Observational Study

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Modified Glasgow coma scale for predicting outcome after subarachnoid hemorrhage surgery

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Abstract

There are many grading scales that attempt to predict outcome following aneurysmal subarachnoid hemorrhage (aSAH). Most scales used to assess outcome are based on the neurological status of the patient. Here, we propose a new scale for aSAH patients that combines the Glasgow Coma Scale (GCS) and the modified Fisher scale (mFS).

Five hundred ninety-seven patients with aSAH who were treated at our institution between January 2008 and December 2017 were retrospectively analyzed. Initial GCS score, Hunt and Hess scale, World Federation of Neurosurgical Societies scale, mFS, and modified Rankin Scale were obtained by reviewing data. Incidence of vasospasm was investigated. Factors found to be significant on a multivariable regression analysis were used to develop a scale that was compared with other grading systems using the area under the curve (AUC) calculated from receiver operating characteristic curve.

The GCS score and mFS were related to outcomes in patients with aSAH. A simple score, which we call the GCS-F score, was calculated using these initial data. The GCS-F score had an AUC of 90.5% for unfavorable outcome prediction, and 88.4% for in-hospital mortality prediction. On the receiver operating characteristic curve analysis for vasospasm, the AUC for World Federation of Neurosurgical Societies, mFS and GCS-F scores were 0.912, 0.704, and 0.936, respectively.

A simple arithmetic combination of the GCS score and mFS, the GCS-F score, includes the radiographic status as well as the clinical status of the patient, so that the state of the patient can be known in more detail than other single scales. The GCS-F score may be a useful scale for predicting outcome and the occurrence of vasospasm in patients with aSAH.

Abbreviations: aSAH = aneurysmal subarachnoid hemorrhage, AUC = area under the curve, CT = computed tomography, GCS = Glasgow Coma Scale, HH = Hunt and Hess, mFS = modified Fisher scale, MR = magnetic resonance, OR = odds ratio, ROC = receiver operating characteristic, WFNS = World Federation of Neurosurgical Societies.

Keywords: Glasgow coma scale, modified fisher scale, outcome, subarachnoid hemorrhage, vasospasm

1. Introduction

Aneurysmal subarachnoid hemorrhage (aSAH) accounts for 5% of all strokes, and the morbidity and mortality in aSAH are considerable when compared with patients with other hemorrhagic or ischemic strokes.[1] In aSAH patients, 12% die immediately, >30% die within 1 month, and 25% to 50% die within 6 months; 30% of survivors remain dependent.[2–4]

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The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Predicting the outcome after SAH is very important, but difficult. This is because the course of the aSAH is determined by several factors, including the initial clinical status, the size, and shape of the aneurysm. Many studies have focused on the development of clinical and radiological scales, with the aim of predicting patient outcomes. Scales to predict outcome after aSAH are important in assessing early patient condition and in determining treatment options. Numerous clinical and radiological grading scales for predicting outcome after aSAH have been introduced. The most commonly used SAH grading systems are the Hunt and Hess (HH) and the World Federation of Neurosurgical Societies (WFNS) scales.[5] Moreover, thickness of the hemorrhage clot at the subarachnoid space has been assessed by the Fisher scale or its modified version. The modified Fisher scale (mFS), which correlates the amount of blood seen on computed tomography (CT) and the risk of developing clinical vasospasm, is used extensively.[6,7]

Most scales that predict outcomes in aSAH patients are based on the initial neurological status of patient obtained on admission. The Glasgow Coma Scale (GCS) is the most widely used scoring system for grading the level of consciousness due to its widespread applicability.[8–10] The GCS is also widely used by neurosurgeons for initial assessment of aSAH patients. However, due to a lack of radiographic features in clinical scales, the various scales suffer from several errors.

In our study, we propose a new scale that combines the GCS score and the mFS, which we call the GCS-F score, for the assessment of aSAH patients. The aim of this study was to evaluate the GCS score and the mFS in relation to outcome in patients with aSAH, and to compare the predictive power of the GCS-F score with previously established clinical scales for patient outcomes after aSAH.

2. Materials and methods

2.1. Study design

We retrospectively reviewed patients with spontaneous aSAH who were treated at our institution from January 2008 to December 2017. Of the 658 consecutive patients with SAH and ruptured aneurysms, 597 patients were included in this study. This study was approved by the institutional review board at the author's institute (HYUH IRB 2018-11-015-001), and conformed to the tenets of the Declaration of Helsinki. Owing to the retrospective nature of the study, the need for informed consent was waived. All individual records were anonymized prior to analysis.

The inclusion criteria were as follows: males or female gender between 20 and 85 years old, ruptured aneurysm identified by a radiologic study, such as CT or cerebral angiography, and aneurysm obliteration by aneurysmal neck clipping or endovascular coil embolization. Exclusion criteria consisted of traumatic aSAH, previous stroke or neurologic deficits, mental retardation, psychological disease, and loss of follow-up before 1 year. The surgical procedure was determined by the neurosurgical team according to age, aneurysm location, initial mental status, neck/dome presentation, and pre-existing comorbidities. Ventriculostomy with external ventricular drainage was performed in patients with acute hydrocephalus.

2.2. Glasgow Coma Scale (GCS) score, Hunt and Hess (HH) scale, World Federation of Neurosurgical Societies (WFNS) scale, and modified Fisher scale (mFS)

A GCS score, HH scale, and WFNS scale were recorded for all patients in the present study upon admission. The eye, verbal, and motor components of the GCS were recorded for each patient at the time of admission. From these data, the total GCS scores were calculated. The initial CT of the brain after admittance was assessed using the mFS by 1 neurosurgeon.

2.3. VASOGRADE and HAIR score

The VASOGRADE was recorded from the previously published studies by Crobeddu et al [11] and de Rooij et al,[12] which showed clinical condition on admission and the amount of blood on CT as the major risk factors for cerebral infarction; green: WFNS 1 to 2 and mFS 1 to 2; yellow: WFNS 1 to 3 and mFS 3 to 4; red: WFNS 4 to 5 and all mFS.

The HAIR score was derived from the previously published studies by Lee et al.[13] The HAIR score (0–8) was made by adding the following data points together[14]: HH (HH 1–3 = 0, HH 4 = 1, HH 5 = 4), age (<60 = 0, 60–80 = 1, >80 = 2), intraventricular hemorrhage (no = 0, yes = 1), and rebleed within 24 hours (no = 0, yes = 1).

2.4. Patient outcomes and investigating radiographic vasospasm

A neurosurgeon completed all outcome assessments using the modified Rankin scale (mRS) at discharge and 1 year after SAH ictus. The proportions of patients in the study who either were dead or had an unfavorable outcome (vegetative state or severe disability) were determined according to the mRS. A mRS of 0 to 2 was deemed a favorable outcome, and 3 to 6 an unfavorable outcome.

We defined cerebral vasospasm as radiographic evidence of intracranial arterial narrowing. Cerebral vasospasm was identified by cerebral angiography, CT angiography, magnetic resonance angiography, or CT perfusion.

2.5. Statistical methods

Data are presented as means and ranges for continuous variables, and as counts and percentage for discrete variables. Statistical analyses were performed by using the Student t test, χ^2 test for linear association, and Fisher exact tests, as appropriate.

The predictive power of the GCS score, WFNS scales, HH scales, mFS, and other factors were assessed using univariate logistic regression analyses. Variables with a P value $<.10$ were reentered in the multivariable logistic regression model using a backward stepwise method. Odds ratios (ORs) and 95% confidence intervals (CI) were reported for statistically significant factors (P value $<.05$).

The receiver operating characteristic (ROC) curve was used to determine the utility of the GCS score, WFNS scales, HH scales, mFS, VASOGRADE, HAIR score, and GCS-F score for predicting overall outcome and the occurrence of radiographic vasospasm in patients with aSAH. The corresponding areas under the curve (AUC) were calculated to evaluate the predictive capability of each score. Each score's AUC was then compared using the DeLong' test. All data were analyzed with R, version 3.3.2 (https://www.r-project.org/; R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Demographic characteristics of patients

Complete data (GCS score, WFNS scale, HH scale, mFS, and mRS) were available for 597 of the 658 patients. Patient characteristics are listed in Table 1. The mean age of the SAH patients was 55.9 ± 11.5 (range 27–85) years. The mean GCS score at admittance was 12.1 ± 3.7 (median 13; range 4–15), and the mean mFS on the initial CT scan was 3.2 ± 1.0 (median 4; range 1–4).

3.2. In-hospital mortality, patient outcomes, and radiographic vasospasm

Overall in-hospital mortality was 20.3%. Univariate analysis showed an increased odds ratio of in-hospital death for old age, low GCS score, high WFNS scale, high HH scale, and high mFS. A logistic regression analysis of mortality, outcome, and vasospasm is shown in Table 2. Two variables remained statistically significant after adjusting for confounding factors: GCS score (OR = 0.80; 95% CI = 0.65–0.98; P = .0285) and mFS (OR = 1.70; 95% CI 1.06–2.75; P = .0287).

A total of 297 (49.7%) patients had unfavorable outcomes at 1 year after the hemorrhage. A logistic regression analysis of unfavorable outcome is shown in Table 2. Three variables remained statistically significant after adjusting for confounding factors: age (OR = 1.03; 95% CI = 1.00–1.06; P = .0341), GCS score (OR = 0.53; 95% CI = 0.33–0.85; P = .0094), and mFS (OR 1.47; 95% CI 1.08–2.00; P = .0154).

Table 1

Demographic characteristics of patients.

Variable	Clip (n=380)	Coil (n=217)	Total (n=597)
Age, years (mean, SD)	56.0±11.8	55.8±11.1	55.9±11.5
Sex			
Male	139	86	225
Female	241	131	372
Hypertension	148	85	233
Diabetes mellitus	26	19	45
Aneurysm size	6.2±3.3	6.3±3.4	
GCS score			
13–15	245	130	375
9–12	50	38	88
3–8	85	49	134
WFNS scale			
1	158	80	238
2	57	32	59
3	30	18	48
4	73	61	134
5	62	26	88
HH scale			
1	22	10	32
2	166	87	253
3	87	57	144
4	101	62	163
5	4	1	5
Unfavorable outcome	182	115	297
Expired	78	43	121
Vasospasm	148	99	247

GCS=Glasgow Coma Scale, HH=Hunt and Hess, mFS=modified Fisher scale, SD=standard deviation, WFNS=World Federation of Neurosurgical Societies.

Size of aneurysm, location of aneurysm, and type of treatment (clipping or coiling) were not statistically related to in-hospital mortality and unfavorable outcomes. Radiographic vasospasm was present in 247 (41.4%) patients. The diagnosis of radiographic vasospasm was based on conventional cerebral angiography in 86 (34.8%) cases, CT angiography in 71 (29.1%) cases, CT perfusion in 65 (26.3%) cases, and magnetic resonance angiography in 25 (10.1%) cases. A logistic regression analysis of vasospasm is shown in Table 2. Two variables remained statistically significant after adjusting for confounding factors: WFNS scale (OR=3.27; 95% CI=2.23–4.79; $P<.001$) and mFS (OR=3.03; 95% CI 1.94–4.71; $P<.001$).

3.3. Relation of GCS score and mFS to patient outcome

Declines in GCS scores were associated with increasing rates of mortality and unfavorable outcome. The in-hospital mortality rate was 4.0% for GCS scores between 13 and 15, 22.2% for those with GCS scores between 9 and 12, and 63.2% for GCS scores between 3 and 8. The percentage of patients with unfavorable outcomes was 14.2% for those with GCS scores between 13 and 15, 59.7% for GCS scores between 9 and 12, and 95.6% for GCS scores between 3 and 8.

The mortality rate was 28.7% in patients with a mFS of 4, and none of the patients with a mFS of 1 died. The unfavorable outcome rate was 18.7% in patients with a mFS of 1, and 52% in patients with a mFS of 4.

The mFS increased with decreasing GCS score. The percentage of patients with a mFS of 4 was 40.6% for those with a GCS score between 13 and 15, 54.2% for those with a GCS score between 9 and12, and 79.4% for those with a GCS score between 3 and 8.

3.4. Model development of the GCS-F score: combining information about the GCS score and mFS

GCS score and mFS were significantly associated with in-hospital mortality and unfavorable outcome (Table 2). We developed a stratification scale (GCS-F score) from the above logistic regression model. We developed a method that combined a patient's GCS score and mFS into a single, unidimensional index. A combined GCS-mFS score (GCS-F) was obtained simply by subtracting the mFS from the GCS total score, as follows: GCS-F=GCS score – mFS. Since the total GCS score in our study ranges from 4 to 15, a GCS-F score thus has a range of possible values from 0 to 14.

3.5. GCS-F score for predicting patient outcome and radiographic vasospasm

The accuracy of the GCS-F score for predicting outcomes and the occurrence of radiographic vasospasm was assessed by the ROC curve. On the ROC curve analysis for unfavorable outcome, the AUCs of the GCS score and the GCS-F score were 0.899 (95% CI, 0.868–0.931; $P<.001$; cutoff value, 13) and 0.905 (95% CI, 0.874–0.936; $P<.001$; cutoff value, 9), respectively (Fig. 1A).

On the ROC curve analysis for in-hospital mortality, the AUCs of the GCS score, mFS, and the GCS-F score were 0.868 (95% CI, 0.817–0.919; $P<.001$; cutoff value, 13), 0.656 (95% CI, 0.604–0.707; $P<.001$; cutoff value, 13), and 0.884 (95% CI, 0.841–0.926; $P<.001$; cutoff value, 9), respectively (Fig. 1B).

On the ROC curve analysis for the occurrence of radiographic vasospasm, the AUCs of WFNS scale, mFS, and GCS-F score were 0.912 (95% CI, 0.882–0.942; $P<.001$), 0.704 (95% CI, 0.657–0.75; $P<.001$), and 0.936 (95% CI, 0.91–0.961; $P<.001$), respectively. The GCS-F score had a higher AUC than the WFNS scale or the mFS for predicting vasospasm after aSAH.

Table 2

Logistic regression analysis for in-hospital mortality, unfavorable outcome, and radiographic vasospasm.

	In-hospital mortality				Unfavorable outcome				Radiographic vasospasm			
	Univariate		Multivariable		Univariate		Multivariable		Univariate		Multivariable	
	OR	P value	OR	P value	OR	P value	OR	P value	OR	P value	OR	P value
Age	1.02	.0287			1.04	<.001	1.03	.0341	1.03	.0013		
HH	5.04	<.001			8.68	<.001			7.34	<.001		
GCS	0.66	<.001	0.80	.0285	0.35	<.001	0.53	.0094	0.53	<.001		
WFNS	3.07	<.001			4.15	<.001			3.95	<.001	3.27	<.001
mFS	2.54	<.001	1.70	.0287	1.83	<.001	1.47	.0154	2.82	<.001	3.03	<.001

GCS=Glasgow Coma Scale, HH=Hunt and Hess, mFS=modified Fisher scale, OR=odds ratio, WFNS=World Federation of Neurosurgical Societies.

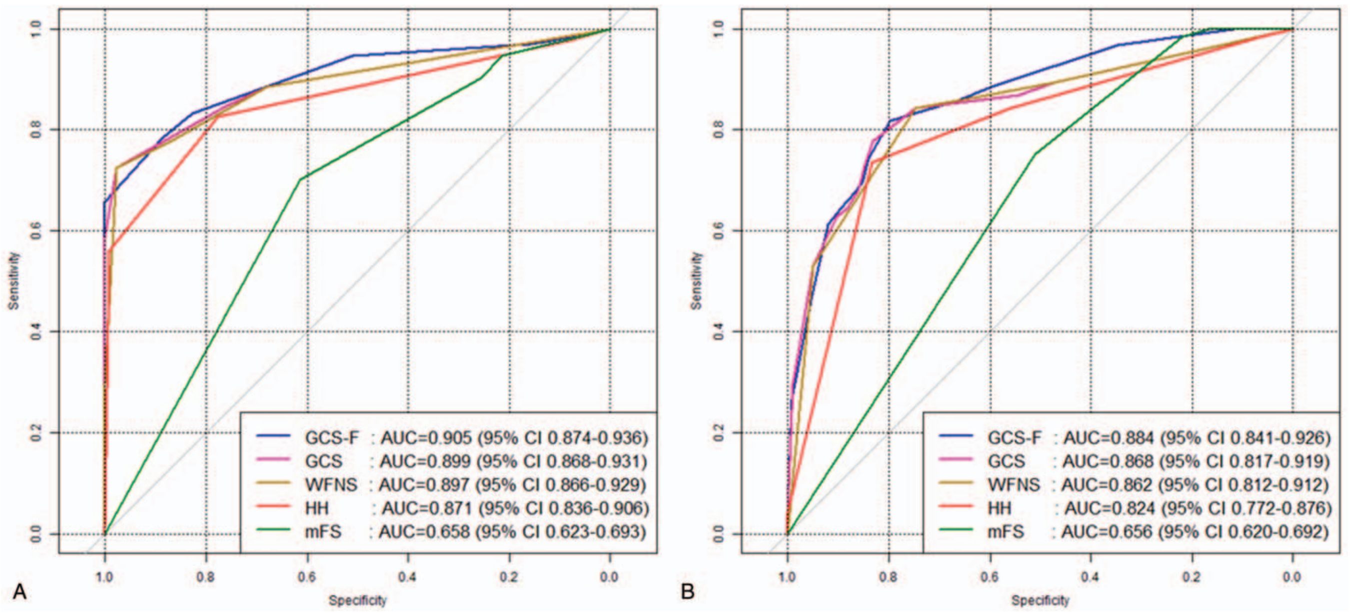

Figure 1. Comparison of the GCS-F score, HH scale, WFNS scale, mFS and GCS score for predicting (A) unfavorable outcome and (B) in-hospital mortality. GCS = Glasgow Coma Scale, HH = Hunt and Hess, mFS = modified Fisher scale, WFNS = World Federation of Neurosurgical Societies.

3.6. GCS-F grading system based on GCS-F score

We developed a method to combine a patient's GCS score and mFS into a single index. The GCS-F score has a broad range of possible values, from 0 to 14. As GCS-F score decreased, the incidence of unfavorable outcome and in-hospital mortality increased (Fig. 2). Breakpoints were derived from comparing the GCS-F scores directly with unfavorable outcomes and in-hospital mortality such that each breakpoint predicted significantly

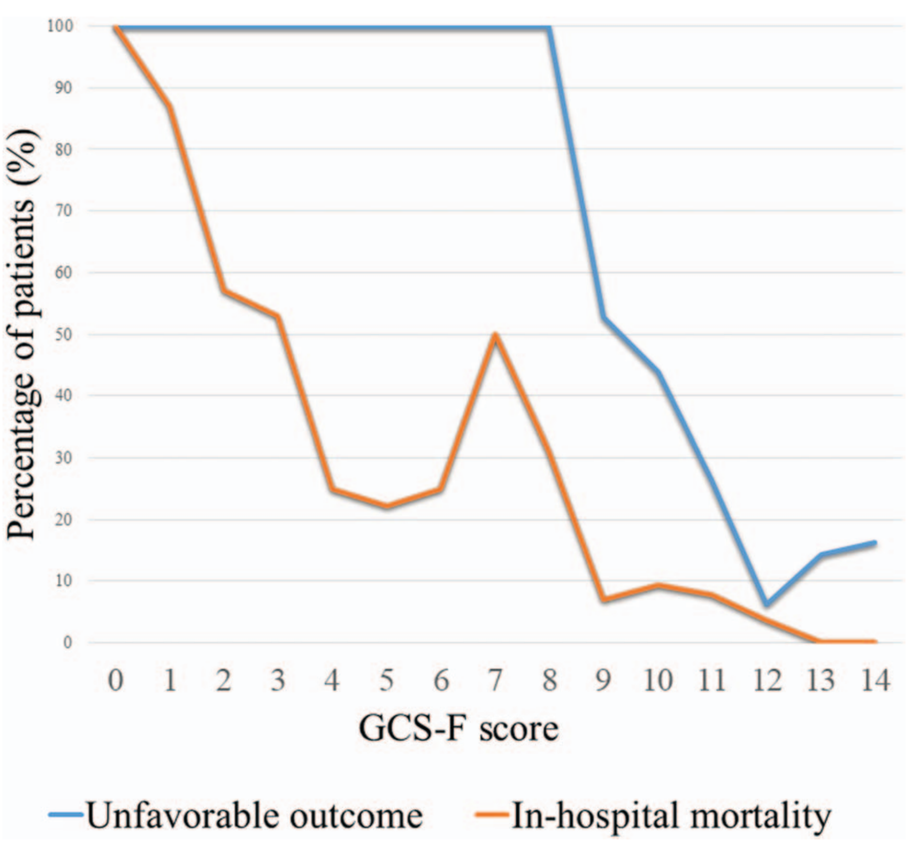

Figure 2. Incidence of unfavorable outcome and in-hospital mortality according to GCS-F score. GCS = Glasgow Coma Scale.

Table 3

Comparison of GCS-F score with other scales for unfavorable outcome and in-hospital mortality.

	Unfavorable outcome					In-hospital mortality				
	AUC	Specificity	Sensitivity	False positive	*P* value	AUC	Specificity	Sensitivity	False positive	*P* value
GCS-F score	0.905	0.899	0.764	0.101		0.884	0.828	0.833	0.172	
GCS score	0.899	0.98	0.72	0.02	.635	0.868	0.775	0.859	0.225	.048
WFNS scale	0.897	0.977	0.724	0.023	.541	0.862	0.748	0.843	0.252	.022
HH scale	0.871	0.798	0.835	0.202	.034	0.824	0.848	0.756	0.152	<.001
mFS	0.658	0.631	0.67	0.369	<.001	0.656	0.54	0.718	0.46	<.001

AUC = area under the curve, GCS = Glasgow Coma Scale, HH = Hunt and Hess, mFS = modified Fisher scale, WFNS = World Federation of Neurosurgical Societies.

different outcomes. We defined the GCS-F grading (GFGRADE) system as follows: GFG 1 = GCS-F score 0 to 3; GFG 2 = GCS-F score 4 to 8; GFG 3 = GCS-F score 9 to 11; GFG 4 = GCS-F score 12 to 14.

The GCS score, HH scale, and WFNS scale each successfully predicted in-hospital mortality and unfavorable outcome in aSAH patients. The GFGRADE system predicted unfavorable outcomes better than the GCS score, HH scale, or WFNS scales on univariate analysis. When controlling for other factors, the GFGRADE was the only scale with predictive value for in-hospital mortality (OR = 0.19; 95% CI 0.13–0.26; $P < .001$) and unfavorable outcome (OR = 0.03; 95% CI 0.01–0.10; $P < .001$).

3.7. Comparison of scoring systems for aSAH

Table 3 presents the AUC for predicting in-hospital mortality and unfavorable outcome using each scale studied, and the *P* values for comparisons of each scale with the GCS-F score. As seen in Table 3 and Figure 1, the GCS-F score had a higher AUC than the GCS score for predicting unfavorable outcome and mortality. However, as shown in Table 3, there was no statistically significant difference for the AUCs between the GCS-F score and GCS score for predicting outcome and mortality.

When comparing the GFGRADE system with other combined grading systems, the VASOGRADE and HAIR score, the GFGRADE system had a higher AUC for predicting unfavorable outcome and in-hospital mortality (Fig. 3). Also, the GFGRADE system had a higher AUC and lower false-positive rate for predicting radiographic vasospasm compared with the existing VASOGRADE or HAIR score, and there was a statistically significant difference (Table 4).

4. Discussion

Initial neurological assessment of patients with aSAH on admission is important for predicting outcomes.[14] The GCS score, HH scale, and WFNS scale are the widely used grading systems, in part because they are easy to access at the initial phase of aSAH. However, these scales were derived clinically; therefore, they suffer from statistical errors and have decreased the power for predicting outcomes after aSAH.[15–17]

The mFS, introduced in 2006, accounts for thick cisternal blood and intraventricular hemorrhage. It was shown to predict the occurrence of symptomatic vasospasm after aSAH more accurately than the original FS, and to be superior in predicting new cerebral infarction and patient outcomes.[6,18] Grading all

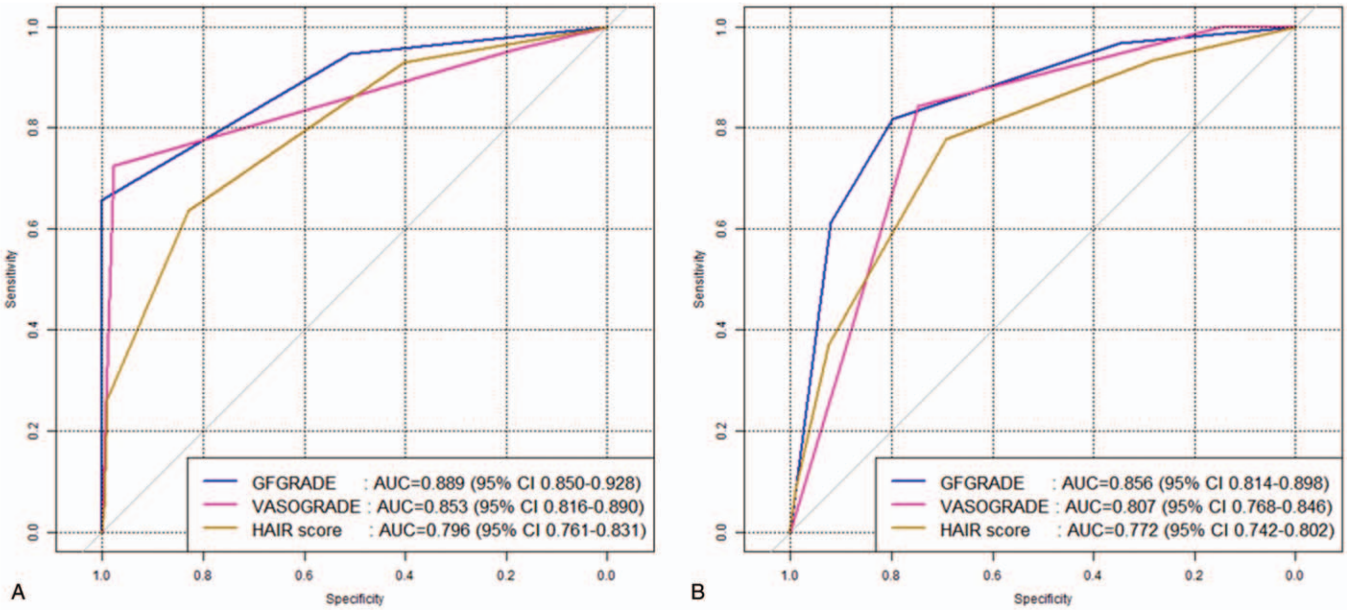

Figure 3. Comparison of the GFGRADE system with HAIR score and VASOGRADE for predicting (A) unfavorable outcome and (B) in-hospital mortality. GFGRADE = GCS-F grading.

Table 4

Comparison of GFGRADE system with other combined grading systems.

	GFGRADE	VASOGRADE	HAIR score
Unfavorable outcome			
AUC	0.889	0.853	0.796
Specificity	1.000	0.977	0.830
Sensitivity	0.657	0.724	0.023
False positive	0.000	0.023	0.170
P value		<.001	<.001
In-hospital mortality			
AUC	0.856	0.807	0.772
Specificity	0.798	0.748	0.693
Sensitivity	0.818	0.843	0.777
False positive	0.202	0.225	0.307
P value		<.001	<.001
Vasospasm			
AUC	0.886	0.867	0.779
Specificity	0.943	0.917	0.786
Sensitivity	0.709	0.781	0.668
False positive	0.057	0.083	0.214
P value		.025	<.001

AUC = area under the curve.

thick SAHs with or without intraventricular hemorrhage as mFS 3 or 4 cannot effectively differentiate those cases with an increasing amount of hematoma, which is one of major concerns of the mFS.

The HH scale is a widely used grading scale after aSAH, but the criteria of the scale are subjective and ambiguous.[5] Several studies have revealed high interobserver variability of the HH scale.[8,19] This problem associated with the HH scale may lead to confusion between physicians in communicating the initial clinical status of patients with aSAH.

The introduction of the GCS score, which defines the level of consciousness with more objective data and which shows high interobserver reliability, led the WFNS scale in 1988 to propose a more reliable grading system for aSAH. The WFNS scale uses the GCS score and presence of focal neurological deficits. If patients have mild focal neurological deficits, it may be unsure whether it is WFNS Scale 2 or 3. In addition, WNFS grade 4 includes a wide range of patients from GCS 7 to 12, so their prognosis cannot be predicted individually. These drawbacks reduce the predictive power of the WFNS scale and may lead to inaccurate conclusions in clinical studies.

Most prognostic scales that predict outcome are based on the level of consciousness and other clinical information obtained on admission. The GCS score is the most widely accepted scale for grading the patient's level of consciousness. The GCS is commonly used in combination with the HH scale, because the GCS has better interobserver reliability. Unfortunately, the GCS suffers from an oversplitting error, as there are significant breakpoints at only a few levels. Studies have combined subgroups of GCS scores in an attempt to decrease these oversplitting errors, to increase interobserver and intraobserver reliability, and to increase its predictive value.

However, the GCS score, HH scale, and WFNS scale were still superior in predicting relevant outcome measures. Disadvantages presented by the nature of clinical scales may include an underestimated risk for conscious patients without severe neurological deficits who have thick hematoma clots in subarachnoid space and ventricles. To overcome the limitations of clinical and radiographic scales, new scores combining clinical and radiographic features, such as the VASOGRADE and HAIR score, have been reported.

The VASOGRADE, which combines the WFNS scale and the mFS, was developed to distinguish between good WFNS grades with and without significant SAH, as well as poor WFNS grades, regarding the prediction of cerebral ischemia.[20,21] Although the VASOGRADE had significant power to predict vasospasm and unfavorable outcome in our study, the GCS-F score was superior to the VASOGRADE. According to Lee et al,[13] the HAIR score was developed to predict in-hospital mortality, and in-hospital mortality increases with an increasing HAIR score. In our study, the predictive performance of the HAIR score was significantly inferior to the GCS-F score.

In this study, we validated a new scoring system, the GCS-F score, a simple and unidimensional scale calculated by an easy method, to predict in-hospital mortality, unfavorable outcomes, and the development of radiographic vasospasm. The GCS-F score proposed in our study includes the radiographic status as well as the clinical status of the patient, so that the state of the patient can be known in more detail than other single scales.

We found the GFGRADE system, which was based on the GCS-F score, to be accurate in predicting in-hospital mortality and unfavorable outcome. The GCS-F score is meaningful because it is easy to obtain from initial data, and it can predict not only the patients' outcomes, but also the radiographic vasospasm after aSAH. In our study, the predictive performance of the GCS-F score was found to be accurate for unfavorable outcome and radiographic vasospasm.

This study has several limitations. First, due to the retrospective nature of our study, our findings may be less accurate when compared with data from a planned, prospective study. Some patients with aSAH may die without coming to the hospital. Therefore, there may be some selection bias. Moreover, the fact that it is a single-center study could limit the generalizability of our findings. Second, the small number of patients may have reduced the statistical power and validation. Thus, these results need to be validated in independent cohorts with larger numbers. However, despite these limitations, the GCS-F score showed promise as a useful clinical grading system for aSAH patients. Prospective validation and potential refinement of this grading system are necessary before its application can be recommended.

A simple combination of the GCS score and mFS, the GCS-F score, extends the information provided about patient outcome to an extent comparable to that obtained using more complex methods. The predictive performance of the GCS-F score was found to be accurate for overall patient outcome and the occurrence of radiographic vasospasm. The GCS-F score may be a useful scoring system for predicting outcomes and occurrence of vasospasm in patients with aSAH.

Author contributions

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Writing – original draft: In-Suk Bae.
Writing – review & editing: In-Suk Bae, Hyeong-Joong Yi.

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