

A scoring model to predict the prognosis of patients with poor-grade aneurysmal subarachnoid hemorrhage

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Abstract

Background

Patients with poor-grade aneurysmal subarachnoid hemorrhage (aSAH), defined as World Federation of Neurosurgical Societies (WFNS) grade IV-V has high rates of disability and mortality. The objective of this research is to prognosticate outcomes of poor-grade aSAH accurately.

Methods

A total of 147 poor-grade aSAH patients in our center were enrolled. Risk variables identified by multivariate logistic regression were used to devise the scoring model (total score of 0–9 points). The score values were estimated according to β coefficients. A cohort of 68 patients from another institute was used to validate the model.

Results

Multivariate analysis revealed that modified Fisher grade above II (odds ratio [OR], 2.972; $p = 0.034$), age ≥ 65 years (OR, 3.534; $p = 0.006$), conservative treatment (OR, 5.078; $p = 0.019$), WFNS Grade V (OR, 2.638; $p = 0.029$), delayed cerebral ischemia (OR, 3.170; $p = 0.016$), shunt-dependent hydrocephalus (OR, 3.202; $p = 0.032$) and cerebral herniation (OR, 7.337; $p < 0.001$) were significant predictors of poor prognosis (modified Rankin Scale [mRS] ≥ 3). By integration of above factors, a scoring system was constructed and divided poor-grade aSAH patients into three categories: low risk (0–1 point), intermediate risk (2–3 points) and high risk (4–9 points), with risk of poor prognosis being 11%, 52% and 87% respectively ($P < 0.001$). The area under the curve in derivation cohort was 0.844 ($p < 0.001$; 95% CI, 0.778–0.909). AUC in validation cohort was 0.831 ($p < 0.001$; 95% CI, 0.732–0.929).

Conclusions

The new scoring model could improve prognostication of prognosis and help decision-making for subsequent complement treatment.

Background

Intracranial aneurysms are abnormal protrusion of the intracranial arterial wall caused by various reasons[1, 2]. The prevalence rate of intracranial aneurysms in global population (average 50 years old) can reach 3.2% [3]. And literatures reported about 1 to 2% of aneurysms would ruptured[4]. According to statistics, the global incidence of aneurysmal subarachnoid hemorrhage (aSAH) is 9–11 per 100000 person years worldwide. And poor-grade aSAH (World Federation of Neurological Surgeons Grades IV and V) comprises 18–30% among all aSAH patients[5, 6]. Patients with poor-grade aSAH are more critically ill,

with moderate to severe hemiplegia, loss of consciousness, even deep coma, and with higher risk for developing intracranial hematoma, diffuse cerebral edema and cerebral vasospasm. The meta-analysis published by Han et al. reported a 26% mortality rate of poor-grade aSAH[7]. Existing literature also indicates that the disability rate of poor-grade aSAH exceeds 60%[8].

For poor-grade aSAH patients, a comprehensive prediction for prognosis is essential. The earlier International Subarachnoid Aneurysm Trial (ISAT) could achieve an accurate prediction of 60 days case-fatality after aneurysmal subarachnoid hemorrhage[9]. And the Subarachnoid Hemorrhage International Trialists (SAHIT) model was highly predictive of outcome and used to counsel all patients with aSAH and their family members[10]. The external validation of SAHIT Predictive Model using Barrow Ruptured Aneurysm Trial (BRAT) Cohort and final result showed its AUC of unfavorable outcome was 0.734[11]. However, these studies included patients exposed to different subgroups of various treatment procedures, while most of them were good-grade aSAH patients who were eligible for surgical treatment. Good-grade aSAH and poor-grade aSAH differ in disease progression and survival prognosis[5, 12]. Previous studies usually combine these two groups for analysis without detailed stratifying[9–11]. Therefore, these predictive models have some limitations in accurately predicting the outcomes of poor-grade aSAH patients. The objective of our research was to devise a new scoring system to evaluate the prognosis of patients with poor-grade aSAH intuitively.

Methods

Study Design

The derivation cohort included poor-grade aSAH patients diagnosed and treated at the department of neurosurgery of our center from January 2013 to January 2019. Validation cohort was collected at the department of neurosurgery of another institute from January 2016 to January 2019. The inclusion criteria were as follows: (1) aSAH was diagnosed by computed tomography (CT) or lumbar puncture in medical center; (2) aneurysms were confirmed as the cause of SAH on digital subtraction angiography (DSA), three-dimensional CT angiography or magnetic resonance angiography (MRA); (3) WFNS grade of level 4 or level 5; (4) family members of patients signed informed consent to cooperate with clinical treatment procedures; (5) patients without surgical treatment in referral centers. The exclusion criteria were: (1) traumatic, mycotic, or arteriovenous malformation-related aneurysms or SAH of unknown etiology; (2) WFNS grade or Hunt-Hess grade lower than level 3; (3) absence of patients' important medical information; (4) patients treated by medical instruments or drugs which were not approved. The STROBE statement guideline has been implemented in this manuscript.

Clinical Therapeutic Protocol

Patients admitted in emergency conditions all accepted early resuscitation, early CT angiography, multidisciplinary consensus consultation, conservative treatment or surgical treatment. A multidisciplinary team of neurosurgeons and anesthesiologists made therapeutic decisions by taking clinical conditions and families' consent into account. The treatment mode in our study was divided into

two categories: (1) Conservative group: patients received pure medicinal conservative treatment and could also be patients received other basic surgical methods but without treating responsible aneurysms, such as external drainage surgery, hematoma evacuation and decompressive craniectomy. (2) Clipping or Coiling group: patients undergoing primary aneurysm embolization or clipping only or combined with basic surgical operation on the basis of coiling or clipping. All patients who decided to undergo surgical treatment followed an early treatment strategy (within 72 hours). Antiplatelets were administered to prevent thrombosis after stent-assisted embolization and nimodipine were routinely used to prevent and treat cerebral vasospasm.

Clinical Data and Variables Definition

Patients' clinical variables were divided into six categories: (1) Demographic characters: gender and age. Age was divided into two subcategories by the demarcation line of 65 years old. (2) Medical history: hyperlipidemia, hypertension, diabetes mellitus, history of cerebrovascular disease, alcohol consumption and smoking. (3) Radiologic Imaging and laboratory examination: white blood cell count (WBC) $\geq 15 \times 10^9$, intracerebral hemorrhage (ICH), intraventricular hemorrhage (IVH), ventricular casting, WFNS grade and modified Fisher grade. Modified Fisher grade was divided into two subcategories by the demarcation line of grade II. (4) Aneurysm morphology: wide-necked aneurysms (aneurysms with a neck width ≥ 4 mm or a neck ratio greater than 1: 2), multiple aneurysms, aneurysm size (mm), location of Aneurysm. (5) Treatment: clipping, coiling, conservative group and continuous lumbar subarachnoid drainage. (6) Complication: acute hydrocephalus, shunt-dependent hydrocephalus, aneurysm rebleeding, epilepsy, pulmonary infection, intracranial infection, cerebral vasospasm (CVS), delayed cerebral ischemia (DCI) and cerebral herniation. CVS was defined as arterial stenosis found by CTA examination when the patient's clinical symptoms deteriorated; Or vasospasm detected during DSA[13]. DCI was defined as: 1. The occurrence of focal neurological impairment, or a decrease of at least 2 points on the Glasgow Coma Scale, and this situation cannot be attributed to other cause, such as cerebral rebleeding or encephaledema; 2. A new low-density area that had not been seen on previous CT scan and not attributable to other causes such as surgical treatment, or low-density shadow after absorption of hematoma[14].

Outcomes Measure

A dynamic follow-up evaluation was performed at 6 months after surgery by neurosurgeons according to modified Rankin score (mRS) via telephone or outpatient appointment. The assessment of patients' neurological prognosis was mainly focused on whether presented with the absence of self-care ability or not. Functional prognosis was classified as good (mRS scores 0 – 2) or poor (mRS scores 3 – 6).

Statistical Analysis

Data were analyzed with SPSS, Version 23.0 (IBM, Armonk, New York). Continuous variables were reported as a mean \pm standard deviation and compared between favorite and poor outcomes using unpaired T test. Categorical variables were reported as a proportion and percentile and were analyzed

using X^2 or Fisher exact test, as appropriate. Univariate and multivariate logistic regression analyses were performed using the poor outcomes as the outcome variable in the derivation cohort. Variables with P value ≤ 0.1 in univariate analysis were entered into multivariate logistic regression with stepwise backward selection. Risk variables independently associated with prognosis were entering into the new scoring model. The points of each factors were assigned based on the corresponding β coefficient in the multivariate analysis. The discrimination of prognostic models was assessed by area under the receiver operating characteristic curves (AUC). Hosmer-Lemeshow goodness of fit test and calibration plot were used to evaluate the calibration of prediction model.

Results

Basic Information of Patients

The detailed process of selection and exclusion of patients in modeling group and validation group was shown in Figure 1. In total, 147 patients were included in the derivation study, while 68 patients were included in the validation cohort.

In the derivation cohort, 55 (37%) patients were male and 92 (63%) were female. The age of cases ranged from 37 to 87, the mean age was 61.3 ± 11.5 years, and approximately 39% of patients were over 65 years old. The baseline characteristics of the 147 patients with poor grade aSAH are presented in Table 1. A total of 124 (84.3%) patients accepted surgical therapies including coiling (29.2%) and clipping (55.1%). The rest of 23 (15.7%) patients accepted conservative treatments. The distribution of mRS score of 147 poor-grade aSAH patients accepted different treatment was shown in Figure 2 (A). In Figure 2 (B, C, D, E), patients accepted coiling or clipping had a better prognosis than patients accepted conservation treatment, but there was no statistical significance of prognosis between patients accepted coiling and clipping. There were 114 (77.6%) poor-grade aSAH patients with modified fisher grade above 2 and 85 (57.8%) patients were recorded with WFNS grade V. And the distribution of mRS score of 147 poor-grade aSAH patients with different modified Fisher grade was shown in Figure 2 (F). Figure 2 (G, H, I, J) reflects the influence of different modified Fisher grade groups on the prognosis of patients. During the 6 months' follow-up after discharge, 85 patients (58%) had poor outcomes.

Of the 68 patients in the validation cohort, 25 (36.7%) patients were over 65 years old. A total of 44 (64.7%) poor-grade aSAH patients with a modified fisher grade above 2 and 40 (58.8%) patients presented with WFNS grade V. Forty-nine (72%) patients accepted surgical therapies. During the 6 months' follow-up after discharge, 38 patients (56%) had poor outcomes. Specific data of validation cohort is presented in Table 1.

Univariate Analysis of Poor Outcome

The association between clinical variables and poor outcomes identified by univariate analysis are shown in Table 1. The poorer prognosis is associated with elderly age (age ≥ 65) (P = 0.027), intraventricular hemorrhage (P = 0.005), WFNS grade V (P < 0.001), conservative treatment (P = 0.009),

modified fisher grade > 2 (P = 0.001), emergence of cerebral herniation (P < 0.001), aneurysm rebleeding (P = 0.004), CVS (P = 0.041) and DCI (P = 0.030). Medical history of patients and data of aneurysm were not significantly interrelated with clinical outcome (Table 1).

Multivariate Regression Analysis of Poor Outcome

Ten variables (P < 0.1 in univariate analysis) were entered into multivariate logistic regression. Table 2 showed age \geq 65 years (OR, 3.534; p = 0.006), modified Fisher grade > 2 (OR, 2.972; p = 0.034), cerebral herniation (OR, 7.337; p < 0.001), WFNS V (OR, 2.638; p = 0.029), SDH (OR, 3.202; p = 0.032), conservative treatment (OR, 5.078; p = 0.019) and DCI (OR, 3.170; p = 0.016) are independent risk factors for poor outcomes. The Hosmer-Lemeshow test reflects a satisfied degree of consistency between the predicted risk of the model and the actual risk (P = 0.589, Table 2).

Development of the Scoring System

By integration of 7 independent risk factors including modified Fisher grade above grade II, age \geq 65 years, conservative treatment, WFNS grade V, DCI, SDH, and cerebral herniation, a scoring system referred to as Poor-grade Aneurysmal Subarachnoid Hemorrhage Prognostic Scoring System (PASHPSS below) was then constructed (Table 3). Based on the β coefficient in the multivariate analysis, a score of 2 was assigned to cerebral herniation and conservative treatment respectively; a score of 1 was assigned to each other risk factors respectively; otherwise, 0 point was assigned. According to the sum of the scores (range from 0 - 9), the new model divided poor-grade aSAH patients into three prognostically different categories (Table 4): the predict risk of poor prognosis is 11% in patients with a total point of 0 - 1 (low risk category), 51% in those with a total point of 2 - 3 (intermediate risk category) and 87% in those with a total point of four or above (high risk category).

Discrimination and Calibration of the Scoring System

In modeling cohort, the AUC of PASHPSS was 0.844 (95% CI: 0.778 - 0.909; Figure 3). And the Hosmer-Lemeshow test showed a good calibration (P = 0.589).

The PASHPSS also showed good discrimination and good calibration in the validation cohort, with an AUC of 0.831 (95% CI, 0.732 - 0.929, Figure 3) and Hosmer-Lemeshow test fit well (P = 0.984). And in validation cohort (Table 3), the observed risks in the three risk groups were also closed to the predicted risks: low risk (actual observed risk of poor prognosis, 19%), intermediate risk (actual observed risk of poor prognosis, 48%) and high risk (actual observed risk of poor prognosis, 81%).

Discussion

As serious cerebrovascular disease, poor-grade aneurysmal subarachnoid hemorrhage has high rates of mortality and disability. In this study, the poor prognosis of patients in the modeling cohort and validation cohort were both more than 55%. Though active and effective treatments is provided, some aSAH patients still present neurological dysfunction and life disorders, which would bring heavy impact on

society and families[1, 4, 6, 8]. It is necessary to explore relevant risk factors and evaluate the prognosis of these patients. Several modifiable and non-modifiable risk factors for poor prognosis of poor-grade aSAH patients were known today, the most common risk factors were older age, cerebral herniation, WFNS grade V, higher modified Fisher grade[9, 10, 12, 15–19]. These risk factors were also identified in our study.

The choice of treatment methods is significantly related to the prognosis of patients with poor-grade aSAH. In a systematic review of 815 patients with aSAH, researchers reported that the good prognosis of clipping, embolization and conservative treatment were 45.3%, 36.3% and 9.0%, respectively[20]. In our study, the adverse prognosis of patients treated with clipping or coiling were significantly lower than those treated with conservative therapy and there was no statistically significant difference in prognosis between clipping and embolization. Combining our center's experience with previous literature, as far as poor-grade aSAH patients are concerned, more aggressive treatment of responsible aneurysms through surgery has better therapeutic prognosis compared to conservative treatment.

Postoperative complications also played an important role in affecting the prognosis of poor-grade aSAH patients. As a critical complication, aneurysmal rebleeding usually causes the sharp rise of intracranial pressure, damages patient's nerve function and increases the risk of death in short term[21–23]. Cerebral vasospasm is generally considered as a risk factor for poor prognosis. But immediate vasospasm is usually difficult to detect. And nimodipine has been routinely used in clinical to prevent occurrence of cerebral vasospasm, leading to a further reduction in the incidence of cerebral vasospasm[24]. More commonly observed and easier detected complication during clinical treatment is delayed cerebral ischemia caused by cerebral vasospasm, which is a strong independent risk factor of poor prognosis of patients with poor-grade aSAH[14, 25, 26]. Delayed cerebral ischemia continues to be an important cause of cognitive impairment and disability after aSAH despite accepted aggressive management[27–29]. A single center study including 888 aSAH patients found that shunt dependent hydrocephalus was a strong independent risk factor for unfavorable functional outcome[30]. Our final results also confirm the predictive role of above-mentioned factors.

There are also some other risk factors that have been raised in recent articles but have not been widely recognized. Intraventricular hemorrhage was also regarded as a risk factor for poor outcomes in many literatures[31]. It has been verified in our univariate analysis, however, eliminated in final multivariate regression analysis. The possible reason might be that intraventricular hemorrhage caused impairment of cerebrospinal fluid absorption by blocking arachnoid villi and brain capillaries, which affected the prognosis by developing into chronic hydrocephalus[32, 33]. Whether or not the location and size of the aneurysm are predictive factors for the poor prognosis of aSAH is still inconclusive[19]. These inconsistent results may be explained by the treatment selection bias in different studies. And there is no connection between the location and size of the aneurysm and long-term prognosis according to our data. In a multicenter study about poor-grade aSAH, Zhao et al. pointed out that wide necked aneurysms and postoperative pneumonia were also poor prognostic factor[16]. But these two risk factors haven't

been identified in our study. Leucocytosis ($\text{WBC} > 15 \times 10^9/\text{L}$) was regarded as a predictive factor for poor prognosis in a 9-year cohort study[17], however, it had not been reported in other articles.

The current literature about poor-grade aSAH focused on reporting risk factors of prognosis in this group of patients, however, prognostic predictive models for this group of patients are rare. A recent systematic review assessed 11 clinical prediction models for aneurysmal subarachnoid hemorrhage and pointed out that the most common factors associated with outcome were age (8 of 11 studies), admission neurologic grade on admission (10 of 11 studies), and amount of blood detected by CT scan upon admission (6 of 11 studies)[19]. Although WFNS and modified Fisher grade scales are commonly used, both scales are not absolutely reliable in patients because of the subjective nature of the parameters on which they were built[34]. For example, WFNS or Hunt-Hess scales are generally unreliable in intubated patients. In addition, in two articles that established predictive scores in poor-grade aSAH patient populations, these factors were also applied; but no additional risk factors were added to circumvent the errors caused by inter- and intrarater variability in part[17, 18]. Undeniably, more valuable risk variables added into the risk score could improve its predictivity. Treatment methods, shunt-dependent hydrocephalus and delayed cerebral ischemia are three factors that affect the long-term neurological prognosis and cognitive impairment of patients, their role in predicting the prognosis of patients is worthy of recognition[14, 30, 32, 35]. Our PASHPSS have significantly improved its discrimination comparing to other risk scores by drawing into these risk factors. For example, the AUC of SAHIT model was 0.734, while the AUC of WAP score which established on poor-grade aSAH patients was 0.74. But the AUC of PASHPSS was 0.844, which can be regarded as excellent, especially when predicting the prognosis of poor-grade aSAH.

At present, several studies have proposed the prognosis model of poor-grade aSAH, but most of them have limitations in reporting calibration, discrimination and external validation. Clinicians generally do not use existing models for predicting the prognosis of poor-grade aSAH, even the internal effectiveness of them are not inferior to PASHPSS[17–19], partly because they lack of external validity. However, PASHPSS showed good discrimination in the validation data; its area under the curve was 0.831, in other words, still performs well when it was applied to a new patient cohort different from the original cohort.

This study shows that the PASHPSS devised by the risk factors predicts the future risk of poor prognosis well. And it could help guide clinical decisions and patient consultation and also reduce the cost of treatment by ensuring effective resource allocation. Such benefits may be particularly important in the management of patients with poor-grade aneurysmal subarachnoid hemorrhage.

Limitations

Some limitations of our risk score need to be discussed. First, statistical data were retrospectively collected. Second, the results of this study only represent the subgroup of poor-grade aSAH patients. Therefore, the scoring model is applicable to the prediction of poor prognosis risk only among poor-grade aSAH patients. With regard to functional neurologic outcomes, we selected six months after discharge as the follow-up cut-off points which is the critical period of neurological recovery, however, if, data on long-

term follow-up could be acquired, the prediction of prognosis will be more accurate. Furthermore, the modeling data was acquired from a single center, these may lead to some inevitable bias of analysis and conclusions.

Conclusion

The obtained results have allowed us to draw the following conclusions. The main risk factors affecting the prognosis of patients with poor-grade aSAH are modified Fisher grade, age, therapeutic schedule, WFNS grade, delayed cerebral ischemia, shunt-dependent hydrocephalus and cerebral herniation. The PASHPSS is an efficient tool for predicting the prognosis of poor grade aneurysm, easily measured and helpful to make the decision of subsequent complement treatment and reduce the cost of treat by ensuring effective resource allocation.

Abbreviations

Aneurysmal Subarachnoid Hemorrhage (aSAH). World Federation of Neurosurgical Societies (WFNS). Odds Ratio (OR). Confidence Interval (CI). Intensive Care Unit (ICU). Delayed Cerebral Ischemia (DCI). Cerebral vasospasm (CVS). Glasgow Outcome Scale (GOS). Intraventricular Hemorrhage (IVH). Intracerebral Hemorrhage (ICH). Computed Tomography (CT). Modified Rankin score (mRS). International Subarachnoid Aneurysm Trail (ISAT). Subarachnoid Hemorrhage International Trialists (SAHIT). Barrow Ruptured Aneurysm Trial (BRAT). Continuous Lumbar Subarachnoid Drainage (CLSD). Area under the curve (AUC). White blood cell count (WBC). Shunt-dependent hydrocephalus (SDH). Poor-grade Aneurysmal Subarachnoid Hemorrhage Prognostic Scoring System (PASHPSS).

Declarations

All authors read and approved the final manuscript. This manuscript has not been published elsewhere and is not under consideration

Consent for publication

Not applicable

Ethics approval and consent to participate

Ethics approval has been obtained from the ethics committee of First Affiliated Hospital of Zhejiang University.

Availability of data and material

All data of this research is included in this published article.

Competing interests

All authors declare that they have no competing interests.

Reporting checklist

STROBE checklist

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Authors' contributions

JS and J-B Y contributed to manuscript writing, acquisition of the data, analysis and interpretation of the data.

S-C H contributed to acquisition of follow-up data and preliminary revision of manuscript content. Rajneesh Mungur as a colleague whose native language is English, contributed to correct the English–language usage in manuscripts.

K-Y H contributed to acquisition of the data, preliminary revision of manuscript content.

X-F P contributed to preliminary revision of manuscript content.

G-F Y contributed to provide the external validation data.

Z-K X, L-H Z, Z-C L and D-X C contributed to review the literature.

J-W P and R-Y Z contributed to critical revision of the manuscript for intellectual content.

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Tables

Table 1: Demographic and baseline characteristics of the study population and univariate analysis results of modeling cohorts					
Variable	Modeling cohort		P value (Modeling cohort)	Validation cohort	
	Favorite Outcome	Poor Outcome		Favorite Outcome	Poor Outcome
	% / Mean ± SD	% / Mean ± SD		% / Mean ± SD	% / Mean ± SD
No.of patients	62(42%)	85(58%)		30(44%)	38(56%)
Demographic Characters					
Age(years)			0.027		
≪65	44(71%)	45(53%)		22(73%)	21(55%)
≥65	18(29%)	40(47%)		8(27%)	17(45%)
Gender			0.147		
Male	19(31%)	36(42%)		10(33%)	16(42%)
Female	43(69%)	49(58%)		20(67%)	22(58%)
Medical History					
Hyperlipidemia	19(31%)	26(31%)	0.994	7(23%)	11(29%)
Hypertension	32(52%)	54(64%)	0.148	18(60%)	22(58%)
Diabetes mellitus	14(23%)	28(33%)	0.170	8(27%)	14(37%)
Cerebrovascular disease	8(13%)	11(13%)	0.995	5(17%)	8(21%)
Alcohol consumption	13(21%)	28(33%)	0.110	8(27%)	10(26%)
Smoking	15(24%)	21(25%)	0.943	10(33%)	9(24%)
Radiologic Imaging and laboratory examination					
WBC ≥ 15×10 ⁹	30(48%)	42(49%)	0.902	13(43%)	19(50%)
ICH	21(34%)	34(40%)	0.448	10(33%)	18(47%)
IVH	41(66%)	73(86%)	0.005	16(53%)	28(74%)
Ventricular Casting	10(16%)	21(25%)	0.195	4(13%)	8(21%)
modified Fisher Grade			0.001		

II	23(37%)	12(14%)		15(50%)	9(24%)
III	13(21%)	32(38%)		5(17%)	11(29%)
IV	26(42%)	41(48%)		10(33%)	18(47%)
WFNS			<0.001		
IV	38(61%)	24(28%)		15(50%)	13(34%)
V	24(39%)	61(72%)		15(50%)	25(66%)
Aneurysm morphology					
Wide-necked aneurysm	31(50%)	49(58%)	0.317	13(43%)	19(50%)
Multiple aneurysms	8(13%)	16(19%)	0.338	5(17%)	10(26%)
Aneurysm size (mm)	5.9 ± 3.3	6.1 ± 3.7	0.860	6.5 ± 2.5	6.7 ± 3.1
Location of Aneurysm			0.435		
ICA	13(21%)	10(12%)		6(20%)	5(13%)
AC	6(10%)	10(12%)		4(13%)	3(8%)
ACA	12(19%)	21(25%)		8(27%)	8(21%)
MCA	15(24%)	15(17%)		5(17%)	9(24%)
PCOM	11(18%)	16(19%)		5(17%)	8(21%)
PC	5(8%)	13(15%)		2(6%)	5(13%)
Treatment					
Therapeutic Strategy			0.009		
Coiling	19(31%)	24(28%)		16(53%)	11(29%)
Clipping	39(63%)	42(49%)		9(30%)	13(34%)
Conservative Treatment	4(6%)	19(23%)		5(17%)	14(37%)
CLSD	21(34%)	28(33%)	0.906	7(23%)	9(24%)
Complication					
Acute hydrocephalus	12(19%)	20(24%)	0.545	7(23%)	10(26%)
SDH	8(13%)	22(26%)	0.054	7(23%)	12(32%)

Aneurysm Rebleeding	1(2%)	13(15%)	0.004	0	8(21%)
Epilepsy	4(7%)	9(11%)	0.383	1(3.3%)	3(8%)
Pulmonary Infection	32(52%)	50(59%)	0.385	16(53%)	21(55%)
Intracranial Infection	33(53%)	40(47%)	0.460	13(43%)	16(42%)
CVS	7(11%)	21(25%)	0.041	7(23%)	16(42%)
DCI	13(21%)	32(38%)	0.030	6(20%)	11(29%)
Cerebral Herniation	6(10%)	38(45%)	<0.001	2(7%)	16(42%)
<p>ICH - Intracerebral Hemorrhage, IVH - Intraventricular Hemorrhage, WFNS - World Federation of Neurosurgical Societies, CLSD - Continuous lumbar Subarachnoid Drainage, SDH - Shunt-dependent hydrocephalus, CVS - cerebral vasospasm, DCI - delayed cerebral ischemia.</p>					

Table 2: Multivariate logistic regression model for poor prognosis risk of poor-grade aSAH				
Variable included in Model	S.E	OR	95%CI	P
modified Fisher Grade (grade III, IV)	0.515	2,972	1.083 - 8.156	0.034
Age (≥ 65)	0.457	3.534	1.442 - 8.662	0.006
Therapeutic Strategy (Conservation)	0.694	5.078	1.303 - 19.790	0.019
WFNS (Grade V)	0.444	2.638	1.104 - 6.300	0.029
DCI	0.478	3.170	1.242 - 8.090	0.016
SDH	0.542	3.202	1.107 - 9.263	0.032
Cerebral Herniation	0.565	7.337	2.426 - 22.192	< 0.001
Hosmer and Lemeshow test				
X²				6.525
Degree of freedom				8
P				0.589
<p>WFNS - World Federation of Neurosurgical Societies SDH - Shunt-dependent hydrocephalus, CVS - cerebral vasospasm, DCI - delayed cerebral ischemia</p>				

Table 3: Aneurysmal Subarachnoid Hemorrhage Prognostic Scoring System (PASHPSS) derived from the β coefficients

Variable included in Model	Categories	β coefficient	Score
modified Fisher Grade			
	below grade II	0 (reference)	0
	grade III, IV	1.09	1
Age			
	< 65	0 (reference)	0
	≥ 65	1.26	1
Therapeutic Strategy			
	Coiling or Clipping	0 (reference)	0
	Conservation	1.63	2
WFNS			
	Grade IV	0 (reference)	0
	Grade V	0.97	1
DCI			
	Non - DCI	0 (reference)	0
	DCI	1.15	1
SDH			
	Non - SDH	0 (reference)	0
	SDH	1.16	1
Cerebral Herniation			
	Non - Cerebral Herniation	0 (reference)	0
	Cerebral Herniation	1.99	2
<p>WFNS - World Federation of Neurosurgical Societies SDH - Shunt-dependent hydrocephalus, CVS - cerebral vasospasm, DCI - delayed cerebral ischemia</p>			

Table 4: Risk of poor prognosis for low, intermediate, and high-risk individuals, according to the PASHPSS risk score				
Risk stratification	Score	Observed risk (validation cohort)	Predicted risk	OR (95% CI)
Low risk stratification	0 - 1	19%	11%	1 (Reference)
Moderate risk stratification	2 - 3	48%	51%	8.6 (2.2 - 18.7)
High risk stratification	4 - 9	81%	87%	54.2 (13.2 - 221.9)

Figures

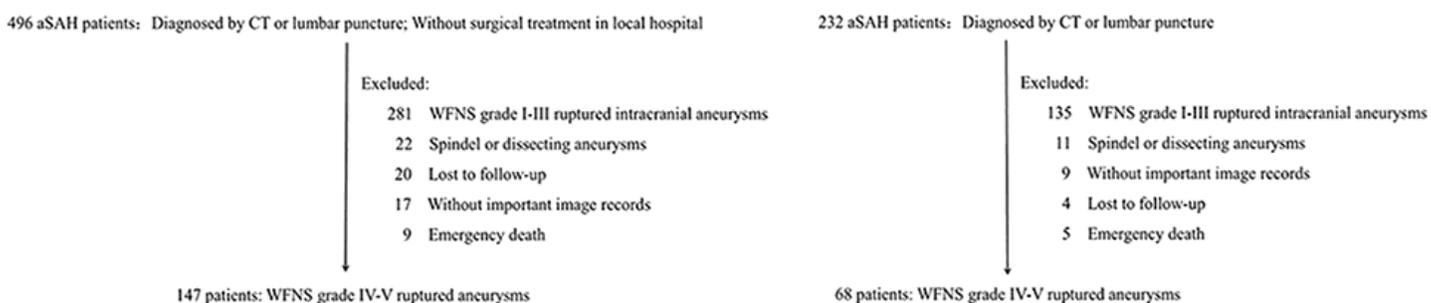


Figure 1

Study flow diagram. aSAH, aneurysmal subarachnoid hemorrhage; CT, computerized tomography; WFNS, World Federation of Neurosurgical Societies.

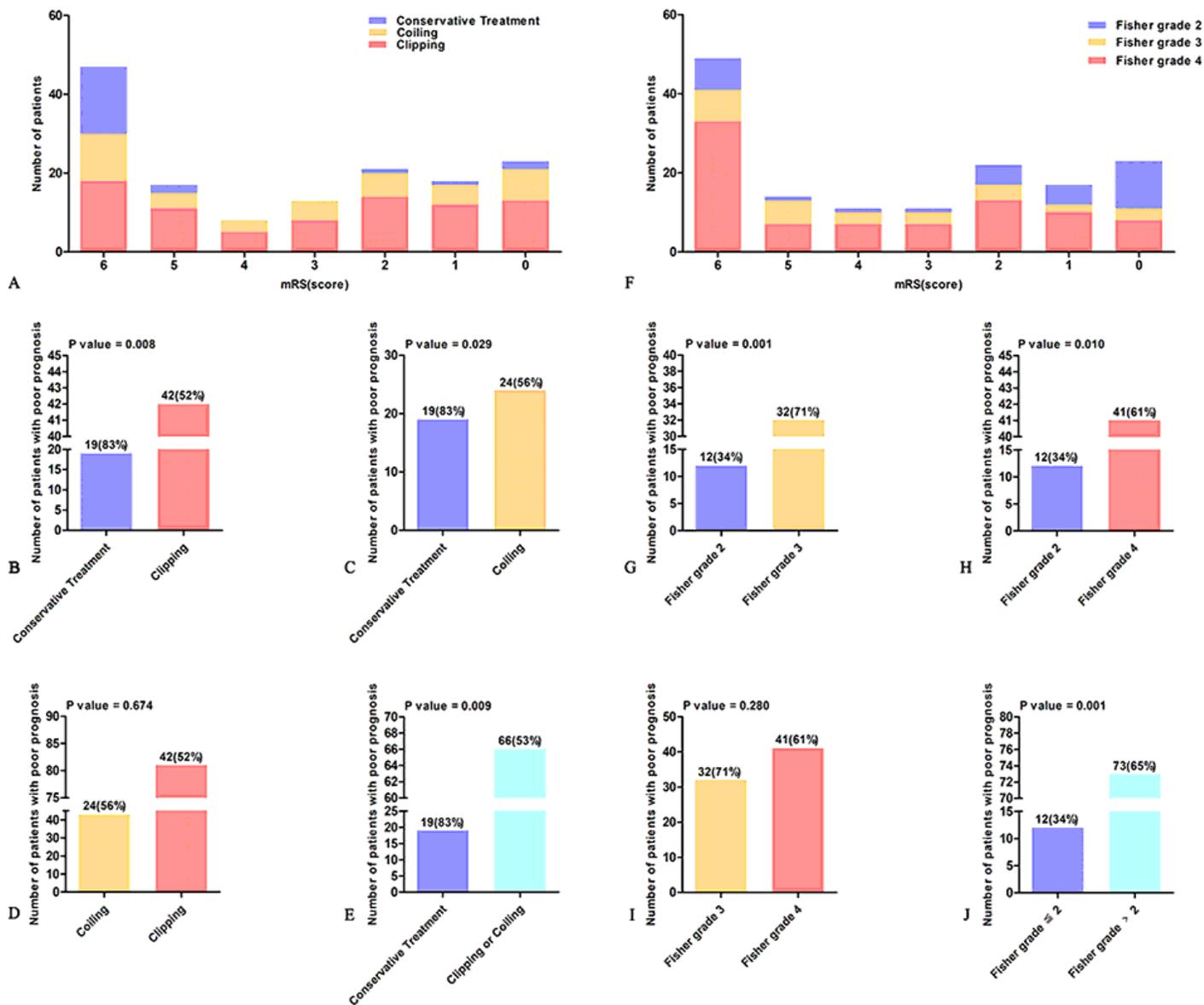


Figure 2

Figure 2 (A) shows the distribution of mRS score of 147 poor-grade aSAH patients accepted different treatment methods. The value above the histogram shows the number of patients with poor prognosis and the percentage of them, for instance, the interpretation of 19 (83%) in Figure 2 (B), 19 (83%) patients with poor outcome among 33 patients who accepted conservation treatment. In Figure 2 (B, C, D, E) reflects the influence of different treatment methods on the prognosis of patients. Figure 2 (F) shows the distribution of mRS score of 147 poor-grade aSAH patients in different Fisher grade. Figure 2 (G, H, I, J) reflects the influence of different Fisher grade groups on the prognosis of patients.

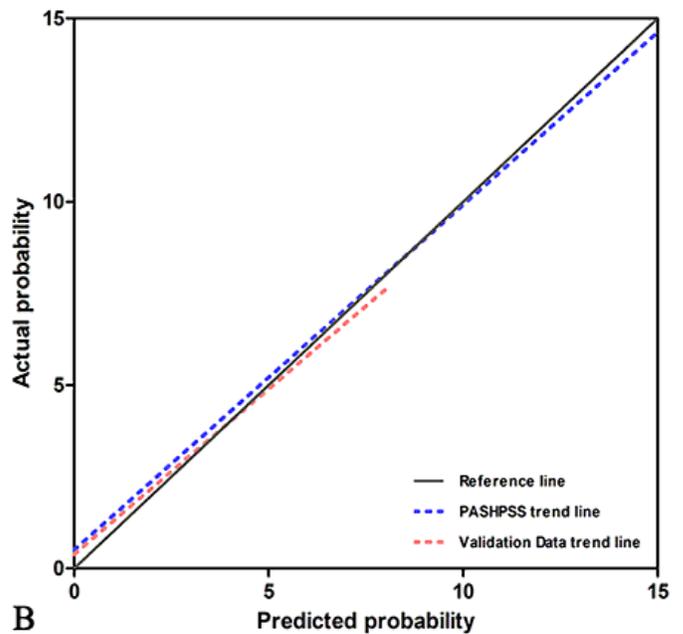
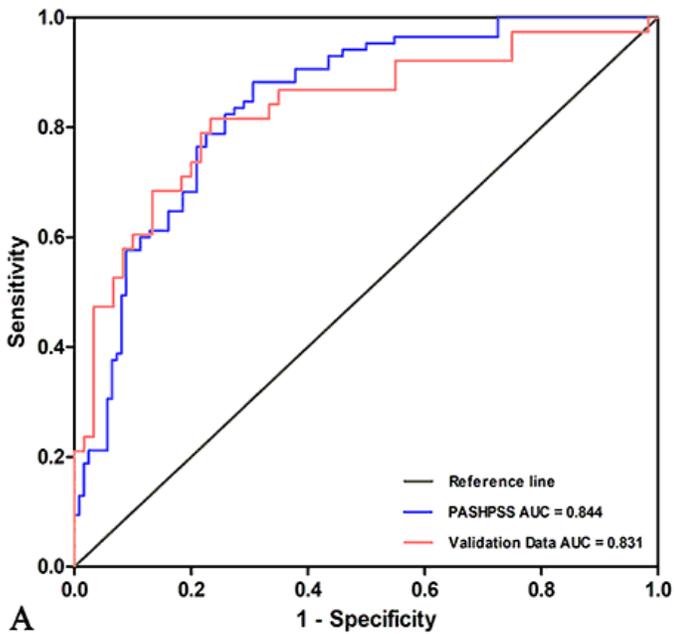


Figure 3

Figure 3 (A) The AUC of the PASHPSS is 0.844 ($p < 0.001$; 95% CI, 0.778 - 0.909) in our center's modeling data, while it is 0.831 ($p < 0.001$; 95% CI, 0.732 - 0.929) in validation data. (B) A slope of 1 (45 degrees) with an intercept of 0 represents perfect calibration, the deviation from the reference line is smaller, the calibration is better. PASHPSS has a good calibration in derivation cohort and validation cohort.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [STROBEchecklist.pdf](#)