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ORIGINAL RESEARCH

Analysis of Prognostic Factors for Drilling Drainage Surgery in Patients with Hypertensive Intracerebral Hemorrhage and Development of a Predictive Nomogram

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Objective: To investigate the influencing factors affecting prognosis in patients undergoing drilling drainage surgery for hypertensive intracerebral hemorrhage (HICH) and to construct a nomogram predictive model.

Methods: Clinical data of 247 patients with HICH admitted to our hospital between October 2020 and February 2024 were retrospectively analyzed. Patients were divided into a modeling cohort (173 cases) and a validation cohort (74 cases). The modeling group was separated into a good prognosis group and a poor prognosis group based on postoperative prognosis.

Results: Among the 173 patients in the modeling cohort, 19 patients (10.98%) experienced poor prognosis. Multivariate logistic regression analysis showed that age, preoperative GCS score, diabetes history, systolic blood pressure, diastolic blood pressure, pulmonary infection and postoperative hematoma volume were the risk factors for the prognosis of drilling drainage surgery for patients with HICH ($P<0.05$). The AUC of the modeling group and validation group was 0.962 and 0.946, and the H-L test showed $\chi^2=7.105$ and 7.246, with $P<0.05$ for both, indicating favorable consistency of the model. Decision curve analysis (DCA) showed high clinical utility of the nomogram model within the probability threshold range of 0.05 to 0.93.

Conclusion: Age, preoperative GCS score, history of diabetes, systolic blood pressure, diastolic blood pressure, pulmonary infection and postoperative hematoma volume are key prognostic factors affecting outcomes after drilling drainage surgery in HICH patients. The established nomogram model based on these variables accurately predicts the risk of poor postoperative prognosis and can serve as an effective clinical reference tool.

Keywords: hypertensive intracerebral hemorrhage, drilling drainage surgery, prognosis, influencing factors, nomogram

Introduction

Hypertension is a prevalent global disease characterized by persistently elevated arterial blood pressure, which contributes to damage in organs such as the brain and heart, notably increasing the risk of stroke.[1,2] Hypertensive intracerebral hemorrhage (HICH) results from arteriolosclerosis and endothelial damage induced by chronic hypertension. Fluctuating blood pressures and impaired cerebral autoregulation further exacerbate arterial sclerosis, increasing the risk of vessel rupture and subsequent cerebral hematoma formation. The ensuing rapid neurological deterioration necessitates prompt intervention for hematoma removal and intracranial pressure reduction. Consequently, HICH has significant morbidity and mortality rates.[3,4] Drilling drainage surgery (burr hole drainage) is widely adopted clinically due to its minimal invasiveness, brief operative duration, straightforward implementation, and substantial clinical efficacy. It efficiently reduces hematoma volume, relieves intracranial hypertension, and mitigates secondary neurological impairment.[5] Nevertheless, certain patients continue to exhibit adverse outcomes postoperatively, placing substantial burdens on families and significantly affecting patients' quality of life. Numerous risk factors contributing to poor postoperative prognosis require timely identification and management.[6]

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Therefore, clarifying prognostic factors following drilling drainage surgery in HICH patients is imperative for optimizing clinical outcomes. A nomogram is a predictive tool integrating multiple prognostic indicators identified by regression analyses, facilitating individualized risk stratification and clinical decision-making.[7,8] Current literature on nomogram development for predicting outcomes in HICH patients post-drilling drainage surgery remains limited. Thus, this study aims to analyze factors influencing postoperative prognosis in HICH patients undergoing burr hole drainage and to develop an accurate, clinically applicable nomogram predictive model.

Materials and Methods

General Data

This retrospective study included 247 patients diagnosed with hypertensive intracerebral hemorrhage (HICH) who underwent burr hole drainage surgery at our hospital between October 2020 and February 2024. Patients were randomly divided into a modeling cohort (173 cases) and a validation cohort (74 cases) at a 7:3 ratio using a random number table. The modeling cohort was further classified into good prognosis and poor prognosis groups based on postoperative outcomes. The flowchart of patient selection is presented in Figure 1. Inclusion criteria were as follows: (1) Diagnosis of HICH based on clinical and imaging criteria,[9] including acute onset, focal neurological deficits, headache, elevated blood pressure, variable consciousness impairment, and radiological evidence of intracerebral hemorrhage; (2) documented history of hypertension; and (3) complete clinical data available.

Exclusion criteria included: (1) Liver or kidney dysfunction identified through blood tests, imaging, or other diagnostic assessments; (2) previous brain surgery; (3) autoimmune diseases; (4) malignant tumors; (5) hematological

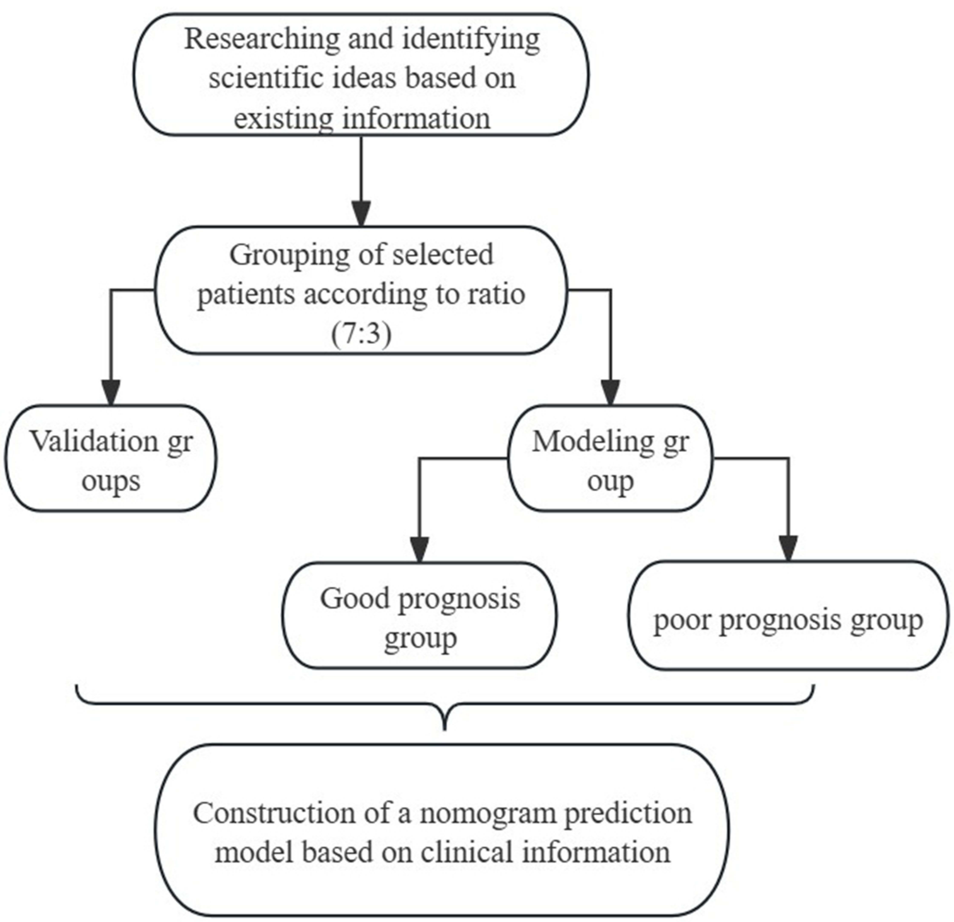

Figure 1 Flow chart of case collection.

disorders; (6) mental disorders confirmed through clinical interviews or standardized psychological assessments; and (7) traumatic intracerebral hemorrhage. Ethical approval was obtained from the ethics committee of our hospital.

Postoperative Prognosis of HICH Patients Undergoing Burr Hole Drainage

Postoperative Prognosis Evaluation Patients were followed up for 6 months postoperatively using the Barthel Index to assess their daily living activities. The Barthel Index comprises 10 items with a maximum score of 100, indicating full independence; scores of 61–99 indicate mild dependency with basic self-care capability; scores of 41–60 indicate moderate dependency requiring daily assistance; scores ≤40 indicate severe dependency with significant assistance required.[10] A score ≥61 was considered a good prognosis, while <61 was considered a poor prognosis.

Clinical Data

Clinical data were collected through routine examinations and electronic medical records, including age, gender, hypertension duration, body mass index (BMI), preoperative Glasgow Coma Scale (GCS) score, history of diabetes, hyperlipidemia, coronary heart disease, previous stroke, smoking and alcohol consumption history, systolic and diastolic blood pressures, pulmonary infection, hematoma morphology, recurrence of hematoma, timing of surgery, preoperative hematoma volume, duration of surgery, chronic obstructive pulmonary disease (COPD), brain herniation, hematoma location, and postoperative hematoma volume.

Statistical Analysis

Data were analyzed using SPSS 25.0. Categorical data were analyzed using the χ^2-test and expressed as n (%), while continuous data were analyzed using the *t*-test and expressed as mean ± standard deviation. Multivariate logistic regression analysis was used to identify factors influencing the prognosis of HICH patients after burr hole drainage. The nomogram model for predicting the prognosis of HICH patients after burr hole drainage was constructed using R software. ROC curves were drawn to evaluate the discrimination of the nomogram model, calibration curves were drawn to assess model consistency, and clinical decision curve analysis (DCA) was used to evaluate the clinical application value of the model. A P-value <0.05 was considered statistically significant.

Results

Comparison of Clinical Data Between Modeling Group and Validation Group

There were no significant differences in clinical data between the modeling group and the validation group (P > 0.05; Table 1).

Comparison of Clinical Data Between Poor Prognosis Group and Good Prognosis Group

Among the 173 patients in the modeling cohort, 19 patients (10.98%) had a poor prognosis. Significant differences were identified between patients with poor and good prognoses in terms of age, preoperative GCS score, history of diabetes, systolic blood pressure, diastolic blood pressure, pulmonary infection, and postoperative hematoma volume (P < 0.05). No significant differences were observed in other clinical variables between the two groups (P > 0.05; Table 2).

Analysis of Factors Influencing Prognosis of HICH Patients After Burr Hole Drainage

Using poor postoperative prognosis as the dependent variable (yes = 1, no = 0) and incorporating significant clinical variables identified above as independent variables (variable assignments shown in Table 3), multivariate logistic regression analysis demonstrated that age (OR = 9.282, 95% CI: 2.651–32.507), preoperative GCS score (OR = 4.843, 95% CI: 1.486–15.779), history of diabetes (OR = 11.767, 95% CI: 2.791–49.610), systolic blood pressure (OR = 6.803, 95% CI: 2.474–18.704), diastolic blood pressure (OR = 13.521, 95% CI: 3.665–49.879), pulmonary infection (OR = 3.573, 95% CI: 1.009–12.659), and postoperative hematoma volume (OR = 21.704, 95% CI: 5.133–91.770) were significant risk factors associated with poor prognosis in patients after burr hole drainage for HICH (P < 0.05; Table 4).

Table 1 Comparison of Clinical Data Between Modeling and Validation Group

Considerations	Modeling Group (n=173)	Validation Group (n=74)	t/χ^2	*P*
Age (years)			0.123	0.726
<60	94 (54.34)	42 (56.76)		
≥60	79 (45.66)	32 (43.24)		
Genders			0.017	0.898
Man	99 (57.23)	43 (58.11)		
Woman	74 (42.77)	31 (41.89)		
Duration of hypertension (years)			0.908	0.341
<10	125 (72.25)	49 (66.22)		
≥10	48 (27.75)	25 (33.78)		
BMI (kg/m^2)			0.123	0.726
<23	94 (54.34)	42 (56.76)		
≥23	79 (45.66)	32 (43.24)		
Preoperative GCS score (points)			0.682	0.409
<8	80 (46.24)	30 (40.54)		
≥8	93 (53.76)	44 (59.46)		
History of diabetes			0.037	0.848
Yes	63 (36.42)	26 (35.14)		
No	110 (63.58)	48 (64.86)		
History of hyperlipidaemia			0.147	0.702
Yes	27 (15.61)	13 (17.57)		
No	146 (84.39)	61 (82.43)		
History of coronary heart disease			0.176	0.674
Yes	22 (12.72)	8 (10.81)		
No	151 (87.28)	66 (89.19)		
History of stroke			0.164	0.685
Yes	18 (10.40)	9 (12.16)		
No	155 (89.60)	65 (87.84)		
Smoking history			0.016	0.900
Yes	81 (46.82)	34 (45.95)		
No	92 (53.18)	40 (54.05)		
Drinking history			0.032	0.857
Yes	91 (52.60)	38 (51.35)		
No	82 (47.40)	36 (48.65)		
Systolic blood pressure (mmHg)			0.016	0.901
≤140	85 (49.13)	37 (50.00)		
>140	88 (50.87)	37 (50.00)		
Diastolic blood pressure (mmHg)			0.236	0.627
≤90	90 (52.02)	36 (48.65)		
>90	83 (47.98)	38 (51.35)		
Lung infection			0.034	0.854
Yes	77 (44.51)	32 (43.24)		
No	96 (55.49)	42 (56.76)		
Haematoma pattern			0.106	0.745
Regulation	32 (18.50)	15 (20.27)		
Irregularly	141 (81.50)	59 (79.73)		
Recurrence of haematoma			0.515	0.473
Yes	35 (20.23)	18 (24.32)		
No	138 (79.77)	56 (75.68)		

(*Continued*)

Table 1 (Continued).

Considerations	Modeling Group (n=173)	Validation Group (n=74)	t/χ^2	*P*
Timing of surgery			0.872	0.351
Early stage	140 (80.92)	56 (75.68)		
Postponement	33 (19.08)	18 (24.32)		
Preoperative haemorrhage (mL)	40.88±5.29	40.91±5.24	0.041	0.967
Surgical time (min)	60.86±10.37	60.76±10.21	0.070	0.944
Chronic obstructive pulmonary disease			0.281	0.596
Yes	15 (8.67)	8 (10.81)		
No	158 (91.33)	66 (89.19)		
Cerebral hernia			0.022	0.881
Yes	46 (26.59)	19 (25.68)		
No	127 (73.41)	55 (74.32)		
Haemorrhage site			0.335	0.563
Basal ganglia	121 (69.94)	49 (66.22)		
Lobe of the brain	52 (30.06)	25 (33.78)		
Postoperative haematoma volume (cm^2)			0.025	0.875
≥15	72 (41.62)	30 (40.54)		
<15	101 (58.38)	44 (59.46)		

Table 2 Comparison of Clinical Data Between Poor Prognosis and Good Prognosis Groups

Considerations	Poor Prognosis Group (n=19)	Good Prognosis Group (n=154)	t/χ^2	*P*
Age (years)			4.455	<0.001
<60	6 (31.58)	88 (57.14)		
≥60	13 (68.42)	66 (42.86)		
Genders			0.307	0.580
Man	12 (63.16)	87 (56.49)		
Woman	7 (36.84)	67 (43.51)		
Duration of hypertension (years)			2.195	0.138
<10	11 (57.89)	114 (74.03)		
≥10	8 (42.11)	40 (25.97)		
BMI (kg/m^2)			0.025	0.874
<23	10 (52.63)	84 (54.55)		
≥23	9 (47.37)	70 (45.45)		
Preoperative GCS score (points)			4.223	0.040
<8	13 (68.42)	67 (43.51)		
≥8	6 (31.58)	87 (56.49)		
History of diabetes			4.253	0.039
Yes	11 (57.89)	52 (33.77)		
No	8 (42.11)	102 (66.23)		
History of hyperlipidaemia			0.001	0.981
Yes	3 (15.79)	24 (15.58)		
No	16 (84.21)	130 (84.42)		
History of coronary heart disease			0.182	0.670
Yes	3 (15.79)	19 (12.34)		
No	16 (84.21)	135 (87.66)		

(*Continued*)

Table 2 (Continued).

Considerations	Poor Prognosis Group (n=19)	Good Prognosis Group (n=154)	t/χ^2	*P*
History of stroke			0.144	0.704
Yes	2 (10.53)	16 (10.39)		
No	17 (89.47)	138 (89.61)		
Smoking history			0.003	0.960
Yes	9 (47.37)	72 (46.75)		
No	10 (52.63)	82 (53.25)		
Drinking history			0.240	0.624
Yes	11 (57.89)	80 (51.95)		
No	8 (42.11)	74 (48.05)		
Systolic blood pressure (mmHg)			4.446	0.035
≤140	5 (26.32)	80 (51.95)		
>140	14 (73.68)	74 (48.05)		
Diastolic blood pressure (mmHg)			5.652	0.017
≤90	5 (26.32)	85 (55.19)		
>90	14 (73.68)	69 (44.81)		
Lung infection			4.941	0.026
Yes	13 (68.42)	64 (41.56)		
No	6 (31.58)	90 (58.44)		
Haematoma pattern			0.092	0.761
Regulation	4 (21.05)	28 (18.18)		
Irregularly	15 (78.95)	126 (81.82)		
Recurrence of haematoma			0.043	0.835
Yes	4 (21.05)	31 (20.13)		
No	15 (78.95)	123 (79.87)		
Timing of surgery			0.006	0.939
Early stage	15 (78.95)	125 (81.17)		
Postponement	4 (21.05)	29 (18.83)		
Preoperative haemorrhage (mL)	40.37±5.27	41.24±5.31	0.674	0.501
Surgical time (min)	61.25±10.41	60.58±10.34	0.266	0.790
Chronic obstructive pulmonary disease			0.016	0.899
Yes	2 (10.53)	13 (8.44)		
No	17 (89.47)	141 (91.56)		
Cerebral hernia			0.272	0.602
Yes	6 (31.58)	40 (25.97)		
No	13 (68.42)	114 (74.03)		
Haemorrhage site			0.023	0.878
Basal ganglia	13 (68.42)	108 (70.13)		
Lobe of the brain	6 (31.58)	46 (29.87)		
Postoperative haematoma volume (cm^2)			6.311	0.012
≥15	13 (68.42)	59 (38.31)		
<15	6 (31.58)	95 (61.69)		

Establishing the Nomogram Model for Prognosis of HICH Patients After Burr Hole Drainage

A nomogram model predicting prognosis was developed using logistic regression coefficients, formulated as: $P=e^x/(1+e^x)$, where x = 2.35 + 2.228 × age + 1.578 × preoperative GCS score + 2.465 × history of diabetes + 1.917 × systolic blood pressure + 2.604 × diastolic blood pressure + 1.274 × lung infection + 3.077 × postoperative hematoma volume.

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Table 3 Independent Variable Assignment Methods

Variable	Assignment Method
Age	<60 years=0, ≥60 years=1
Preoperative GCS score	≥8 points=0, <8 points=1
History of diabetes	No=0, Yes=1
Systolic blood pressure	≤140mmHg=0, >140mmHg=1
Diastolic blood pressure	≤90mmHg=0, >90mmHg=1
Lung infection	No=0, Yes=1
Postoperative haematoma volume	<15cm^2=0, ≥15cm^2=1

Table 4 Analysis of Factors Influencing the Prognosis of Patients with HICH After Drilling and Drainage

Variable	β Value	SE Value	Wald χ^2 Value	*P* Value	OR Value	95% CI
Age	2.228	0.639	12.141	<0.001	9.282	2.651~32.507
Preoperative GCS score	1.578	0.603	6.852	0.009	4.843	1.486~15.779
History of diabetes	2.465	0.734	11.276	0.001	11.767	2.791~49.610
Systolic blood pressure	1.917	0.516	13.805	<0.001	6.803	2.474~18.704
Diastolic blood pressure	2.604	0.666	15.289	<0.001	13.521	3.665~49.879
Lung infection	1.274	0.645	3.894	0.048	3.573	1.009~12.659
Postoperative haematoma volume	3.077	0.736	17.501	<0.001	21.704	5.133~91.770
Constant	−6.205	1.064	34.035	<0.001	0.002	–

The constructed nomogram (Figure 2) revealed that the influencing factors ranked by predictive importance were postoperative hematoma volume, diastolic blood pressure, diabetes history, age, preoperative GCS score, pulmonary infection, and systolic blood pressure.

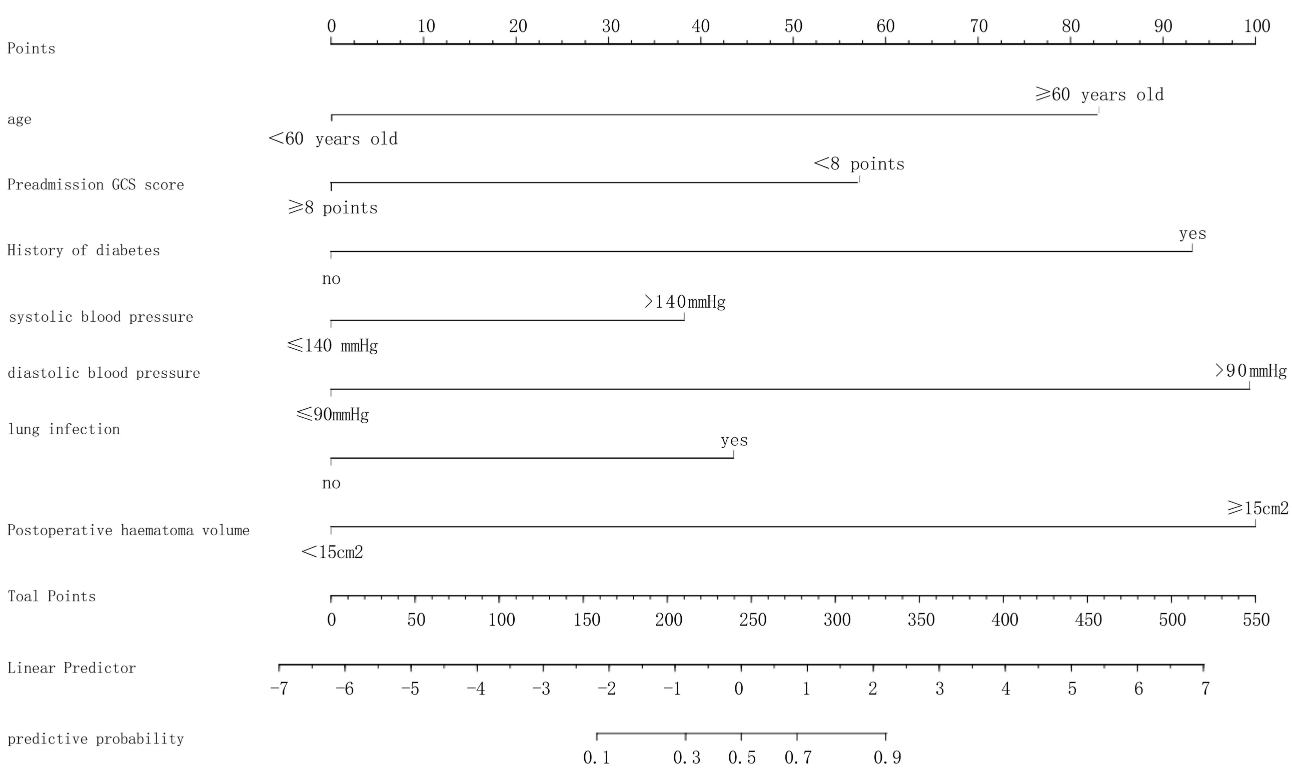

Figure 2 Nomogram model of prognosis after drilling and draining in patients with HICH.

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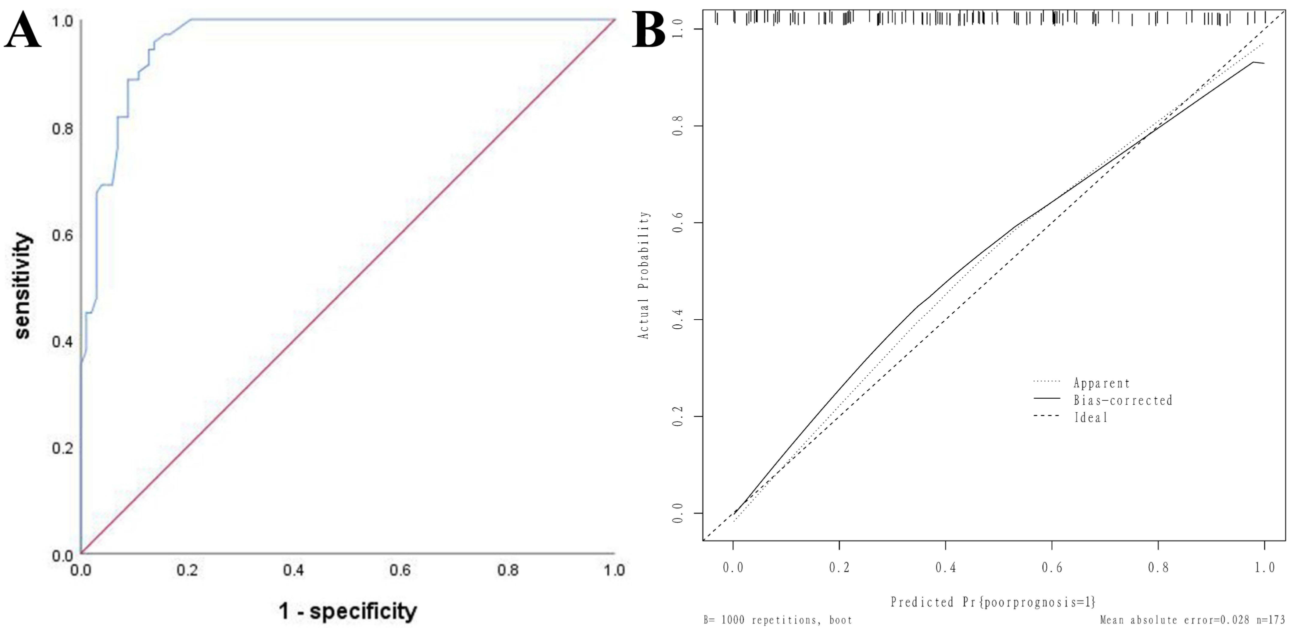

Figure 3 Nomogram Model for Prognosis of HICH Patients after Burr Hole Drainage in the Modeling Group. (**A**) ROC curve for modeling group; (**B**) Modeling group calibration curves.

Nomogram Model for Prognosis of HICH Patients After Burr Hole Drainage in the Modeling Group

The ROC curve analysis for the modeling cohort demonstrated an AUC of 0.962 (95% CI: 0.937–0.987). The calibration curve closely approximated the ideal slope (slope = 1), and the Hosmer-Lemeshow goodness-of-fit test yielded χ^2 = 7.105, P = 0.723, indicating good predictive consistency (Figure 3).

Nomogram Model for Prognosis of HICH Patients After Burr Hole Drainage in the Validation Group

The ROC curve analysis for the validation cohort showed an AUC of 0.946 (95% CI: 0.900–0.993). The calibration curve closely matched the ideal curve, and the Hosmer-Lemeshow test result was χ^2 = 7.246, P = 0.725, demonstrating strong consistency and reliability of the model (Figure 4).

DCA Curve of the Nomogram Model

The DCA demonstrated that when the threshold probability of predicting poor prognosis ranged between 0.05 and 0.93, the nomogram exhibited high clinical value and utility in guiding clinical decision-making (Figure 5).

Discussion

Hypertensive intracerebral hemorrhage (HICH) primarily results from long-standing hypertension causing fibrinoid necrosis and focal degenerative changes in cerebral arteries. This leads to vascular dilation, decreased elasticity, and increased fragility. Emotional stress or physical exertion can cause abrupt increases in blood pressure, leading to rupture of compromised cerebral vessels and significant neurological impairment.[11,12] Burr hole drainage surgery is clinically employed to rapidly evacuate intracerebral hematomas, thereby alleviating intracranial pressure, preventing hematoma expansion, reducing neurological damage, and lowering mortality rates.[13] Our study identified 19 of 173 patients (10.98%) with poor postoperative prognosis, emphasizing the importance of identifying factors influencing surgical outcomes.

Seven prognostic factors were determined: (1) Advanced age correlates with increased surgical and anesthetic risks due to decreased physiological reserve, reduced tolerance to stress, and frequent presence of comorbidities such as

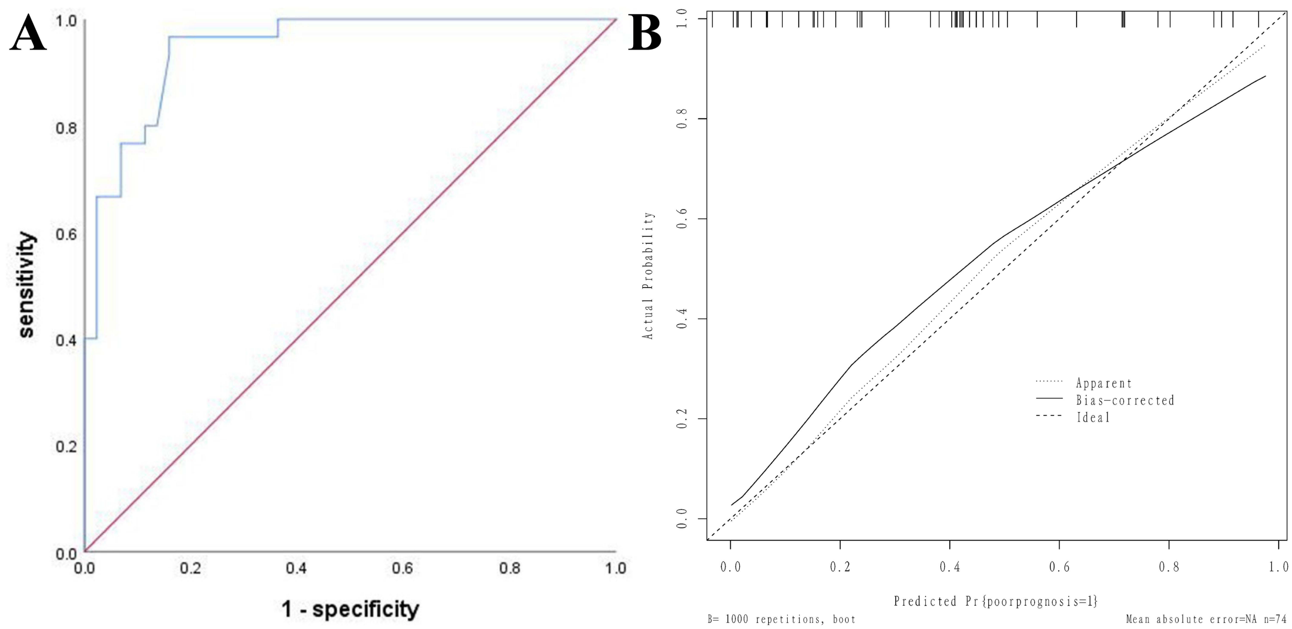

Figure 4 Nomogram Model for Prognosis of HICH Patients after Burr Hole Drainage in the Validation Group. (**A**) ROC curve for the validation group; (**B**) Calibration curve for the validation group.

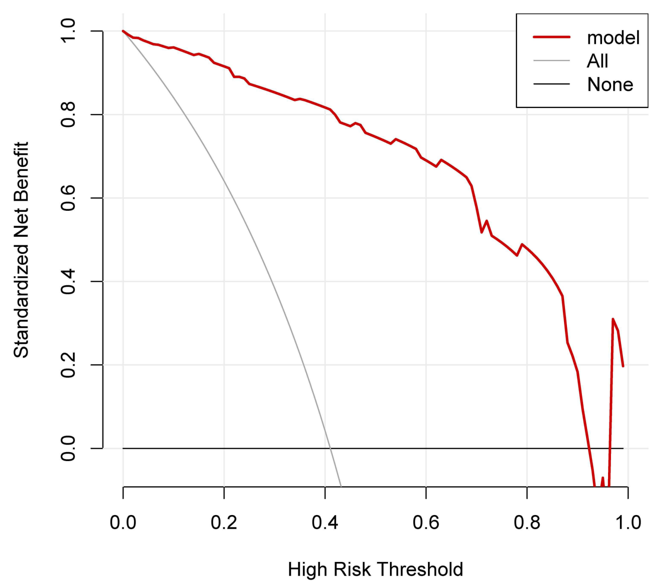

Figure 5 DCA curve for the nomogram.

hyperlipidemia and hyperglycemia. These factors result in slower postoperative recovery and poorer prognosis.[14,15] Personalized management strategies and active control of comorbidities are therefore recommended for elderly patients. (2) Preoperative Glasgow Coma Scale (GCS) scores reflect the extent of neurological impairment. Lower scores typically indicate more severe cerebral injury, increased risk of hematoma progression, and a correspondingly poorer prognosis.[16] (3) Diabetes mellitus contributes to endothelial dysfunction through altered lipid metabolism, elevating the risk of recurrent intracerebral hemorrhage. Hyperglycemia further activates the sympathetic nervous system, disrupting circadian blood pressure rhythms, increasing cerebrovascular vulnerability, and impairing postoperative recovery. Elevated glucose levels also intensify cerebral edema and hematoma expansion through enhanced plasma kallikrein activity, exacerbating neurological damage.[17] Close monitoring and effective glycemic control are crucial for improving patient outcomes. (4) Persistent hypertension disrupts cerebral vascular integrity through hyaline degeneration and fibrinoid necrosis, weakening vessel walls, precipitating rupture, and promoting hematoma instability and expansion. Aggressive blood pressure management post-admission is therefore essential to minimize hematoma progression and reduce rebleeding risk.[18,19] (5) Prolonged postoperative immobility can cause nutritional deficits and pulmonary complications, particularly infections, which significantly worsen inflammatory responses and clinical outcomes. Timely and appropriate antimicrobial interventions are necessary for patients exhibiting pulmonary infections to enhance prognosis.[20] (6) Hematoma volume directly correlates with consciousness impairment severity. Large hematomas amplify primary cerebral injuries, elevate intracranial pressure, and impede neurological recovery. Precise surgical evacuation to minimize residual postoperative hematoma volume is critical to improve patient outcomes.[21]

In this study, a nomogram model was developed to predict postoperative prognosis in HICH patients undergoing burr hole drainage. The model demonstrated excellent discriminative ability, with area under the ROC curve (AUC) values of 0.962 and 0.946 for the modeling and validation cohorts, respectively. Calibration curves indicated strong concordance between predicted and observed outcomes. Decision curve analysis (DCA) further established high clinical applicability of the nomogram within a threshold probability range of 0.05 to 0.93, aiding clinicians in identifying and mitigating risks of poor outcomes based on identified prognostic factors.

In summary, age, preoperative GCS score, diabetes history, systolic and diastolic blood pressure, pulmonary infection, and postoperative hematoma volume significantly influence prognosis following burr hole drainage surgery in patients with HICH. The established nomogram provides an accurate tool for predicting adverse outcomes, enhancing clinical decision-making. However, this retrospective, single-center study is limited by potential biases and a modest sample size. Future multi-center, prospective studies with larger sample sizes are warranted for further validation.

Data Sharing Statement

The original contributions presented in the study are included in the article.

Research Involving Human Participants

The study was in accordance with Meizhou People's Hospital ethics review board (2021-03-26) and with the 1964 helsinki Declaration. Written informed consent to participate in this study was provided by the participants.

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Disclosure

Authors declared no conflict of interest.

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