 February 2025
Published online: 12 March 2025

References

1. Villa RF, Ferrari F, Moretti A. Post-stroke depression: mechanisms and Pharmacological treatment[J]. Volume 184. Pharmacology & therapeutics; 2018. pp. 131–44.
2. Robinson RG, Jorge RE. Post-Stroke depression: A Review[J]. Am J Psychiatry. 2016;173(3):221–31.
3. Castilla-Guerra L, Fernandez Moreno MDC, Esparrago-Llorca G, et al. Pharmacological management of post-stroke depression[J]. Expert Rev Neurother. 2020;20(2):157–66.
4. Cai W, Mueller C, Li YJ, et al. Post stroke depression and risk of stroke recurrence and mortality: A systematic review and meta-analysis[J]. Ageing Res Rev. 2019;50:102–9.
5. Medeiros GC, Roy D, Kontos N, et al. Post-stroke depression: A 2020 updated review[J]. Gen Hosp Psychiatry. 2020;66:70–80.
6. Guo J, Wang J, Sun W, et al. The advances of post-stroke depression: 2021 update[J]. J Neurol. 2022;269(3):1236–49.
7. Huang J, Zhou FC, Guan B et al. Predictors of remission of Early-Onset post-stroke depression and the interaction between depression and cognition during Follow-Up[J]. Front Psychiatry, 2018, 9(738.
8. Lin W, Xiong L, Yang Z, et al. Severe periodontitis is associated with Early-Onset poststroke depression Status[J]. J Stroke Cerebrovasc Diseases: Official J Natl Stroke Association. 2019;28(12):104413.
9. Zhou H, Wei YJ, Xie GY. Research progress on post-stroke depression[J]. Exp Neurol, 2024, 373(114660.
10. Mitchell AJ, Sheth B, Gill J, et al. Prevalence and predictors of post-stroke mood disorders: A meta-analysis and meta-regression of depression, anxiety and adjustment disorder[J]. Gen Hosp Psychiatry. 2017;47:48–60.
11. Kowalska K, Pasinska P, Klimiec-Moskal E, et al. C-reactive protein and post-stroke depressive symptoms[J]. Sci Rep. 2020;10(1):1431.
12. Cheng LS, Tu WJ, Shen Y, et al. Combination of High-Sensitivity C-Reactive protein and homocysteine predicts the Post-Stroke depression in patients with ischemic Stroke[J]. Mol Neurobiol. 2018;55(4):2952–8.
13. Tang CZ, Zhang YL, Wang WS, et al. Serum levels of High-sensitivity C-Reactive protein at admission are more strongly associated with poststroke depression in acute ischemic stroke than homocysteine levels[J]. Mol Neurobiol. 2016;53(4):2152–60.
14. Yang Y, Zhu L, Zhang B, et al. Higher levels of C-reactive protein in the acute phase of stroke indicate an increased risk for post-stroke depression: A systematic review and meta-analysis[J]. Neuroscience and biobehavioral reviews; 2022. 134(104309.
15. Dziedzic T. Clinical significance of acute phase reaction in stroke patients[J]. Front Bioscience: J Virtual Libr. 2008;13:2922–7.
16. Jiang G, Zhou D, Yan X, et al. Association between C-reactive protein levels and development of post-stroke depression: A systematic review and meta-analysis[J]. Scot Med J. 2022;67(4):135–43.
17. Chen Y, Zou H, Peng M, et al. Association between homocysteine levels in acute stroke and poststroke depression: A systematic review and meta-analysis[J]. Brain Behav. 2022;12(6):e2626.
18. Liang Y, Shi X, Chen L et al. Homocysteine level at the acute stage of ischemic stroke as a biomarker of poststroke depression: A systematic review and meta-analysis[J]. Front Psychiatry, 2022, 13(1016700.
19. Nabi H, Bochud M, Glaus J, et al. Association of serum homocysteine with major depressive disorder: results from a large population-based study[J]. Psychoneuroendocrinology. 2013;38(10):2309–18.
20. Zhang H, Huang J, Zhou Y, et al. Association of homocysteine level with adverse outcomes in patients with acute ischemic stroke: A Meta-Analysis[J]. Curr Med Chem. 2021;28(36):7583–91.

21. Coppen A, Bolander-Gouaille C. Treatment of depression: time to consider folic acid and vitamin B12[J]. J Psychopharmacol (Oxford England). 2005;19(1):59–65.
22. Barry S, Phillips OM, Williams DC, et al. Platelet 5-HT uptake in post-stroke depression[J]. Acta Psychiatrica Scandinavica. 1990;82(1):88–9.
23. Daut RA, Fonken LK. Circadian regulation of depression: A role for serotonin[J]. Front Neuroendocr, 2019, 54(100746.
24. Yi J, Lu J, Yang A, et al. In-hospital predictors of post-stroke depression for targeted initiation of selective serotonin reuptake inhibitors (SSRIs)[J]. BMC Psychiatry. 2022;22(1):722.
25. Chen YM, Chen PC, Lin WC et al. Predicting new-onset post-stroke depression from real-world data using machine learning algorithm[J]. Front Psychiatry, 2023, 14(1195586.
26. Li S, Guo B, Yang Q et al. Evaluation of depression status and its influencing factors in convalescent elderly patients with first-episode stroke[J]. Asian J Psychiatry, 2022, 77(103252.
27. Isuru A, Hapangama A, Ediriweera D et al. Prevalence and predictors of new onset depression in the acute phase of stroke[J]. Asian J Psychiatry, 2021, 59(102636.
28. Hankey GJ, London. England). 2017;389(10069):641–54.
29. Wang Y, Qian Y, Smerin D, et al. Newly detected atrial fibrillation after acute stroke: A narrative review of causes and Implications[J]. Cardiology. 2019;144(3–4):112–21.
30. Li G, Jing P, Chen G, et al. Development and validation of 3-Month major Post-Stroke depression prediction nomogram after acute ischemic stroke Onset[J]. Clin Interv Aging. 2021;16:1439–47.
31. Román GC, Nash DT, Fillit H. Translating current knowledge into dementia prevention[J]. Alzheimer Dis Assoc Disord. 2012;26(4):295–9.
32. Willis KJ, Hakim AM. Stroke prevention and cognitive reserve: emerging approaches to modifying risk and delaying onset of dementia[J]. Front Neurol, 2013, 4(13.
33. Backhouse EV, McHutchison CA, Cvoro V, et al. Cognitive ability, education and socioeconomic status in childhood and risk of post-stroke depression in later life: A systematic review and meta-analysis[J]. PLoS ONE. 2018;13(7):e0200525.
34. Shi Y, Yang D, Zeng Y et al. Risk factors for Post-stroke depression: A Meta-analysis[J]. Front Aging Neurosci, 2017, 9(218.
35. Ayasrah SM, Ahmad MM, Basheti IA. Post-Stroke depression in Jordan: prevalence correlates and Predictors[J]. J Stroke Cerebrovasc Diseases: Official J Natl Stroke Association. 2018;27(5):1134–42.
36. Ilut S, Stan A, Blesneag A, et al. Factors that influence the severity of post-stroke depression[J]. J Med Life. 2017;10(3):167–71.
37. Hung KC, Wu JY, Illias AM et al. Association of a low vitamin D status with risk of post-stroke depression: A meta-analysis and systematic review[J]. Front Nutr, 2023, 10(1142035.
38. Zhang Y, Cheng L, Chen Y, et al. Clinical predictor and Circulating MicroRNA profile expression in patients with early onset post-stroke depression[J]. J Affect Disord. 2016;193:51–8.
39. Meng G, Ma X, Li L, et al. Predictors of early-onset post-ischemic stroke depression: a cross-sectional study[J]. BMC Neurol. 2017;17(1):199.
40. Wang Z, Zhu M, Su Z, et al. Post-stroke depression: different characteristics based on follow-up stage and gender-a cohort perspective study from Mainland China[J]. Neurol Res. 2017;39(11):996–1005.
41. Zhang S, Cheng S, Zhang Z, et al. Related risk factors associated with post-stroke fatigue: a systematic review and meta-analysis[J]. Neurol Sciences: Official J Italian Neurol Soc Italian Soc Clin Neurophysiol. 2021;42(4):1463–71.
42. Yue W, Wang A, Zhu R, et al. Association between carotid artery stenosis and cognitive impairment in stroke patients: A Cross-Sectional Study[J]. PLoS ONE. 2016;11(1):e0146890.
43. Hu B, Yang XR, Xu Y, et al. Systemic immune-inflammation index predicts prognosis of patients after curative resection for hepatocellular carcinoma[J]. Clin cancer Research: Official J Am Association Cancer Res. 2014;20(23):6212–22.
44. Agard TA, Hass R, Cavrak ME et al. Neutrophil lymphocyte ratio (NLR) and systemic immune inflammatory index (SII) for the differential diagnosis of CT-negative mild acute ischemic stroke and transient ischemic attack[J]. Int J Neurosci, 2023, 1–8.
45. Weng Y, Zeng T, Huang H, et al. Systemic Immune-Inflammation index predicts 3-Month functional outcome in acute ischemic stroke patients treated with intravenous Thrombolysis[J]. Clin Interv Aging. 2021;16:877–86.

Publisher's note