Prognosis Predicting Score for Endovascular Treatment of Aneurysmal Subarachnoid Hemorrhage
A Risk Modeling Study for Individual Elderly Patients

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Abstract: The elderly patients with aneurysmal subarachnoid hemorrhage (aSAH) have a greater risk of poor clinical outcome after endovascular treatment (EVT) than younger patients do. Hence, it is necessary to explore which factors are associated with poor outcome and develop a predictive score specifically for elderly patients with aSAH receiving EVT.

The aim of this study was to develop and validate a predictive score for 1-year outcomes in individual elderly patients with aSAH underwent EVT.

In this 10-year prospective study, 520 consecutive aSAH elderly (age ≥ 60 years) patients underwent EVT in a single center were included. The risk factors, periprocedural, and 1-year follow-up data of all patients were entered in a specific prospective database.

The modified Rankin scale was used for evaluating clinical outcome. To optimize the model’s predictive capacity, the original matrix was randomly divided into 2 submatrices (learning and testing). The predictive score was developed using Arabic numerals for all variables based on the variable coefficients (β) of multivariable logistic regression analysis in the learning set and the predictive performance evaluation was assessed in the testing set. The risk classes were constructed using classification criteria based on sensitivity and specificity.

The poor outcome rate at 1 year was 26.15%. Six risk factors, including age, hypertension, Hunt–Hess scale, Fisher scale, aneurysm location, and periprocedural complications, were independently associated with poor outcome and assembled the Changhai score. The discriminative power analysis with the area under the characteristic curve (AUC) of the Changhai score was statistically significant (0.864, 0.824–0.904, P < 0.001). The sensitivity and specificity of the Changhai score were 82.07% and 78.06%, respectively.

Our study indicated that age, hypertension, Hunt–Hess scale, Fisher scale, aneurysm location, and periprocedural complications were independent risk factors of poor outcome for elderly aSAH patients underwent EVT. In combination with these risk factors, the Changhai score can be a useful tool in the prediction of clinical outcome but needs to be validated in various centers before it can be recommended for application.

INTRODUCTION

The incidence of aneurysmal subarachnoid hemorrhage (aSAH) increases with advancing age.1–4 Hence, the elderly account for a significant number of the patients presenting with aSAH. Moreover, the elderly patients with aSAH have a greater risk of complications and poor outcomes than younger patients do, due to worse clinical status on admission, less active management, and a higher frequency of comorbidity.5–8 Until now, the management of elderly patients with aSAH is still a clinical challenge.

With the prospect of reducing the risk of rebleeding without the need for craniotomy, thus reducing surgical trauma, endovascular treatment (EVT) was conceived as a promising alternative to neurosurgical treatment (NST), especially in elderly and poor-grade patients with aSAH. The keynotes of EVT for elderly patients with aSAH were reducing complication rate, improving safety and prognosis. However, the safety and effectiveness of EVT for elderly aSAH patients were affected by a great many factors, including patient conditions, lesion characteristics, and procedure-related factors. There were some previous studies reporting that the risk factors of outcomes and complications of aSAH patients underwent EVT.9 However, they either lacked comprehensive factors included or age stratification, which made them difficult to evaluate the risk of EVT for elderly aSAH patients comprehensively.7,10,11 Hence, it is necessary to explore which factors are associated with poor outcome and develop a risk score specifically for elderly patients with aSAH receiving EVT that can be easily used in clinical practice and facilitate clinical decision-making process.
Accordingly, our aim of the present work is to evaluate the outcome of aSAH in elderly patients underwent EVT, explore preliminarily risk factors, and then establish a mathematical predicting model for poor outcome after EVT for elderly patients with aSAH.

**MATERIALS AND METHODS**

**Patient Selection**

In this prospective study, consecutive elderly aSAH patients underwent EVT over a period of 10 years (June 2004–June 2014) in our center were included. Patients inclusion criteria were age ≥ 60 years; and with aSAH treated endovascularly. Patients with any of the following were excluded: specific types of aneurysms such as traumatic aneurysm, pseudoaneurysm, and iatrogenic aneurysm; and patients with incomplete medical records. The Ethics Committee of Changhai hospital approved the study and informed consent was obtained from all patients before any procedure. Figure 1 shows a flow diagram of the whole population of elderly patients with aSAH treated at our institute during the study period.

**Definitions of Variables and Data Collection**

The research team entered the risk factors, intraoperative and 1-year follow-up data in a specific prospective database. All the selected predictive factors of poor clinical outcome including patient-related, lesion-related, and procedure-related variables were analyzed blind to outcome events. Particularly, clinical grade including Fisher scale\(^{12}\) and Hunt–Hess scale\(^{13}\) were evaluated preprocedure by operators. Lesion-related variables were defined and calculated based on the 3-dimensional digital subtraction angiography image according to Dhar et al.'s\(^{14}\) and Bor et al.'s\(^{15}\) studies. Aneurysms located on internal carotid artery (ICA), posterior communicating artery (Pcoma), vertebral artery (VA), and basilar artery (BA) were divided into the group of located proximal the circle of Willis. Others including middle cerebral artery (MCA), anterior cerebral artery (ACA), anterior communicating artery (Acoma), posterior cerebral artery (PCA), and BA apex were divided into the group of located on and distal the circle of Willis. Wide-necked aneurysms were defined as having a large aneurysm neck (>4 mm) and/or a small dome-to-neck ratio (≤2). The aortic arch was classified according to the origin of the arch vessels.\(^{16}\) We divided the aneurysms size into 4 subgroups (<3, 3–6, 7–10, and >10 mm). EVT strategies were classified into coiling only group, double catheter-assisted group, stent-assisted group, and balloon-assisted group.

**Procedure Technique**

For aSAH patients, the treatment strategies (clipping or EVT) were jointed discussion and development by neurosurgeons and endovascular neurosurgeons. Meanwhile, if EVT was decided, the EVT strategies were decided by endovascular neurosurgeons based on the morphology of aneurysm and parent vessels. In this study, 5 well-trained and experienced endovascular neurosurgeons treated these patients. All procedures were performed under general anesthesia using a transfemoral approach and systemic heparinization aiming for elevation of the activated clotting time to a level of 2 to 3 over baseline. A loading dose of clopidogrel and aspirin (300 mg each) was administered orally or rectally before the procedure if a stent was necessary.

A 6 French guiding catheter was inserted into the distal ICA or vertebral artery as appropriate. All microcatheters, coils, and stents (if needed) were delivered through this catheter. If acute thrombosis occurred during the procedure, Tirofiban, a glycoprotein IIb/IIIa inhibitor was used. The immediate angiographic results were evaluated independently by 2 endovascular neurosurgeons using Raymond classification.\(^{17}\)

**Follow-Up Protocol and Outcome**

The main outcome measure was modified Rankin scale (mRS).\(^{18}\) The poor outcome was defined as mRS ≥ 3. The peri-procedural complications included hemorrhagic and ischemic stroke, pulmonary infection, acute heart failure, and acute renal dysfunction, hemorrhage of digestive tract which requiring blood transfusion occurred after EVT. Hemorrhagic stroke included intraprocedural rupture and rebleeding after EVT. Intraprocedural rupture was defined as the extravasation of contrast material demonstrated on concurrent angiography, regardless of the extrusion of coil, microcatheter, or microguidewire outside the lumen of an aneurysm. Rebleeding including recurrent SAH, subdural hemorrhage, and intraparenchymal hemorrhage were diagnosed according to a new clinically neurological defect and confirmed on computed tomographic (CT)/magnetic resonance (MR) imaging within 30 days after EVT. Ischemic stroke including thromboembolic events and vasospasm-related ischemic events were defined as a vessel occlusion recognized by angiography at the period of EVT, or a clinically evident ischemic stroke with evidence of infarction on diffusion-weighted imaging, which occurred within 30 days after EVT.

All patients underwent independent neurological evaluation before the procedure, discharge, 30 days, and 1 year after the procedure. All patients underwent a cerebral CT scan before procedure and immediately after procedure. Whereas additional CT/MR scan was performed in patients with suspected neurological complications.

**Statistical Analyses**

These data were expressed as mean and standard deviations (mean ± SD) or as absolute frequencies and percentages. \(P < 0.05\) (2-tailed) was considered statistically significant. All

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**FIGURE 1.** Procedure flow diagram of elderly patients with aSAH underwent EVT procedure at our institute. aSAH = aneurysmal subarachnoid hemorrhage, EVT = endovascular treatment.
Results

Clinical Outcomes

Five hundred twenty elderly patients received EVT procedures and completed follow-up at 1 year after procedures during the study period. Periprocedural complications occurred in 150 patients (28.85%, 150 of 520). Fifty-six of these (10.77%, 56 of 520) resulted in death. Poor outcome (mRS ≥ 3) occurred in 136 patients (26.15%, 136 of 520). Specially, during the period of study, there were 41 patients with symptomatic cerebral vasospasm refractory to hypertensive therapy. All of them accepted endovascular procedures again, including balloon angioplasty in 3 cases and intra-arterial infusion of Fasudil hydrochloride in 38 cases. The rates of mortality, complications, and poor outcome were compared within 2 sets. The results show that there are no statistical differences between these 2 sets. The detailed results were provided in Table 1.

Univariate Analysis of Outcomes

As results of univariable analysis, the P values of age, hypertension, coronary heart disease, chronic obstructive pulmonary disease, Hunt–Hess scale, Fisher scale, aneurysm located on and distally the circle of Willis, wide-necked aneurysm, with bleb on aneurysm sac, irregular aneurysm shape, EVT strategies, timing of EVT, and periprocedural complications were <0.1. The results were shown in Table 2. Therefore, these factors were considered for inclusion in the multivariable analysis.

Multivariate logistic regression followed by backward stepwise analysis determined that only age, hypertension, Hunt–Hess scale, Fischer scale, aneurysm located on and distally the circle of Willis, and periprocedural complications were independently associated with poor outcome. Further, the age was divided into 2 subcategory (≥75 years or not) and second round multivariate logistic regression analysis followed by enter method was performed. The results were shown in Table 3.

Score Model Development

Six risk factors including age ≥ 75 years, hypertension, Hunt–Hess scale, Fisher scale, aneurysm located on and distally the circle of Willis, and periprocedural complications were used to form the risk score by |β| of variable/minimal |β| after quantizing and the risk classes were constructed using classification criteria based on sensitivity and specificity. The discriminative ability was analyzed with the area under the receiver operating characteristic curve (AUC) and the Hosmer–Lemeshow goodness-of-fit test was used to determine calibration of the model (low P values indicate poor goodness-of-fit).

The score model was validated in testing set. In testing set, the risk score model was used to assign a score for every patient. Then, the discriminative ability, sensitivity, and specificity of risk score were analyzed in testing set and compared with learning set.

Table 1. Periprocedural Complications and 1-y Outcome of 520 Patients

| Total Sets (%), n = 520 | Learning Sets (%), n = 416 | Testing Sets (%), n = 104 | P |
|------------------------|---------------------------|------------------------|----|
| Periprocedural complications | 150 (28.85) | 116 (27.88) | 34 (32.69) | 0.333 |
| Intraprocedural rupture | 12 (2.31) | 9 (2.16) | 3 (2.88) | 0.942 |
| Ischemic stroke | 36 (6.92) | 30 (7.21) | 6 (5.77) | 0.604 |
| Rebleeding | 22 (3.27) | 16 (2.88) | 6 (5.81) | 0.684 |
| Pulmonary infection | 62 (11.92) | 47 (11.30) | 15 (14.22) | 0.379 |
| Acute heart failure | 7 (1.35) | 5 (1.20) | 2 (1.92) | 0.924 |
| Acute renal dysfunction | 6 (1.15) | 5 (1.20) | 1 (0.96) | 1.000 |
| Hemorrhage of digestive tract | 5 (1.35) | 4 (0.96) | 1 (0.96) | 1.000 |
| Death | 56 (10.77) | 43 (9.94) | 13 (12.50) | 0.546 |
| Poor outcome (mRS ≥ 3) | 136 (26.15) | 106 (25.48) | 30 (28.85) | 0.485 |

Periprocedural complications included 7 adverse events occurred within 30 d after procedure. The mortality rate and poor outcome rate were assessed 1 y after procedure.

mRS = modified Rankin scale.
| Variables                                      | No     | Yes    | P    |
|------------------------------------------------|--------|--------|------|
| **Patient-related factor**                     |        |        |      |
| Age, y (mean = 67.88 ± 6.44), mean ± SD       | 67.69 ± 6.39 | 69.12 ± 6.48 | 0.034 |
| Age, y                                         |        |        |      |
| 60–74                                          | 258    | 79     | 0.049 |
| ≥75                                            | 52     | 27     |      |
| Gender                                         |        |        |      |
| Male                                           | 92     | 36     | 0.409 |
| Female                                         | 218    | 70     |      |
| Smoking                                        |        |        |      |
| No                                             | 291    | 97     | 0.402 |
| Yes                                            | 19     | 9      |      |
| Hypertension                                   |        |        |      |
| No                                             | 131    | 28     | 0.004 |
| Yes                                            | 179    | 78     |      |
| Coronary heart disease                         |        |        |      |
| No                                             | 281    | 87     | 0.017 |
| Yes                                            | 29     | 19     |      |
| Renal function insufficiency                   |        |        |      |
| No                                             | 306    | 104    | 1.000 |
| Yes                                            | 4      | 2      |      |
| Chronic obstructive pulmonary disease          |        |        |      |
| No                                             | 293    | 90     | 0.002 |
| Yes                                            | 17     | 16     |      |
| Diabetes mellitus                              |        |        |      |
| No                                             | 281    | 92     | 0.261 |
| Yes                                            | 29     | 14     |      |
| Long-term use of antiplatelet drug             |        |        |      |
| No                                             | 301    | 102    | 0.903 |
| Yes                                            | 9      | 4      |      |
| With other cerebrovascular diseases            |        |        |      |
| No                                             | 267    | 91     | 1.000 |
| Yes                                            | 43     | 15     |      |
| Fisher scale                                   |        |        |      |
| 1–2                                            | 263    | 34     | 0.000 |
| 3–4                                            | 47     | 72     |      |
| Hunt–Hess scale                                |        |        |      |
| 1–3                                            | 295    | 79     | 0.000 |
| 4–5                                            | 15     | 27     |      |
| **Lesion-related factors**                     |        |        |      |
| Location I                                     |        |        |      |
| Anterior circulation                           | 293    | 96     | 0.154 |
| Posterior circulation                          | 17     | 10     |      |
| Location II (the Circle of Willis)             |        |        |      |
| On and distal                                  | 187    | 47     | 0.004 |
| Proximal                                       | 123    | 59     |      |
| Multiple aneurysms                              |        |        |      |
| Single                                         | 235    | 81     | 0.899 |
| Multiple                                       | 75     | 25     |      |
| Maximum dimension, mm                          |        |        |      |
| Tiny (<3)                                      | 27     | 9      | 0.833 |
| Small (3–6)                                    | 51     | 21     |      |
| Medium (7–10)                                  | 196    | 66     |      |
| Large (>10)                                    | 36     | 10     |      |
| Wide-necked aneurysms                          |        |        |      |
| No                                             | 193    | 61     | 0.391 |
| Yes                                            | 117    | 45     |      |
In order to make the Changhai score become a handy tool, we divide this continuous score into 3 subgroups, indicating the EVT procedure could be predicted as being a low risk (rate 6.44%), a moderate risk (rate 41.10%), or a high risk (rate 83.33%) for poor outcome. The results were shown in Table 5.

Score Model Validation

In testing set, the AUC of the Changhai score was statistically significant (0.891, 0.825–0.956, \( P < 0.001 \)). The calibration of the Changhai score was statistically significant (\( P = 0.273 \)). The sensitivity and specificity of the Changhai score were 90.00% and 83.78%, respectively. All of these 4 parameters were slightly higher than in learning set.

Comparisons of the Changhai Score With Its Components

In learning set, comparisons of the receiver operating characteristic curve (ROC) AUCs showed that the Changhai score was superior to the ROC AUCs of these 6 factors including age, hypertension, Hunt–Hess scale, Fisher scale, aneurysm located on and distally to the circle of Willis, and periprocedural complications for predicting 1-year outcome. The results were shown in Figure 2.

DISCUSSION

The findings we present are based on a prospective real-world cohort study comprising 520 consecutive elderly aSAH patients hospitalized for EVT in a single center. In this study, we developed and validated a prognosis predictive score (Changhai score) to predict 1-year clinical outcome for individual elderly patients with aSAH underwent EVT. In Changhai score, 6 factors including age, hypertension, Hunt–Hess scale, Fisher scale, aneurysm located on and distally to the circle of Willis, and periprocedural complications were included. The discriminative power and calibration of the Changhai score were significantly higher.

Along with the development of neuro-interventional techniques and materials, EVT has become an important method for treatment of intracranial aneurysms.20,21 The choice of treatment between EVT and surgical clipping for an individual elderly patient with aSAH remains a controversial issue. Even if some studies have shown that EVT is safer than surgical clipping in these patients, there is still lacking of randomized, clinical trial to support it.7,22 Poor prognosis after aSAH is always associated with age, especially for elderly patients with a high incidence of adverse outcomes.18,23,24 The rate of poor outcome and mortality at 1 year in our cohort was lower than the results reported in other previous studies.7,22,25 It may be
because that the cut-off age for elderly patients in our study was 60 years old and younger than these previous studies. After classification of age, our results shown 75 years old is a critical age which affecting outcome for elderly aSAH patients underwent EVT. This is similar to some previous studies.24–26

In aneurysmal SAH, the neurological condition of patient on admission and the amount of extravasated blood seen on CT scan are most closely related to outcome.5,6,11,25 However, the contribution made by each specific predictor remains unknown for elderly aSAH patients. Not surprisingly, Fisher grade has the most profound influence on 1-year poor outcomes, followed by periprocedural complications and Hunt–Hess grade.18,27,28 Although, EVT possess many advantages included minimally invasive and have become an important method for aSAH patients, elderly patients frequently present higher periprocedural complications, aneurysm located on and distal the circle of Willis was an independent risk factors of poor outcome, which may be due to relatively smaller diameter of parent artery, longer procedural vascular path, and lead to higher complications rate. What is interesting is that some factors which previously been consider as risk factors included intervention strategies, treatment opportunity, and immediate embolization result were proved have nothing to do with poor clinical outcome.

Some studies have proved that blood pressure of patients in acute phase of hemorrhagic stroke may affect outcome of patients.31 However, blood pressures of SAH patients were fluctuant and controllable. After aneurysm ruptured, increasing of blood pressure may be a response performance of intracranial hypertension. Previously study has indicated that intracranial pressure elevation was independent risk factors of cerebral infarction after aSAH.32 When established the protocol of this study, we just included history of hypertension as a potential risk factor instead of blood pressure after onset. Regarding the patient’s clinical conditions, in our model, history of hypertension was found to be slightly predictive of poor outcome. This may be due to elderly patients with history of hypertension frequently accompanying more systemic disease. Meanwhile, for elderly patients with aSAH, blood pressure adjustment and managing were difficult. Hence, for elderly aSAH patients, blood pressure must be controlled to maintenance of the relationship between cerebral perfusion pressures and the risk of ischemic stroke and rebleeding during the whole period of treatment.33

Timing of EVT is critical for rupture aneurysm. Delayed EVT may increase the risk of rebleeding or vasospasm. However, it has not confirmed the effect of timing on clinical outcome. Our results shown that the timing of EVT was not an independently factor associated with poor outcome. Moreover, coronary heart disease and chronic obstructive pulmonary disease were proved been related to 1-year poor outcome with univariate analysis. However, these 2 factors did not included in multivariables logistic model. The reason may be that coronary heart disease and chronic obstructive pulmonary disease were closely related to periprocedural complications and affected by

### TABLE 4. Changhai Score model of Poor Outcome

| Risk Factors                                  | Score |
|-----------------------------------------------|-------|
| Age, y                                        |       |
| ≥75                                           | 2     |
| <75                                           | 0     |
| Hypertension                                  | 1     |
| Hunt–Hess score                               |       |
| 1–3                                           | 0     |
| 4 or 5                                        | 2     |
| Fisher scale                                  |       |
| 1 or 2                                        | 0     |
| 3 or 4                                        | 5     |
| Aneurysm location                             |       |
| Located on and distal the Circle of Willis    | 0     |
| Located proximal the Circle of Willis         | 1     |
| Periprocedural complications                  | 3     |
| Total score                                   | 16    |

### TABLE 5. Predicted Poor Outcome Rate in 3 Categories of Changhai Score

| Score Classification | Total Score | Poor Outcome Rate, % | Risk Classification |
|----------------------|-------------|----------------------|---------------------|
| I                    | 0–3         | 7.28                 | Low                 |
| II                   | 4–7         | 45.71                | Moderate            |
| III                  | 8–16        | 78.00                | High                |

CI = confidence interval, OR = odds ratio.
the linear relationship between them and might explain the interaction between coronary heart disease, chronic obstructive pulmonary disease, and periprocedural complications.

In this Changhai score, 6 factors were included. All of them were independent risk factors of poor outcome and can be as predictive factors for outcome. In order to embody the advantages of our new score model, we compared Changhai score with its component variables and the results shown that the ROC AUC of Changhai score was superior to age, hypertension, Hunt–Hess scale, Fisher scale, aneurysm located on and distally to the circle of Willis, and periprocedural complications for predicting 1-year outcome. That suggests that the Changhai score is better for predicting outcome of elderly patients with aSAH underwent EVT.

There are some limitations in the present study. First, our study was conducted in a single center and suffered from the limitations that are inherent in this kind of study. Prospective validation studies should be conducted in multi-center trial with larger sample size to confirm our findings. Although this study involved 520 elderly patients, it did not assess all the variables that may have influenced outcome because the analysis lacked the statistical power to adequately identify the relative importance of several other variables occurring at a low frequency in the study group. Moreover, the assessment of some anatomic characteristics was subjective and strictly related to the definitions utilized.

CONCLUSIONS

Our study indicated that age, hypertension, Hunt–Hess scale, Fisher scale, aneurysm located on and distally to the circle of Willis, and periprocedural complications were independent risk factors of poor outcome for elderly aSAH patients underwent EVT. In combination with these risk factors, the Changhai score can be a useful tool in the prediction of outcome but needs to be validated in various centers before it can be recommended for application.

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REFERENCES

1. Anderson CS. Epidemiology of aneurysmal subarachnoid hemorrhage in Australia and New Zealand: incidence and case fatality from the Australasian Cooperative Research on Subarachnoid Hemorrhage Study (ACROSS). Stroke. 2000;31:1843–1850.
2. Lindekleiv HM, Njolstad I, Ingebrigtsen T, et al. Incidence of aneurysmal subarachnoid hemorrhage in Norway, 1999–2007. Acta Neurol Scand. 2011;123:34–40.
3. Kwon JW, Lee HJ, Hyun MK, et al. Trends in the incidence of subarachnoid hemorrhage in South Korea from 2006–2009: an ecological study. World Neurosurg. 2013;79:499–503.
4. Wong GK, Wun Tam YY, Zhu XL, et al. Incidence and mortality of spontaneous subarachnoid hemorrhage in Hong Kong from 2002 to 2010: a Hong Kong hospital authority clinical management system database analysis. World Neurosurg. 2014;81:552–556.
5. Inagawa T, Yamamoto M, Kamiya K, et al. Management of elderly patients with aneurysmal subarachnoid hemorrhage. J Neurosurg. 1988;69:332–339.
6. O’Sullivan MG, Dorward N, Whittle IR, et al. Management and long-term outcome following subarachnoid haemorrhage and intracranial aneurysm surgery in elderly patients: an audit of 199 consecutive cases. Br J Neurosurg. 1994;8:23–30.
7. Ryttlefers M, Enblad P, Kerr RS, et al. International subarachnoid aneurysm trial of neurosurgical clipping versus endovascular coiling: subgroup analysis of 278 elderly patients. Stroke. 2008;39:2720–2726.
8. Elijovich I, Higashida RT, Lawton MT, et al. Predictors and outcomes of intraoperative rupture in patients treated for ruptured intracranial aneurysms: the CARAT study. Stroke. 2008;39:1501–1506.
9. van Donkelaar CE, Bakker NA, Veeger NJ, et al. Predictive factors for rebleeding after aneurysmal subarachnoid hemorrhage: rebleeding aneurysmal subarachnoid hemorrhage study. Stroke. 2015;46:2100–2106.
10. Greving JP, Wermers MJ, Brown RD Jr et al. Development of the PHASES score for prediction of risk of rupture of intracranial aneurysms: a pooled analysis of six prospective cohort studies. Lancet Neurol. 2014;13:59–66.
11. Bekelis K, Missios S, Mackenzie TA, et al. A predictive model of outcomes during cerebral aneurysm coiling. J Neurointerv Surg. 2014;6:342–348.
12. Fisher CM, Kistler JP, Davis JM. Relation of cerebral vasospasm to subarachnoid hemorrhage visualized by computerized tomographic scanning. Neurosurgery. 1980;6:1–9.
13. Hunt WE, Hess RM. Surgical risk as related to time of intervention in the repair of intracranial aneurysms. J Neurosurg. 1968;28:14–20.
14. Dhar S, Tremlmel M, Mocco J, et al. Morphology parameters for intracranial aneurysm rupture risk assessment. Neurosurgery. 2008;63:185–196.
15. Bor AS, Tiel Groenestegte AT, terBrugge KG, et al. Clinical, radiological, and flow-related risk factors for growth of untreated, unruptured intracranial aneurysms. Stroke. 2015;46:42–48.
16. Setacci C, Chiisci E, Setacci F, et al. Siena carotid artery stenting score: a risk modelling study for individual patients. Stroke. 2010;41:1259–1265.
17. Raymond J, Roy D. Safety and efficacy of endovascular treatment of acutely ruptured aneurysms. Neurosurgery. 1997;41:1235–1245.
18. Rivero Rodriguez D, Scherle Matamoros C, Fernandez Cue L, et al. Factors associated with poor outcome for aneurysmal subarachnoid haemorrhage in a series of 334 patients. Neurologia. 2015 pii: S0213-4853(14)00269-2. doi: 10.1016/j.neurni.2014.12.006. [Epub ahead of print].
19. Moons KG, Harrell FE, Steyerberg EW. Should scoring rules be based on odds ratios or regression coefficients? J Clin Epidemiol. 2002;55:1054–1055.

20. Molyneux A, Kerr R, Stratton I, et al. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial. Lancet. 2002;360:1267–1274.

21. Molyneux A, Kerr R, Stratton I, et al. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomized trial. J Stroke Cerebrovasc Dis. 2002;11:304–314.

22. Sturiale CL, Brinjikji W, Murad MH, et al. Endovascular treatment of intracranial aneurysms in elderly patients: a systematic review and meta-analysis. Stroke. 2013;44:1897–1902.

23. Rosenorn J, Eskesen V, Schmidt K. Age as a prognostic factor after intracranial aneurysm rupture. Br J Neurosurg. 1987;1:335–341.

24. Nieuwkamp DJ, Rinkel GJ, Silva R, et al. Subarachnoid haemorrhage in patients > or = 75 years: clinical course, treatment and outcome. J Neurol Neurosurg Psychiatry. 2006;77:933–937.

25. Degos V, Gourraud PA, Tursis VT, et al. Elderly age as a prognostic marker of 1-year poor outcome for subarachnoid hemorrhage patients through its interaction with admission hydrocephalus. Anesthesiology. 2012;117:1289–1299.

26. Park J, Woo H, Kang DH, et al. Critical age affecting 1-year functional outcome in elderly patients aged > or = 70 years with aneurysmal subarachnoid hemorrhage. Acta Neurochir (Wien). 2014;156:1655–1661.

27. Bonilha L, Marques EL, Carelli EF, et al. Risk factors and outcome in 100 patients with aneurysmal subarachnoid hemorrhage. Arq Neuropsiquiatr. 2001;59:676–680.

28. Jabbarli R, Reinhard M, Roelz R, et al. Early identification of individuals at high risk for cerebral infarction after aneurysmal subarachnoid hemorrhage: the BEHAVIOR score. J Cereb Blood Flow Metab. 2015;35:1587–1592.

29. Watanabe D, Hashimoto T, Koyama S, et al. Endovascular treatment of ruptured intracranial aneurysms in patients 70 years of age and older. Surg Neurol Int. 2014;5:104.

30. Larrew T, Pryor W III, Weinberg J, et al. Aneurysmal subarachnoid hemorrhage: a statewide assessment of outcome based on risk factors, aneurysm characteristics, and geo-demography. J Neurointerv Surg. 2015;7:855–860.

31. Seo W, Oh H. Acute physiologic predictors of mortality and functional and cognitive recovery in hemorrhagic stroke: 1-, 3-, and 6-month assessments. J Stroke Cerebrovasc Dis. 2007;16:57–63.

32. Jabbarli R, Reinhard M, Roelz R, et al. Early identification of individuals at high risk for cerebral infarction after aneurysmal subarachnoid hemorrhage: the BEHAVIOR score. J Cereb Blood Flow Metab. 2015;35:1587–1592.

33. Connolly ES Jr, Rabinstein AA, Carhuapoma JR, et al. Guidelines for the management of aneurysmal subarachnoid hemorrhage: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2012;43:1711–1737.