Modified World Federation of Neurosurgical Societies Subarachnoid Hemorrhage Grading System

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Key words
- Glasgow Coma Scale
- Modified Rankin Scale
- Outcomes
- Subarachnoid hemorrhage
- World Federation of Neurosurgical Societies

Abbreviations and Acronyms

AUC: Area under the curve
GCS: Glasgow Coma Scale
GOS: Glasgow Outcome Scale
mRS: Modified Rankin Scale
m-WFNS: modified World Federation of Neurosurgical Societies
ROC: Receiver operating characteristic
SAH: Subarachnoid hemorrhage
WFNS: World Federation of Neurosurgical Societies

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■ OBJECT: **A modified World Federation of Neurosurgical Societies scale (m-WFNS scale) for aneurysmal subarachnoid hemorrhage (SAH) recently has been proposed, in which patients with Glasgow Coma Scale (GCS) scores of 14 are assigned to grade II and those with GCS scores of 13 are assigned to grade III regardless of the presence of neurologic deficits. The study objective was to evaluate outcome predictability of the m-WFNS scale in a large cohort.**

■ METHODS: **This was a multicenter prospective observational study conducted in Japan. A total of 1656 patients with SAH were registered during the 2.5-year study period, and the outcome predictability, using the Glasgow Outcome Scale (GOS) and modified Rankin Scale (mRS) scores at discharge and at 90 days after onset, was evaluated by comparing the m-WFNS with the original WFNS scale. We focused on whether significant differences in these scores were present between the neighboring grades.**

■ RESULTS: **In the m-WFNS scale, significant difference between any neighboring grades was observed both in the mean GOS and mRS scores at 90 days except between grades III/IV. However, differences were not significant between grades II/III and between grades III/IV in the original WFNS scale.**

■ CONCLUSIONS: **SAH-induced brain injury may be substantially severer in patients with GCS 13 than those with GCS 14, which may explain why grade III patients faired significantly worse than grade II patients by the modified WFNS scale. Although further validation is necessary, the m-WFNS scale has a potential of providing neurosurgeons with simpler and more reliable prognostication of patients with SAH.**

INTRODUCTION

A grading scale for aneurysmal subarachnoid hemorrhage (SAH) was first introduced by Botterell et al. in 1956 (2), followed by the Hunt and Hess (8)/Hunt-Kosnik (9) and the World Federation of Neurosurgical Societies (WFNS) scales (5), which have gained widespread acceptance in the last 2–3 decades (1, 4). Despite moderate differences, all these scales use the patient's level of consciousness as the major predictor of outcomes. Earlier grading scales, however, such as Hunt and Hess, used less clearly defined scales of consciousness (8). The WFNS scale attempted to overcome this issue by using the Glasgow Coma Scale (GCS) as its major input. The decision to use the GCS as the major predictor of outcomes was reached by consensus of the WFNS Committee (5) and was refined further to include the presence of focal neurologic deficits.

The lack of formal validation of the original WFNS scale, however, has led to occasional overlap between grades (particularly between grade II and grade III), where the outcomes predicted by the assigned grade may not differ substantially (6, 7). Therefore, it may be worthwhile to review the current WFNS scale and modify it according to outcomes necessary. The WFNS Cerebrovascular Disease & Treatment Committee and the Japan Neurosurgical Society have jointly proposed a modified World Federation of Neurosurgical Societies (m-WFNS) scale, in which SAH patients with a total GCS score of 14 are assigned to grade II and those with a total GCS score of 13 are assigned to grade III, regardless of the presence of neurologic deficits.

An SAH scale that relies only on initial GCS scores already has been proposed by van Heuven et al. (12), whose main objective was to make a better prognostication tool for patients with poor-grade SAH. The objective of this study, by contrast, was to evaluate whether the proposed m-WFNS scale was superior to the original WFNS scale in prediction of outcomes for patients with mild-grade SAH: we focused on whether grade III on the m-WFNS scale had better outcome predictability compared with the original WFNS scale.

METHODS

Patients

This was a multicenter, prospective observational study conducted between October 2010 and March 2013, and a total of 38 neurosurgical institutions across Japan participated in the study. The exclusion criteria for the study were patients <20 years of age and interval between symptom onset and admission >72 hours. Pertinent clinical data collected prospectively included age, sex, location of ruptured aneurysm, each component of the GCS score (on admission and after initial stabilization), presence/type of concomitant neurologic deficits (weakness and/or aphasia), premorbid modified Rankin Scale (mRS) scores, medical comorbidities, type of treatment for aneurysm obliteration, type of perioperative complications, Glasgow Outcome Scale (GOS) scores at discharge and 90 days after onset, and mRS scores at discharge and 90 days after onset.

The clinical data such as GCS scores were assessed by board-certified neurosurgeons in each institution. The GCS scores obtained after initial stabilization of the patient were used for grading. Treatment methods for aneurysm obliteration were not randomized and were at the discretion of each participating institution. Data were stored in a secured, electronic database after anonymization. Patients and their surrogates were informed of concept and design of this study, and only data of those who provided consent to us were used.

Evaluation of Outcomes and Statistical Analysis

The clinical outcomes were assessed using both GOS and mRS scores. In both WFNS scales (i.e., m-WFNS scale and original WFNS scale), mean GOS and mRS scores at discharge and at 90 days after onset of symptoms were calculated (for conversion from descriptive GOS scores to numerical GOS scores, see Table 1). In both WFNS scales, the mean (numerical) GOS and mRS scores between the neighboring grades were compared to evaluate the outcome predictability via the Mann-Whitney U test and nonparametric test by Dunn's multiple comparisons. In both WFNS scales, distributions of the descriptive GOS scores in relation to grades (assessed at discharge) were compared with the Wilcoxon rank-sum test with no adjustment for multiple comparisons, with the aim to evaluate intergrade difference in the ranking/ordered profile of these descriptive GOS scores.

Table 1. Numerical/Descriptive Glasgow Outcome Scale (GOS)

1	Low disability (LD)
2	Moderate disability (MD)
3	Severe disability (SD)
4	Persistent vegetative state (PVS)
5	Death (D)

Furthermore, receiver operating characteristic (ROC) curve analysis was conducted to determine whether the m-WFNS scale was superior to the original WFNS scale in predicting those with favorable outcomes: patients either with mRS ≤ 1 or GOS $= 1$ at the time of evaluations (i.e., at discharge and at 90 days) were defined as those having favorable outcomes, and for each outcome scale, area under the curve (AUC) values were compared between the 2 groups at the 2 time points. Statistical significance was set at a P-value < 0.05. Statistical analysis was performed using the JMP version 10 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Patients

During the 2.5-year study period, a total of 1863 patients with SAH from 38 institutions were registered. Two-hundred seven patients (11.1%) were excluded, either because the interval between symptom onset and admission was >72 hours or because the timing of symptom onset was unidentifiable. The data of the remaining 1656 patients were analyzed. The mean age was 63.7 ± 14.1 years, and male/female ratio was 1:2. Sixteen-hundred forty-two patients (99.2%) were followed till hospital discharge, whereas 1552 patients (93.2%) were followed till 90 days after symptom onset (Table 1). Thirteen-hundred twenty-nine patients underwent treatment for the obliteration of ruptured aneurysm, and the other 327 patients were managed conservatively. Of those treated, 839 (63.1%) were treated by open surgery, 473 (35.6%) were treated by endovascular surgery, and 17 (1.3%) were treated by both (Figure 1). By the original WFNS scale, classification of the 1642 patients into the 5 grades was: 478 in grade I, 345 in grade II, 41 in grade III, 306 in grade IV, and 472 in grade V. By the m-WFNS scale, 249 patients were assigned to grade II and 137 patients were assigned to grade III.

Evaluation of Outcomes

The results of mean GOS scores at discharge are shown in Figure 2A and B. In the m-WFNS scale, there was a significant difference between all neighboring grades (Figure 2A). In contrast, in the original WFNS scale, significant difference was observed only between grade I and grade II and between grade IV and grade V patients (Figure 2B). The results of mean mRS scores at discharge are shown in Figure 2C and D. In the m-WFNS scale, there was a significant difference between all neighboring grades (Figure 2D). In contrast, in the original WFNS scale, a significant difference was observed only between grade I and grade II and between grade IV and grade V patients (Figure 2D).

The results of mean GOS scores at 90 days after symptom onset are shown in Figure 3A and B. In the m-WFNS scale, there was a significant difference between all neighboring grades except between grade III and grade IV (Figure 3A). Similarly, in the original WFNS scale, a significant difference was observed between all neighboring grades except between grade III and grade IV patients (Figure 3B). The results of mean mRS scores at 90 days after symptom onset are shown in Figure 3C and D. In the m-WFNS scale, there was a significant difference between all neighboring grades except between grade III and IV patients (Figure 3C). In the original WFNS scale, a significant difference was observed only between grade II and grade III and between grade IV and grade V patients (Figure 3D).

The distribution of the descriptive GOS scores in relation to progressing SAH grades (assessed at discharge) is shown in Figure 4A and B. On the m-WFNS scale, there was a significant difference between all neighboring groups, indicating that progressing SAH grades might be predictive of poorer outcomes (Figure 4A). In contrast, there were no significant differences between grade II and grade III and between grade III and grade IV patients on the

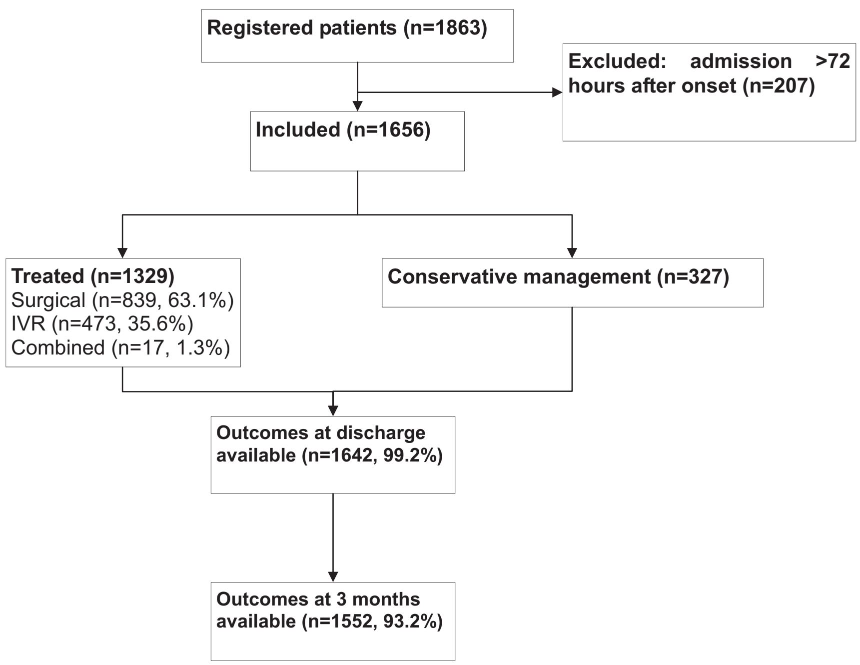

Figure 1. Breakdown of the 1863 patients with subarachnoid hemorrhage (SAH) registered.

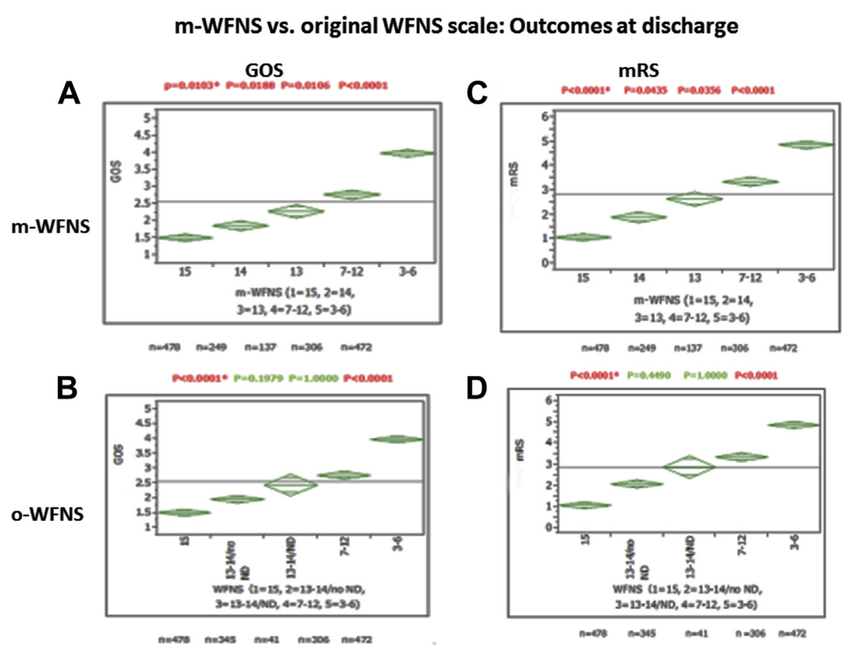

Figure 2. (**A**) Mean Glasgow Outcome Scale (GOS) scores at discharge showing that on the modified World Federation of Neurosurgical Societies (m-WFNS) scale, there was a significant difference between all neighboring grades. (**B**) In contrast, on the original World Federation of Neurosurgical Societies (o-WFNS) scale, the significant difference was observed only between grade I/II and between grade IV/V patients. (**C**) Mean modified Rankin Scale (mRS) scores at discharge showing that on the m-WFNS scale, there was a significant difference between all neighboring grades. (**D**) In contrast, on the original WFNS scale, the significant difference was observed only between grades I/II, and between grades IV/V patients. *Nonparametric test by Dunn's multiple comparisons.

original scale, indicating that progressing SAH grades might *not* necessarily be predictive of poorer outcomes by the original WFNS scale (**Figure 4B**).

The ROC curve analysis on the mRS score demonstrated that the AUC values by the m-WFNS scale were significantly greater than those by the original WFNS scale both at discharge (0.830 vs. 0.827, $P = 0.02$) and at 90 days (0.834 vs. 0.830, $P = 0.03$) (**Table 2**). In contrast, there were no significant differences in the AUC values either at discharge or at 90 days when clinical outcomes were evaluated by the GOS score (**Table 2**).

Although the presence of neurologic deficits in patients with GCS scores of 14 led to significantly worse outcomes at discharge, the difference was not significant at 90 days after onset of symptoms (data not shown). In similar patients, but with GCSs score of 13, there was no significant difference in outcomes neither at discharge nor at 90 days after onset of symptoms (data not shown).

DISCUSSION

The best clinical indicator of severity of SAH is the patient's level of consciousness. The GCS score is a simple test with a low inter-user discrepancy that has been adopted universally in the medical community as a tool for the evaluation of a patient's level of consciousness (1). It therefore provides a reliable input on which a grading system can be based. The original WFNS scale uses GCS score as an input together with the presence of neurologic deficits. There seems to be substantial interrater variability, however, in the application of the original WFNS scale because of ambiguity in identifying the presence of neurologic deficits (3, 11). It also has been thought among neurosurgeons that a difference in the outcomes occasionally may be subtle between grades, particularly between grade II and grade III: ideally, a simple SAH scale that correlates with the outcomes of patients with SAH more precisely would be useful to neurosurgeons. The aim of this prospective study, conceived and endorsed jointly by the WFNS Cerebrovascular Disease and Treatment Committee and the Japan Neurosurgical Society, was to verify the validity of the m-WFNS scale, which we believe is simpler and less vulnerable to the

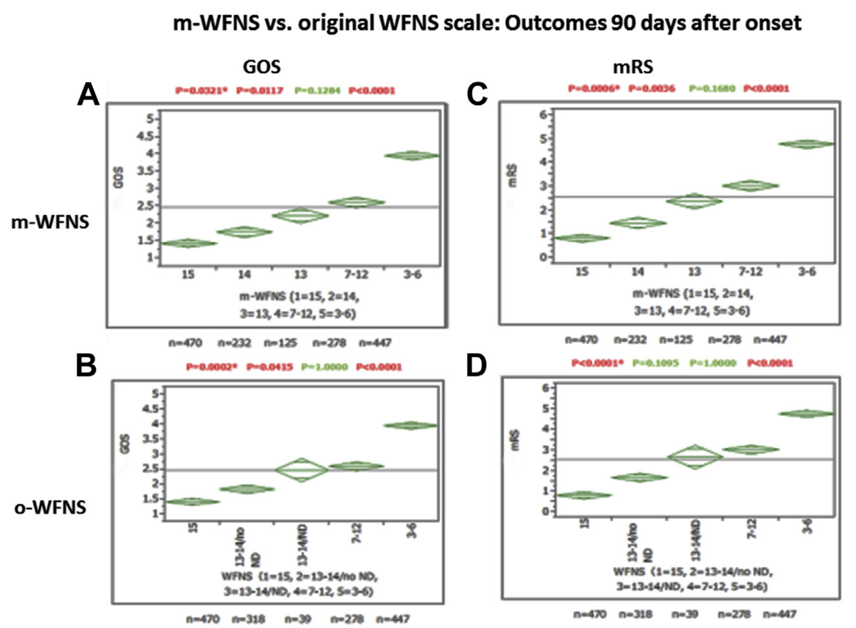

Figure 3. (**A**) Mean Glasgow Outcome Scale (GOS) scores at 90 days after onset of symptoms showing that on the modified World Federation of Neurosurgical Societies (m-WFNS) scale, there was a significant difference between all neighboring grades except between grade III/IV patients. (**B**) Similarly, on the original WFNS scale, a significant difference was observed between all neighboring grades except between grade III/IV patients. (**C**) Mean modified Rankin Scale (mRS) scores at 90 days after onset of symptoms showing that on the m-WFNS scale there was a significant difference between all neighboring grades except between grade III and IV. (**D**) On the original World Federation of Neurosurgical Societies (o-WFNS) scale, significant difference was observed only between grade II/III and between grade IV/V patients. *Nonparametric test by Dunn's multiple comparisons.

interrater variability, in the prognostication of patients with SAH.

Analyses on the GOS and mRS scores at discharge indicated that intergrade differences in the outcomes were highlighted more clearly on the m-WFNS scale (Figure 2). In contrast, the differences between grade II and III and those between grade III and IV failed to reach statistical significance on the original WFNS scale (Figure 2). The superior outcome predictability by the m-WFNS scale also was demonstrated by the Wilcoxon rank-sum test (Figure 4) and by ROC curve analyses (Table 2). Therefore, modification of the original WFNS scale may have created a simpler and more user-friendly SAH grading system. The results at 90 days by Mann-Whitney *U* test indicate that the superiority of the m-WFNS scale in outcome prediction of patients with SAH may be less distinct between grade III and grade IV, as exemplified by a loss of statistical significance (Figure 3). Nevertheless, the prognostic distinction between grade III and grade IV at 90 days was still better on the m-WFNS scale: whereas *P* values between grade III and grade IV were 0.128 with GOS and 0.168 with mRS by the m-WFNS scale, those between grade III and grade IV were 1.00 with GOS and 1.00 with mRS by the original WFNS scale (Figure 3). Meanwhile, the superiority of w-WFNS scale between grade II and grade III persisted at 90 days (Figure 3).

These results may not be surprising, because our modification was conceived mainly with an intention to make better prognostic distinction between grade II and grade III patients. The ROC curve analysis also demonstrated the superiority of the m-WFNS scale in the outcome prediction of those with favorable outcomes (mRS $\leq$ 1) at 90 days (Table 2). It remains unclear, however, why there was no significant difference when the outcomes were evaluated with the GOS (Table 2).

The number of patients with grades II/III was substantially different between the 2 WFNS scales (345 grade II and 41 grade III patients in the original scale/249 grade II and 137 grade III patients in the modified scale). This result was mostly because patents with GCS scores of 13 who exhibited no neurologic deficits, who might otherwise have been classified into grade II in the original scale, were assigned to grade III according to the modified scale. Patients with GCS scores of 13 faired persistently worse than those with GCS scores of 14 (Figures 2 and 3). This can be explained if we assume that the degree of brain injury in SAH patients with GCS scores of 13 was significantly more profound compared with that in patients with GCS scores of 14.

In patients with traumatic brain injury, it has been shown that the outcomes of patients with GCS scores of 13 were significantly worse than those with GCS scores of 14 (10). Patients with GCS scores of 13 are classified into the *moderate* head injury category, which is different from those with GCS scores of 14, who are classified into the *mild* head injury category. The same observation may hold true in patients with SAH: a lack of significant difference in the outcomes between grade II and grade III patients in the original WFNS scale may have been because patients of both categories, with GCS scores of 13 and of 14, were treated as equal and put into a single category. Compared with the difference in GCS scores, impact of the presence of neurologic deficits on the outcomes is modest. Although the reason is unclear, it may be attributable to improvement of treatment and rehabilitation methods.

The integrity of these results is supported by a number of strengths. The large sample size (1656 patients, of which 1552 were followed till 90 days after symptom onset), which included patients from multiple neurosurgical institutions across Japan, may have minimized the impact of individual confounding factors. The follow-up rate at discharge and at 90 days was high (99.2% and 93.7%, respectively). The combination of the 2 outcome scales (GOS and mRS) provides a robust credibility of this study.

There also were a few limitations in this study. The follow-up period was limited to 90 days after onset of symptoms, and it is no doubt that a longer observation period is necessary to ensure that superiority of the m-WFNS scale is long-lasting. Although most patients with disabilities were

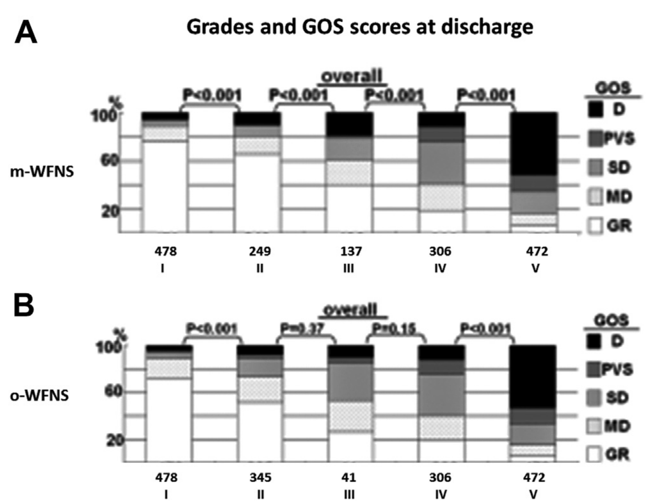

Figure 4. (**A**) Outcomes (descriptive Glasgow Outcome Scale [GOS] at discharge) by the modified World Federation of Neurosurgical Societies (m-WFNS) scale showing that significant difference was present between all neighboring groups, indicating that progressing subarachnoid hemorrhage (SAH) grades might be predictive of poorer outcomes by the m-WFNS scale. (**B**) Outcomes by the original WFNS scale showing that significant difference was present only between grade II/III and between grade IV/V, indicating that progressing SAH grades might *not* necessarily be predictive of poorer outcomes by the original WFNS (o-WFNS) scale. The Wilcoxon rank-sum test with no adjustment for multiple comparisons was used for statistical analysis.

transferred to rehabilitation facilities after treatment in the acute phase, timing of the transfer and the length of hospital stay might have varied substantially from institution to institution: a concern may arise that the outcomes evaluated at discharge might have been less reliable than those evaluated at 90 days. The method of aneurysm obliteration (either open surgery or endovascular surgery) was not randomized and may have been a source of bias. The lack of standardized protocol in perioperative patient management also might have resulted in potential interinstitutional difference in the outcomes. The lack of independent physicians to standardize the neurologic examination also may have led to variability in the recorded GCS. Although GCS scores were evaluated after initial stabilization, several patients might have presented with seemingly worse grade because of seizure or stunned myocardium. Neurosurgeons who evaluated the outcomes in each institution were not blinded to the treatment, which might have resulted in biases. Finally, it is of no doubt that the current results require further internal and external validations: for the modified scale to be accepted widely by neurosurgeons, more studies are warranted in the settings of totally different geographic and socioeconomic areas of the world.

Table 2. Area Under the Curve Values on the Modified WFNS Scale and Original WFNS Scale

	Modified WFNS	Original WFNS	*P* Value
At discharge			
GOS = 1	0.819	0.816	0.0516
mRS ≤ 1	0.830	0.827	0.0161*
At 90 days			
GOS = 1	0.830	0.828	0.147
mRS ≤ 1	0.834	0.830	0.0331†

WFNS, World Federation of Neurosurgical Societies; GOS, Glasgow Outcome Scale; mRS, modified Rankin Scale.
*,†Statistically significant.

CONCLUSION

With the use of m-WFNS scale, which differs from the original scale in that patients with GCS scores of 14 and 13 are assigned to grade II and grade III, respectively, regardless of the presence of neurologic deficits, prognostication of patients with SAH was more accurate than the original scale. Although further validation is necessary, the modified scale has a potential of providing neurosurgeons with simpler and more reliable prognostication of patients with SAH.

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Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

For the 38 Registered Institutions & Cerebrovascular diseases and treatment, see Appendix.

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APPENDIX

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