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Original Research

A Nomogram Model for Predicting Prognosis in Spontaneous Intracerebral Hemorrhage Patients

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Abstract

Objectives: Intracranial hemorrhage is the second most common stroke subtype following ischemic stroke and usually induces high mortality and disability. Here, we conducted a retrospective study to establish a nomogram clinical prediction model. **Methods**: First, the baseline data of patients who presented to our hospital in 2015–2021 were collected and compared (789 patients for the training cohort and 378 patients for the validation cohort). Second, univariate and binary logistic analyses were performed to screen out alternative indicators. Finally, a clinical prediction model by nomogram was established that included such indicators to estimate the prognosis of intracranial hemorrhage patients. **Results**: Univariate logistic analysis was used to screen several possible impact factors, including hypertension, hematoma volume, Glasgow Coma Scale (GCS) score, intracranial hemorrhage (ICH) score, irregular shape, uneven density, intraventricular hemorrhage (IVH) relation, fibrinogen, D-dimer, low density lipoprotein (LDL), high-density lipoprotein (HDL), creatinine, total protein, hemoglobin (HB), white blood cell (WBC), neutrophil blood cell (NBC), lymphocyte blood cell (LBC), the neutrophil lymphocyte ratio (NLR), surgery, deep venous thrombosis (DVT) or pulmonary embolism (PE) rate, hospital day, and hypertension control. Further binary logistic analysis revealed that ICH score ($p = 0.036$), GCS score ($p = 0.000$), irregular shape ($p = 0.000$), uneven density ($p = 0.002$), IVH relation ($p = 0.014$), surgery ($p = 0.000$) were independent indicators to construct a nomogram clinical prediction model. The C statistic was 0.840. **Conclusions**: ICH score, GCS score, irregular shape, uneven density, IVH relation, surgery are easily available indicators to assist neurologists in formulating the most appropriate therapy for every intracranial hemorrhage patient. Further large prospective clinical trials are needed to obtain more integrated and reliable conclusions.

Keywords: intracerebral hemorrhage; nomogram; prognosis; clinical study; retrospective

1. Introduction

Intracranial hemorrhage is the second most common type of stroke after ischemic stroke. It is estimated that intracranial hemorrhage occurs in approximately 10–30 per 100,000 people each year, with a mortality rate of up to 50% within one month of intracranial hemorrhage, and functional independence is achieved in less than 40% of patients [1,2]. The incidence rate is increasing, especially in developing countries [3]. A total of 60–70% of cases of intracranial hemorrhage are attributed to hypertension, usually located in the caudate-putamen (basal nuclei), thalamus, cerebellum and pons [4–6], which presents more serious performance issues and poor prognosis. However, there is still no appropriate treatment to improve the prognosis of patients with intracerebral hemorrhage [2,7]. Due to the sudden onset of cerebral hemorrhage and poor prognosis, it is very important for the neurologist and the patient's family to accurately evaluate the prognosis of the patient, especially their ability to live independently. There are several clinical prediction models [8], and the most commonly used model is Hemphill's ICH (intracranial hemorrhage) score [9]. However, these scores are not very conveniently or widely used. Nomograms are visual displays of regression equations, which has gained widespread attention in recent years [10,11]. Here, we used several common indicators to create a nomogram clinical prediction model to assist clinicians in assessing the prognosis of intracranial hemorrhage.

2. Materials and Methods

This retrospective study was approved by the Ethics Committee of Tongji Hospital of the Huazhong University of Science and Technology (TJ-IRB20220118). Informed consents were obtained from patients.

2.1 Participants

We continuously enrolled all spontaneous intracranial hemorrhage patients (confirmed by non-contrast brain computerized tomography (CT), including supratentorial and infratentorial hemorrhage) who presented to our hospital in the period from 2015–2021. A total of 789 patients who came from the Tongji Hospital affiliated to Tongji Medical College of Huazhong University of Science & Technology were included in the training cohort, and 378 patients who came from Optics Valley Hospital of HUST Tongji Hospital and Sino-French New City Campus (two branch of Tongji Hospital) were included in the validation cohort.

The inclusion criteria were as follows: (1) patients aged $\geq$18 years; (2) patients with parenchymal hemorrhage

Table 1. Indicators of patients in the training and validation cohorts.

Indicators		Training	Validation	Test value	*p*
Age		56.31 ± 11.74	58.74 ± 11.74	3.313	0.74
Sex	Male	553	250	1.859	0.173
	Female	236	128		
Hypertension		563	258	1.179	0.278
Diabetes		84	35	0.537	0.464
Ischemic		74	24	3.05	0.081
Intracranial hemorrhage		57	23	0.52	0.471
Smoke		265	123	0.126	0.722
Alcohol		250	92	6.659	0.01
Antihypertensive drugs		310	146	0.048	0.827
Glucose-lowering drugs		66	22	2.374	0.123
Antiplatelet agents		57	21	1.141	0.285
SBP		155.26 ± 22.73	155.52 ± 23.02	0.183	0.569
DBP		91.52 ± 14.62	93.08 ± 13.9	1.735	0.309
Hematoma volume		11.16	8.2	–5.005	0.000
GCS score		11.94 ± 4.33	13.72 ± 2.66	7.351	0.000
ICH score		1	0	–7.484	0.000
Hemorrhage	1	644	325	3.443	0.064
Location	2	145	53		
Irregular shape		216	173	38.896	0.000
Uneven density		171	108	6.685	0.01
IVH		258	82	14.995	0.000
APTT		36.6 ± 4.3	36.8 ± 3.9	0.828	0.408
PT		13.54 ± 1.43	13.62 ± 0.78	1.022	0.307
INR		1.09 ± 0.33	1.07 ± 0.52	0.375	0.708
Fibrinogen		3.8 ± 1.22	3.34 ± 1.03	6.292	0.000
D-dimer		0.62	0.7	2.431	0.015
LDL		2.8 ± 0.81	2.76 ± 0.77	0.783	0.434
Triglycerides		1.5 ± 1.18	1.44 ± 0.96	0.887	0.375
HDL		1.19 ± 0.33	1.13 ± 0.34	2.842	0.005
Total cholesterol		4.38 ± 0.95	4.32 ± 0.95	1.059	0.29
Creatinine		73	71.5	2.204	0.028
AST		17	18	2.34	0.019
Total protein		72.31 ± 6.66	69.71 ± 7.13	6.092	0.000
Calcium		2.28 ± 0.12	2.18 ± 0.03	4.923	0.000
HB		138.94 ± 19.2	137.79 ± 19.08	0.956	0.339
WBC		9.80 ± 3.73	8.42 ± 5.14	5.183	0.000
NBC		7.82 ± 3.65	6.10 ± 2.69	8.13	0.000
LBC		1.24 ± 0.5	1.49 ± 1.29	4.648	0.000
NLR		6.1	3.8	8.363	0.000
RDW		43.22 ± 3.84	41.71 ± 4.16	6.135	0.000
PDW		13.75 ± 2.75	13.75 ± 5.71	0.004	0.997
PLT		216.24 ± 72.6	210.71 ± 67.5	1.245	0.213
Surgery		148	23	16.791	0.000
DVT or PE		85	31	1.889	0.169
Hospital day		17.43 ± 12.5	15.77 ± 7.9	2.35	0.019

SBP, systolic blood pressure; DBP, diastolic blood pressure; GCS, Glasgow Coma Scale; ICH, intracranial hemorrhage; IVH, intraventricular hemorrhage; APTT, activated partial thromboplastin time; PT, prothrombin time; INR, international normalized ratio; LDL, low density lipoprotein; HDL, high-density lipoprotein; AST, aspartate aminotransferase; HB, hemoglobin; WBC, white blood cell; NBC, neutrophil blood cell; LBC, lymphocyte blood cell; NLR, neutrophil lymphocyte ratio; RDW, red blood cell distribution width; PDW, platelet distribution width; PLT, platelet; DVT, deep venous thrombosis; PE, pulmonary embolism.

Table 2. Results of the univariate logistic analysis affecting prognosis.

Indicators	B	Error	Wald	*p*	OR	Lower	Upper
Hypertension	0.452	0.161	7.924	0.005	1.572	1.147	2.154
Hematoma volume	–0.069	0.007	91.881	0	0.933	0.92	0.946
GCS score	0.405	0.039	106.24	0	1.499	1.388	1.619
ICH score	–0.888	0.087	104.731	0	0.411	0.347	0.488
Irregular shape	1.733	0.204	72.264	0	5.658	3.794	8.437
Uneven density	1.233	0.206	35.912	0	3.433	2.293	5.139
IVH	0.817	0.163	25.226	0	2.263	1.646	3.113
Fibrinogen	–0.191	0.064	9.049	0.003	0.826	0.729	0.935
D-dimer	–0.066	0.026	6.472	0.011	0.936	0.89	0.985
LDL	0.186	0.09	4.268	0.039	1.204	1.01	1.436
HDL	–0.842	0.23	13.356	0	0.431	0.274	0.677
Creatinine	–0.002	0.001	8.909	0.003	0.998	0.996	0.999
Total protein	–0.028	0.011	6.086	0.014	0.973	0.951	0.994
HB	0.009	0.004	5.639	0.018	1.009	1.002	1.017
WBC	–0.193	0.025	61.298	0	0.825	0.786	0.865
NBC	–0.235	0.026	79.612	0	0.79	0.751	0.832
LBC	1.25	0.162	59.866	0	3.49	2.543	4.791
NLR	–0.207	0.021	93.213	0	0.813	0.78	0.848
Surgery	2.358	0.292	65.182	0	0.095	0.053	0.168
DVT or PE	1.051	0.267	15.497	0	2.859	1.695	4.824
Hospital day	–0.031	0.007	19.659	0	0.969	0.956	0.983
Hypertension control	1.312	0.192	46.709	0	0.269	0.185	0.392

OR, odds ratio; GCS, Glasgow Coma Scale; ICH, intracranial hemorrhage; IVH, intraventricular hemorrhage; LDL, low-density lipoprotein; HDL, high-density lipoprotein; HB, hemoglobin; WBC, white blood cell; NBC, neutrophil blood cell; LBC, lymphocyte blood cell; NLR, neutrophil lymphocyte ratio; DVT, deep venous thrombosis; PE, pulmonary embolism.

confirmed by a brain CT scan; (3) patients with complete medical records; and (4) patients with follow-up periods of more than six months.

The exclusion criteria were as follows: (1) patients with primary IVH (intraventricular hemorrhage) or subarachnoid hemorrhage (SAH); (2) patients with secondary intracranial hemorrhage (arteriovenous malformation (AVM), moyamoya disease, aneurysm, coagulopathy, brain tumor and amyloid angiopathy); (3) patients with incomplete medical records.; and (4) patients with a lack of follow-up data.

2.2 Data Collection

Baseline data was collected for the following: sex, age, medical history (hypertension, diabetes, ischemic stroke, intracranial hemorrhage), personal history (smoking, drinking), drug use history (antihypertension drugs, hypoglycemic agents, antiplatelet drugs), systolic blood pressure, diastolic blood pressure, hematoma volume, Glasgow Coma Scale (GCS) score, hemorrhage location, irregular shape [12], uneven density [13], IVH relation, blood test indicators (activated partial thromboplastin time (APTT), prothrombin time (PT), the international normalized ratio (INR), fibrinogen, D-dimer, low density lipoprotein (LDL), triglyceride, high-density lipoprotein (HDL), total cholesterol, creatinine, aspartate aminotransferase (AST), total protein, calcium, hemoglobin (HB), white blood cell (WBC), neutrophil blood cell (NBC), lymphocyte blood cell (LBC), the neutrophil lymphocyte ratio (NLR), red blood cell distribution width (RDW), platelet distribution width (PDW), platelet (PLT)), surgery, deep venous thrombosis (DVT) or pulmonary embolism (PE) rate, hospital day, hypertension control, and follow-up data (modified Rankin Scale (mRS) score at six months follow-up).

2.3 Statistical Methods

The categorical data is expressed as percentages. If the continuous data satisfied the normal distribution and equal variances, the mean $\pm$ standard deviation was used to express; otherwise, the median were used. The two-cohort single factor comparative analysis was performed using the *t*-test or Mann–Whitney U test and the chi-square test. Logistic regression analysis was used to screen the risk factors that may have affected the mRS score at six months follow-up, and then a p value < 0.05 was included in the binary logistic regression analysis. The important variables (p value < 0.05) obtained by multivariate regression analysis were incorporated into the nomogram model to create a clinical prediction model. Finally, the C statistics and the verification curve were calculated. All test results adopted

Table 3. Results of the binary logistic analysis affecting prognosis.

Indicators	B	Error	Wald	*p*	OR	Lower	Upper
ICH score	0.386	0.184	4.416	0.036	1.472	1.026	2.11
GCS score	0.407	0.054	56.702	0.000	1.503	1.352	1.671
Irregular shape	0.975	0.242	16.227	0.000	2.652	1.65	4.262
Uneven density	0.775	0.252	9.497	0.002	2.171	1.326	3.554
IVH	0.658	0.268	6.039	0.014	1.93	1.142	3.262
Surgery	1.362	0.331	16.884	0.000	3.903	2.039	7.474

ICH, intracranial hemorrhage; GCS, Glasgow Coma Scale; IVH, intraventricular hemorrhage.

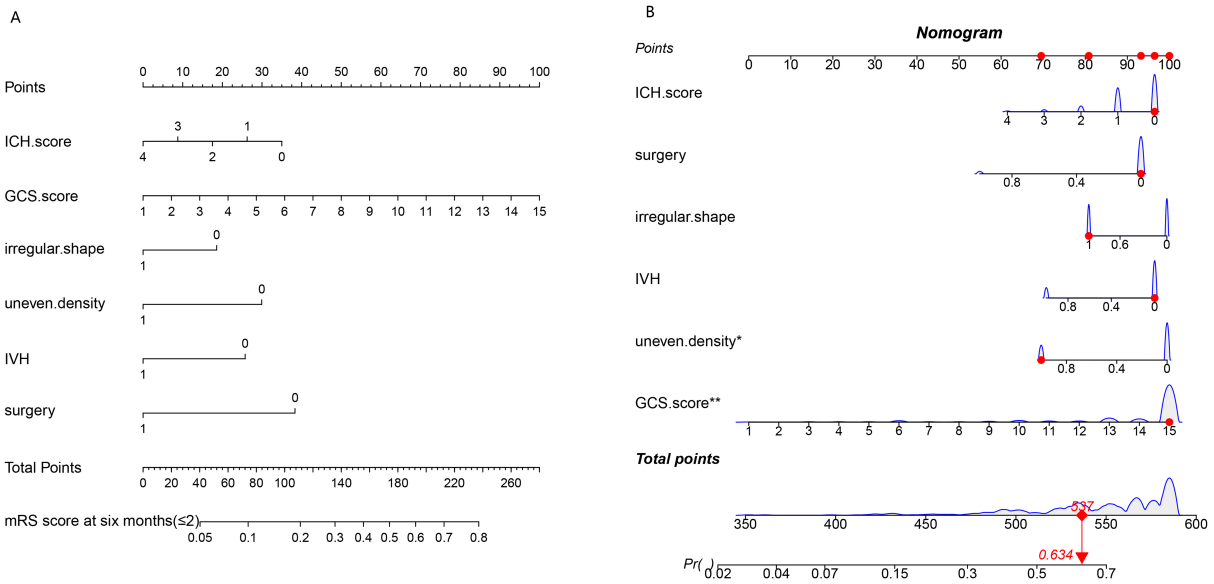

Fig. 1. Nomogram plot. (A) Conventional nomogram plot. (B) Pattern nomogram plot. Total points indicate the total points and are the sum of the four indicators (hemorrhage location, IVH, D-dimer, hypertension control rate). Pr is the probability of obtaining a good prognosis from the total points.

a two-tailed test, and $p < 0.05$ was considered statistically significant. All operations were performed using SPSS 24 (IBM Corp, Armonk, NY, USA) and R4.0.5 (R Development Core Team, Auckland, New Zealand).

3. Results

In the period from 2015–2021, 2114 ICH patients presented to our hospital. 947 patients were excluded as follows: 39 patients had primary IVH; 120 had primary SAH; 427 had incomplete records; 98 had secondary ICH; 12 had drug-induced ICH; 24 had amyloid angiopathy; 9 had intracranial venous sinus thrombosis; 196 had cerebral infarction hemorrhage transformation; and 22 had neoplastic bleeding. A total of 1167 patients were ultimately enrolled and divided into a training cohort and a validation cohort according to the visiting branch.

3.1 Baseline Characteristics

The baseline characteristics between the training cohort and validation cohort were compared (Table 1). The mean ages were 56.31 years old and 58.74 years old. The sex ratio was approximately 2:1. The alcohol, hematoma volume, ICH score, IVH relation, fibrinogen, HDL, creatinine, total protein, calcium, WBC, NBC, NLR, RDW, surgery, hospital day were higher in the training cohort than in the validation cohort ($p = 0.01$, $p = 0.000$, $p = 0.000$, $p = 0.000$, $p = 0.000$, $p = 0.005$, $p = 0.028$, $p = 0.000$, $p = 0.000$, $p = 0.000$, $p = 0.000$, $p = 0.000$, $p = 0.000$, $p = 0.000$, $p = 0.019$ respectively), and the GCS score, irregular shape, uneven density, D-dimer, AST, LBC was lower in the training cohort than in the validation cohort ($p = 0.000$, $p = 0.000$, $p = 0.01$, $p = 0.015$, $p = 0.019$, $p = 0.000$ respectively). The remaining indicators were not significantly different.

3.2 Univariate Logistic Analysis

Then, we used univariate logistic analysis to identify possible indicators that influenced the mRS score at six months follow-up. Hypertension (p = 0.005), hematoma volume (p = 0.000), GCS score (p = 0.000), ICH score (p = 0.000), irregular shape (p = 0.000), uneven density (p = 0.000), IVH relation (p = 0.000), fibrinogen (p = 0.003), D-dimer (p = 0.011), LDL (p = 0.039), HDL (p = 0.000), creatinine (p = 0.003), total protein (p = 0.014), HB (p = 0.018), WBC (p = 0.000), NBC (p = 0.000), LBC (p = 0.000), NLR (p = 0.000), surgery (p = 0.000), DVT or PE rate (p = 0.004), hospital day (p = 0.011), and hypertension control (p = 0.000) were significantly different between patients with a good prognosis (mRS score at six months follow-up $\leq$2) and those with a poor prognosis (mRS score at six months follow-up $>$2) in the training cohort (Table 2). Next, all of the above indicators were adopted in binary logistic regression.

3.3 Multivariate Logistic Analysis

ICH score (p = 0.036, Odds Ratio (OR) = 1.472, 95% confidence interval (CI) 1.026–2.11), GCS score (p = 0.000, OR = 1.503, 95% CI 1.352–1.671), irregular shape (p = 0.000, OR = 2.652, 95% CI 1.65–4.262), uneven density (p = 0.002, OR = 2.171, 95% CI 1.326–3.554), IVH relation (p = 0.014, OR = 1.93, 95% CI 1.142–3.262), surgery (p = 0.000, OR = 3.903, 95% CI 2.039–7.474) were independent risk factors for the mRS score ($\leq$2) at six months follow-up (Table 3).

3.4 Nomogram Prediction Model

A nomogram to predict good prognosis (mRS score at six months follow-up $\leq$2), ICH score, GCS score, irregular shape rate, uneven density, IVH relation and surgery were used to construct the nomogram clinical prediction model (Fig. 1).

3.5 Calibration Curve

The calibration curve shows the consistency between the probability of a good prognosis for the patient predicted by the model and the actual result. The calibration curve showed good calibration (Fig. 2A,B).

3.6 DCA Curve

The DCA (decision curve analysis) curve of this model is shown in Fig. 3. The threshold probability was $\geq$7%, and the use of this model to identify patients with intracranial hemorrhage who would achieve good prognosis was better than the 'treat-all-patients' or 'treat-none' schemes (Fig. 3).

4. Discussion

Despite the development of many advanced surgical approaches and standard medical treatments, it has been reported that only 12–39% of hemorrhage patients acquire the ability to live independently [14]. It is critical to accurately assess the prognosis of hemorrhage patients to assist clinicians in formulating the best poststroke care program. Here, we used several indicators to construct a convenient clinical prevention model. Our results showed that the ICH score, GCS score, irregular shape, uneven density, IVH relation and surgery were related to the outcomes of intracranial hemorrhage patients. Some scholars have reported that intracranial hemorrhage patient prognosis is related to age, GCS score, blood pressure, hematoma location and volume [15,16], intraventricular hemorrhage, use of anticoagulation drugs, hematoma expansion [17] and some inflammatory factors [18], which is consistent with our results.

Hemphill's ICH score is a widely used scoring system that incorporates admission GCS score, age, hematoma volume, IVH relation, and infratentorial/supratentorial location [19,20]. A meta-analysis conducted by Mattishent *et al*. [19] showed that the Hemphill-ICH score had the most validation queues (9 studies involving 3819 patients), and the area under the curve (AUC) was 0.80. The GCS score assesses the consciousness of patients by eye-opening response, verbal response, and motor response. Shah's results showed that the GCS score was independently associated with functional outcomes at three months after traumatic intracranial hemorrhage [16]. Wang's [21] results showed that both the GCS score and ICH score independently predicted 30-day mortality in ICH patients. Similarly, our results showed that the ICH score and GCS score at admission were independent predictors of 6-month prognosis in patients with spontaneous ICH. The ICH score and GCS score objectively reflect the state of ICH patients, which is potentially related to hematoma volume and other indicators and is likely to predict prognosis.

The irregular shape of the intracranial hemorrhage indicates multiple sites of hemorrhage, while the uneven density indicates active hemorrhage [22]. Therefore, some scholars speculate that these two imaging features can predict the prognosis of ICH patients [23]. Barras' results showed that ICH patients with irregular shapes had larger bleeding volumes and were more likely to experience hematoma enlargement than patients with regular shapes, and uneven density was an independent predictor of hematoma enlargement [22]. Delcourt's results showed that irregular shape was an independent predictor of death and severe disability in ICH patients, but uneven density was not a significant predictor of prognosis [24]. Masotti's results showed that ICH patients with irregularly shaped hematomas were more likely to require observation in the intensive care unit (ICU) ward [25]. Wang's results showed that irregular shape was independently associated with 30-day mortality in ICH patients [21]. Combined with our study, irregular shape and uneven density are important indicators for predicting the prognosis of ICH patients. More attention should be given to ICH patients with the above-mentioned imaging characteristics to obtain a good prognosis.

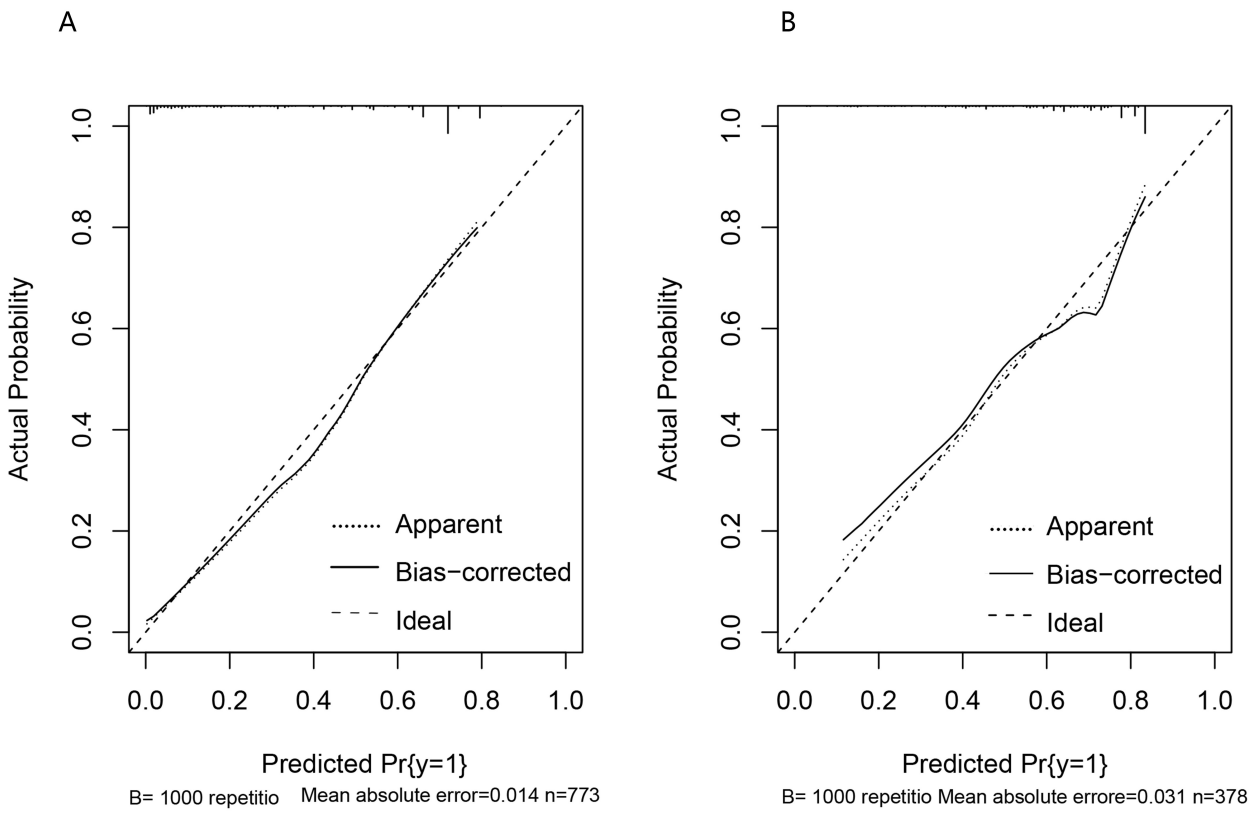

Fig. 2. Calibration curve. (A) The calibration curve for the training curve. (B) The calibration curve for the verification curve.

According to previous reports, intracranial hemorrhage rupture into the ventricle is a predictor of poor prognosis [26]. Our univariate analysis and multivariate analysis showed that the IVH relationship was an independent predictor of prognosis. A retrospective study by Nishikawa *et al*. [27] showed that older age, IVH volume, acute hydrocephalus, and poor initial level of consciousness were independent predictors of poor prognosis of spontaneous intracranial hemorrhage. Some scholars found that enlarged ventricle hemorrhage in patients with spontaneous intracranial hemorrhage was also associated with poor prognosis [28–30]. Li *et al*. [30] found that increased ventricular hemorrhage (newly bleeding ventricular hemorrhage or an increase >1 mL) was an independent risk factor for poor outcomes at the 90-day follow-up (mRS score 3–6).

In some emergency situations, surgical treatment is an emergency measure to save the lives of ICH patients. The surgical methods include craniotomy, minimally invasive surgery and decompression surgery. Whether surgery improves the outcome of ICH patients compared with conservative treatment has not been determined. The Surgical Trial in Intracerebral Haemorrhage (STICH) study found that early craniotomy hematoma removal did not improve the prognosis of ICH patients and may be beneficial for patients with hematoma locations ≤ 1 cm from the brain surface [31]. STICH II found that early surgical clearance of lob hemorrhage did not lead to better clinical outcome and only a slight survival advantage compared with medical conservative treatment alone [32]. For cerebellar hemorrhage, patients with ventricular hemorrhage or brain stem compression have better surgical treatment results [33]. The minimally invasive surgery with thrombolysis in intracerebral haemorrhage evacuation (MISTIE) III demonstrated that minimally invasive hematoma removal reduced 365-day mortality but did not significantly improve neurological function. The degree of hematoma clearance was associated with a good prognosis (mRS score 0–3) [34]. A total of 171 patients underwent minimally invasive hematoma removal in this study (148 in the training cohort and 23 in the validation cohort), and the average hematoma volume in these patients was significantly higher than the average (35 mL in the training cohort and 24 mL in the validation cohort). Our results show that surgical treatment improved neurological function at 6 months in patients with intracerebral hemorrhage. This may be because the operation reduces the time for the complete removal of the hematoma and alleviates the direct injury by the hematoma and secondary injury caused, such as inflammation. Additionally, all the ICH patients treated surgically in the study center were carefully managed in the ICU. Close care may also be a factor in the good prognosis.

A predictive model of patients with hypertensive intracranial hemorrhage established by Ding *et al*. [35] found that a GCS score ≤ 12 points and a hematoma volume ≥ 25

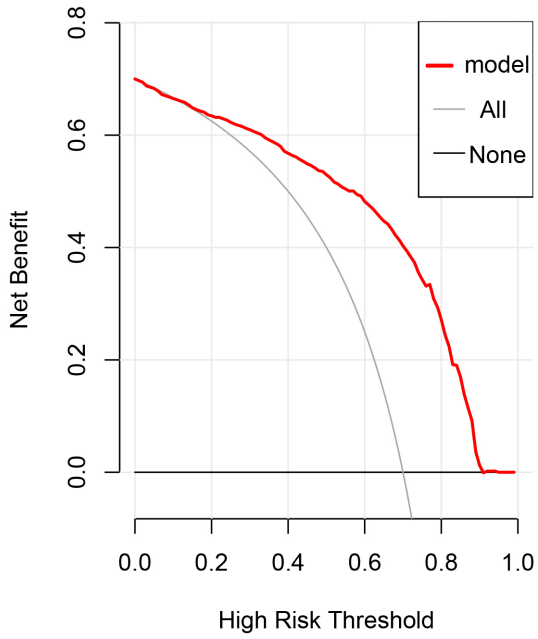

Fig. 3. Decision curve analysis of the prediction model in the validation cohort. The dashed line represents the model, the thick solid line represents the assumption that all subjects are actively treated, and the thin solid line indicates that all patients are not treated. Decision curve analysis (DCA) shows that when the threshold probability >7%, using this model to identify patients with intracranial hemorrhage who may return to an mRS score ≤2 will be better than using the treat-all-patients and treat-none schemes.

mL were independent risk factors affecting prognosis. The average volume of hematomas in the patient population of this study was approximately 10 mL (training cohort, 11.16 mL and validation cohort, 8.2 mL). A small hematoma volume may not be able to achieve the corresponding statistical power, so similar conclusions cannot be drawn. Many reports have confirmed that hematoma enlargement (absolute hematoma volume increase ≥12.5 mL or a proportional increase ≥33% compared to the baseline CT scan) affects the prognosis of patients with intracranial hemorrhage [36,37]. As this study was a retrospective study, complete hematoma enlargement data could not be obtained, so whether hematoma enlargement could be used as an important factor in this clinical prediction model could not be verified. Hemorrhage location is a potent indicator to predict intracranial hemorrhage patient prognosis. Hu *et al.* [9] conducted a retrospective study to confirm that D-dimer influences hemorrhage patient outcomes and reported that infratentorial hemorrhage induced poor outcomes at the three-month follow-up (p = 0.023, OR = 28.937, 95% CI 1.602–522.77). According to the literature, diabetes mellitus [38], NLR [39], coagulation factors [40], inflammation factors [41], anticoagulant use [42,43] and electrolyte levels [44] are also important factors affecting the prognosis of intracranial hemorrhage, but these factors were not included in our clinical prediction model. We speculated that the predictive value of some factors could not be accurately identified due to the strong collinearity of the overabundance of basic variables.

There are several nomogram models for predicting the prognosis of patients with intracranial hemorrhage. Han *et al.* [1] established a nomogram model to predict 30-day mortality in patients with spontaneous intracranial hemorrhage, incorporating the GCS score, hematoma location, hematoma volume, white blood cell count, and D-dimer indicators. Similarly, the GCS score, hematoma location, hematoma volume, and primary intraventricular hemorrhage were included to construct a nomogram for predicting death within 2 days in intracranial hemorrhage patients [45]. In this nomogram model established by Song *et al.* [46] to predict the functional status (good: mRS score 0–3, poor: mRS score 4–6) of spontaneous ICH patients at the 3-month follow-up, midline shift, noncontrast computed tomography (NCCT) time from sICH onset, GCS score, serum glucose levels, uric acid levels, and Radiomics Score (Rad-score) were included. Comparing these results with the results of the current study, the short-term prognosis (2-day mortality) of patients with intracranial hemorrhage was mainly related to the characteristics of intracranial hemorrhage (GCS score, hematoma location, hematoma volume and IVH). After gradual stabilization (30-day mortality, mRS score at 3 months, mRS score at 6 months), prognosis may be related to other factors (D-dimer level, serum glucose level, uric acid level, white blood cell count and long-term blood pressure control).

As mentioned earlier, we used the ICH score, GCS score, irregular shape, uneven density, IVH relation and surgery to construct this clinical predictive model. According to the C statistic (0.840), this prediction model has good discriminability. The calibration curve shows that the model has good calibration in the training cohort and similar results in the validation cohort. In future clinical work, the use of the abovementioned convenient and simple indicators can accurately assess the possibility of intracranial hemorrhage patients living independently six months later and provide important information for the formulation of rehabilitation programs.

There are several limitations in our study. First, this is a single-center study, and the problem of selection bias cannot be completely avoided. Second, this was a retrospective study, and errors were inevitable in data collection. Third, the sample size of our data was small, so it was difficult to avoid statistical errors in the process of data analysis. Therefore, in some cases, the application of the prediction model should be combined with clinical findings. In the future, the results of prospective studies with large samples may increase the reliability and generalization of the prediction model.

5. Conclusions

We established a nomogram model to predict the prognosis of patients with intracranial hemorrhage that included the indicators of ICH score, GCS score, irregular shape rate, uneven density, IVH relation and surgery. The model needs to be confirmed in more large clinical trials.

Abbreviations

GCS, Glasgow Coma Scale; ICH, intracranial hemorrhage; IVH, intraventricular hemorrhage; LDL, low density lipoprotein; HDL, high-density lipoprotein; HB, hemoglobin; WBC, white blood cell; NBC, neutrophil blood cell; LBC, lymphocyte blood cell; NLR, neutrophil lymphocyte ratio; DVT, deep venous thrombosis; PE, pulmonary embolism; CT, computerized tomography; SAH, subarachnoid hemorrhage; AVM, arteriovenous malformation; APTT, activated partial thromboplastin time; PT, prothrombin time; INR, international normalized ratio; AST, aspartate aminotransferase; RDW, red blood cell distribution width; PDW, platelet distribution width; PLT, platelet; mRS, modified Rankin Scale; OR, odds ratio; AUC, area under the curve; ICU, intensive care unit; NCCT, noncontrast computed tomography.

Author Contributions

Research program formulation and data collection—YL, XL, JW CP; paper writing—YL; language polishing, paper review and editing—CP, ZT.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of Tongji Hospital of the Huazhong University of Science and Technology (TJ-IRB20220118). Informed consents were obtained from patients.

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Conflict of Interest

The authors declare no conflict of interest.

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