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Predictors of early functional outcome after microsurgical clipping of ruptured intracranial aneurysms: A retrospective series focusing on ventricular system variables

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Abstract

Early functional status after aneurysmal subarachnoid hemorrhage (aSAH) reflects the interaction of admission severity, hemorrhage burden, ventricular involvement, and systemic complications. This study examined clinical, radiological, ventricular-system, and metabolic factors associated with early outcome in patients who underwent microsurgical clipping for ruptured intracranial aneurysms. We retrospectively reviewed 43 adult patients treated with surgical clipping between January 2022 and April 2026. Functional outcome was graded with the Glasgow Outcome Score (GOS) at the first-month follow-up after discharge or, for patients who died before follow-up, according to the last available in-hospital outcome status. Outcomes were classified as favorable for GOS 4-5 and unfavorable for GOS 1-3, with GOS 1 representing death. Ventricular-system involvement was evaluated using continuous Evans index values, the Evans index ≥ 0.30 threshold, intraventricular hemorrhage (IVH), external ventricular drainage (EVD) requirement, and shunt requirement. Twenty-six patients (60.5%) had a favorable outcome, while 17 patients (39.5%) had an unfavorable outcome. WFNS score and Fisher grade were higher in the unfavorable outcome group. EVD requirement, rebleeding, metabolic disturbance, and intracerebral hematoma were also associated with unfavorable outcome. Continuous Evans index values were not significant; however, the Evans index ≥ 0.30 threshold was associated with unfavorable outcome, EVD requirement, and shunt requirement. Of seven patients treated with EVD, only one later required shunt placement, whereas five had GOS 1/death. Early unfavorable outcome after aSAH appears to result from the combined influence of admission severity, hemorrhage burden, acute CSF diversion need, rebleeding, intracerebral hematoma, and metabolic deterioration rather than a single radiological measure. Evans index ≥ 0.30 may be a clinically meaningful threshold for ventricular enlargement.

Keywords: Subarachnoid hemorrhage, intracranial aneurysm, neurosurgical procedures, ventricular drainage, Glasgow Outcome Scale, treatment outcome

Introduction

Aneurysmal subarachnoid hemorrhage (aSAH) is a high-risk neurovascular condition in which early recognition and timely aneurysm treatment are central to patient management [1,2]. Contemporary recommendations focus on rapid diagnosis, early exclusion of the ruptured aneurysm from the circulation, maintenance of cerebral perfusion, and reduction of secondary neurological injury [1,2]. Prolonged time from aneurysm rupture to treatment may worsen the early clinical course and functional outcome [3].

Outcomes after aSAH depend on the initial bleeding severity as well as secondary intracranial and systemic events, including delayed cerebral ischemia, vasospasm, rebleeding, IVH, ICH, hydrocephalus-related changes, and laboratory abnormalities [4,5]. Accordingly, early risk stratification has become an important focus in recent aSAH research. Recent studies have explored individualized decision tools, vasospasm/DCI prediction models, quantitative hemorrhage assessment, ventricular measurements, biomarker-based approaches, laboratory nomograms, and machine-learning models for outcome estimation [6-9].

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Many contemporary prediction-model studies have been developed using multicenter cohorts, mixed treatment populations, or heterogeneous clinical-radiological datasets [6,10-12]. Therefore, we analyzed whether demographic characteristics, admission severity, radiological findings, ventricular-system parameters, and metabolic disturbances were associated with early functional outcome after microsurgical clipping of ruptured intracranial aneurysms. The analysis specifically addressed admission severity, hemorrhage burden, ventricular enlargement, EVD requirement, shunt requirement, and early complications as factors related to unfavorable clinical outcome.

Material and Methods

This was a retrospective analysis of patients treated with microsurgical clipping for ruptured intracranial aneurysms. Adult consecutive cases managed by surgical clipping at our institution between January 2022 and April 2026 were eligible when clinical, imaging, perioperative, and outcome data were available. Data were extracted from archived patient files and electronic hospital records. Ethical approval was obtained from the İzmir Bakırçay University Non-Interventional Clinical Research Ethics Committee, dated April 28, 2026, with decision number 2908. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The cohort included patients with aneurysm-related subarachnoid hemorrhage who underwent clipping. Exclusion criteria were endovascular treatment, unruptured or incidental aneurysm, conservative management, and missing essential outcome information.

Recorded variables included age, sex, aneurysm site, admission grade, hemorrhage severity on imaging, ventricular-system parameters, and accompanying intracranial lesions. We also assessed vasospasm, need for EVD, permanent shunt placement, rebleeding, ICH, IVH, and metabolic abnormalities.

Aneurysm sites were recorded anatomically and were grouped as anterior or posterior circulation when appropriate. Clinical severity at admission was graded with the World Federation of Neurosurgical Societies (WFNS) score, and radiological hemorrhage burden was evaluated with the Fisher grade.

Postoperative radiological assessment was performed with cranial CT on postoperative day 1. Although the timing of subsequent CT examinations was determined according to the clinical course, patients with an uncomplicated postoperative course underwent repeat cranial CT between postoperative days 12 and 14 before discharge.

Ventricular involvement was characterized by continuous Evans index values, the Evans index ≥ 0.30 threshold, IVH status, EVD use, and permanent shunt placement. For additional analysis, patients with at least one of the following variables - Evans index ≥ 0.30, IVH, EVD requirement, or shunt requirement - were classified as having at least one ventricular-system finding or intervention. Patients with at least two of these findings were classified as having multiple ventricular-system involvement.

Functional status was graded with the Glasgow Outcome Score (GOS). GOS was determined at the first post-discharge month when available; deaths occurring before that time were coded as GOS 1 according to the final in-hospital record. For analysis, favorable outcome was defined as GOS 4 – 5 and unfavorable outcome as GOS 1 – 3. GOS 1 was accepted as death. In patients treated with EVD, shunt requirement was interpreted together with GOS 1/death status, because early mortality may occur before permanent cerebrospinal fluid (CSF) diversion becomes clinically apparent.

Dataset coding was standardized before statistical analysis. The sign "+" indicated that the relevant clinical or radiological finding was present, "-" indicated absence, and "N" indicated normal findings. Metabolic status was categorized as normal or abnormal according to predefined sodium and glucose thresholds. Hyponatremia was defined as serum sodium < 136 mmol/L, hypernatremia as serum sodium > 145 mmol/L, and hyperglycemia as serum glucose > 140 mg/dL. The metabolic disturbance group included any patient meeting criteria for hypo-/hypernatremia or hyperglycemia.

Analyses were conducted in Python 3.13.5 using the SciPy, pandas, and NumPy libraries. Continuous and ordinal variables were summarized as mean +/- standard deviation and/or median, minimum-maximum, and interquartile range (IQR), whereas categorical variables were reported as number (n) and percentage (%). Given the small sample size and the ordinal distribution of several variables, continuous and ordinal parameters were compared between outcome groups with the Mann-Whitney U test. Categorical variables were evaluated with Fisher's exact test when expected cell counts were low in 2x2 tables; Pearson's chi-square test was used when appropriate. All tests were two-tailed, and $p < 0.05$ was considered statistically significant. Multivariable logistic regression was avoided because the cohort and event numbers were insufficient for stable model estimation.

Results

The final cohort consisted of 43 patients. The mean age was 55.3 +/- 13.1 years, and the median age was 55 years (range, 30 – 85); 24 patients (55.8%) were male. Based on the combined follow-up and final in-hospital outcome assessment, favorable outcome (GOS 4 – 5) was observed in 26 patients (60.5%), whereas unfavorable outcome (GOS 1 – 3) was observed in 17 patients (39.5%). GOS 1/death was recorded in 16 patients (37.2%).

The most frequent aneurysm sites were the anterior communicating artery (16/43, 37.2%) and middle cerebral artery bifurcation (12/43, 27.9%). Posterior circulation aneurysms were identified in 6 patients (14.0%). In the overall cohort, vasospasm occurred in 12 patients (27.9%), EVD was required in 7 patients (16.3%), shunt placement in 3 patients (7.0%), rebleeding in 7 patients (16.3%), metabolic disturbance in 11 patients (25.6%), ICH in 9 patients (20.9%), and IVH in 11 patients (25.6%).

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Representative preoperative cranial CT showing subarachnoid hemorrhage and postoperative cranial CT demonstrating the clip position in a patient with a ruptured anterior communicating artery aneurysm and a favorable functional outcome are presented in Figure 1.

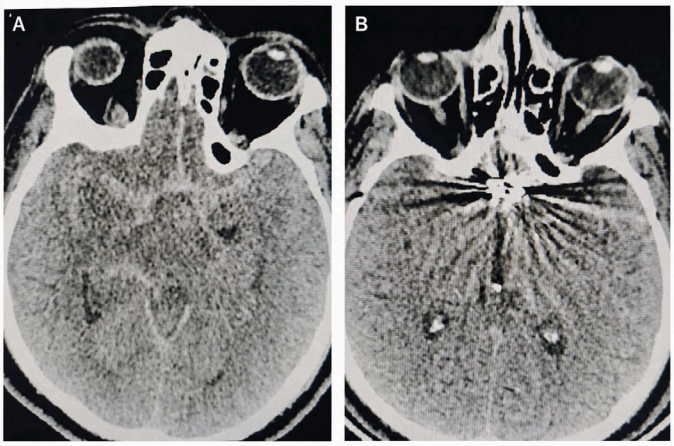

Figure 1. Representative cranial CT images of a patient with a ruptured anterior communicating artery aneurysm and a favorable functional outcome; (**A**) Preoperative cranial CT showing subarachnoid hemorrhage; (**B**) Postoperative cranial CT demonstrating the aneurysm clip

Representative preoperative cranial CT showing subarachnoid hemorrhage and postoperative cranial CT demonstrating the clip position in a patient with a ruptured middle cerebral artery aneurysm and an unfavorable functional outcome are presented in Figure 2.

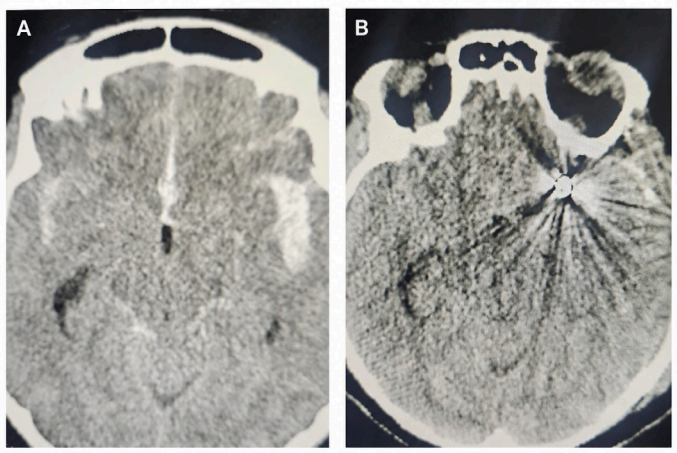

Figure 2. Representative cranial CT images of a patient with a ruptured middle cerebral artery aneurysm and an unfavorable functional outcome; (**A**) Preoperative cranial CT showing subarachnoid hemorrhage; (B) Postoperative cranial CT demonstrating the aneurysm clip

Comparisons between outcome groups showed greater clinical and radiological severity at admission among patients with unfavorable outcome. The median WFNS score was 4.0 (IQR 3.0 – 4.0) in the unfavorable outcome group and 2.0 (IQR 1.0 – 2.0) in the favorable outcome group (Mann-Whitney U, U = 387.5, p < 0.001). Similarly, the median Fisher grade was 4.0 (IQR 3.0 – 4.0) in the unfavorable outcome group and 2.0 (IQR 2.0 – 3.0) in the favorable outcome group (U = 337.5, p = 0.002). Age was numerically higher in the unfavorable outcome group, although the difference was not statistically significant (58 (48 – 70) years vs. 54.5 (46 – 62) years; U = 274.0, p = 0.191). When the Evans index was evaluated as a continuous variable, no significant difference was observed between outcome groups (0.25 (0.16 – 0.31) vs. 0.25 (0.20 – 0.28); U = 219.5, p = 0.98).

Among categorical parameters, EVD use was more common in patients with unfavorable outcome (35.3% vs. 3.8%; Fisher's exact p = 0.011). Rebleeding (35.3% vs. 3.8%; p = 0.011), metabolic disturbance (52.9% vs. 7.7%; p = 0.003), and ICH (41.2% vs. 7.7%; p = 0.018) were also significantly associated with unfavorable outcome. Sex, posterior circulation location, vasospasm, shunt requirement, and IVH did not differ significantly between outcome groups (p = 0.21, p = 0.19, p = 0.17, p = 0.55, and p = 0.08, respectively).

Ventricular-system parameters were then examined separately. Evans index ≥ 0.30 was present in 9/43 patients (20.9%). Patients with Evans index ≥ 0.30 had a higher rate of unfavorable outcome (77.8% vs. 29.4%; Fisher's exact p = 0.018). Among the 9 patients with Evans index ≥ 0.30, 7 underwent EVD (77.8%); no patient with Evans index < 0.30 required EVD (0/34; p < 0.001). Among patients with Evans index ≥ 0.30, 3 required shunt placement (33.3%); no patient with Evans index < 0.30 underwent shunt placement (0/34; p = 0.007).

In the specific analysis of EVD and subsequent shunt placement, only 1 of 7 patients who underwent EVD required shunt placement (14.3%), whereas 2 of 36 patients without EVD required shunt placement (5.6%); this difference was not statistically significant (p = 0.42). Nevertheless, EVD-treated patients were predominantly represented in the unfavorable outcome group. Among the 7 patients with EVD, 5 had GOS 1/death, 1 had GOS 2, and 1 had GOS 4. The association between EVD and GOS 1/death did not reach statistical significance but showed a numerical trend (71.4% vs. 30.6%; p = 0.082). EVD was significantly associated with unfavorable outcome (85.7% vs. 30.6%; p = 0.011) (Table 1). The anonymized patient-level clinical, radiological, operative, and outcome dataset is presented in Table 2.

IVH showed a significant relationship with EVD use. Among 11 patients with IVH, 5 underwent EVD (45.5%); among 32 patients without IVH, this rate was 2/32 (6.3%) (p = 0.008). In contrast, IVH was not significantly associated with shunt requirement (9.1% vs. 6.3%; p = 1.00). Death occurred more often in the IVH group than in the non-IVH group numerically (54.5% (6/11) vs. 31.3% (10/32)); however, this difference was not statistically significant (Fisher's exact p = 0.278).

When ventricular-system burden was evaluated as a composite variable, unfavorable outcome was more frequent in patients with at least one ventricular-system finding or CSF diversion

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intervention (66.7% vs. 25.0%; p = 0.011). This relationship was stronger in patients with two or more ventricular-system findings/interventions (77.8% vs. 29.4%; p = 0.018).

Overall, early unfavorable functional outcome was associated with higher WFNS score, higher Fisher grade, EVD requirement, rebleeding, metabolic disturbance, ICH, and ventricular enlargement defined by Evans index ≥ 0.30. Although continuous Evans index values were not significant, crossing the 0.30 threshold showed a more clinically meaningful association with unfavorable outcome, EVD use, and shunt placement.

Table 1. Distribution of shunt requirement and GOS 1/death according to EVD status

Variable	EVD present n = 7	EVD absent n = 36	p
Shunt requirement	1/7 (14.3%)	2/36 (5.6%)	0.42
GOS 1 / death	5/7 (71.4%)	12/36 (33.3%)	0.093
Unfavorable outcome, GOS 1-3	6/7 (85.7%)	12/36 (33.3%)	0.015
Favorable outcome, GOS 4-5	1/7 (14.3%)	24/36 (66.7%)	0.015

EVD: external ventricular drainage, GOS: Glasgow Outcome Score

Table 2. Aneurysm operation table (Anonymized)

Age	Sex	WFNS	Fisher	Aneurysm	GOS	Op. date	Craniotomy	Hydrocephalus	Evans	Vasospasm	EVD	Shunt	Rebleed	Metabolic	ICH	IVH
35	M	3	3	Anterior communicating artery	1	12.01.2022	Right pterional	-	0.22	+	-	-	+	N	-	-
54	F	1	4	Anterior cerebral artery (A2-A3 junction)	5	18.02.2022	Interhemispheric	-	0.24	-	-	-	-	N	+	-
77	F	2	3	Anterior cerebral artery (A2-A3 junction)	5	11.04.2022	Interhemispheric	-	0.27	-	-	-	-	N	-	-
65	F	2	3	Middle cerebral artery (bifurcation)	5	05.05.2022	Right pterional	-	0.25	-	-	-	-	N	-	-
62	M	1	2	Anterior communicating artery	5	01.06.2022	Right pterional	-	0.19	-	-	-	-	N	-	-
58	M	3	3	Middle cerebral artery (bifurcation)	1	03.06.2022	Right pterional	-	0.25	+	-	-	-	Na ↑	+	-
47	M	2	2	Middle cerebral artery (bifurcation)	5	05.06.2022	Left pterional	-	0.22	-	-	-	-	N	-	-
75	F	4	4	PICA	1	24.06.2022	Right median suboccipital	+	0.32	-	+	-	-	Na ↓	-	+
60	F	1	2	Anterior communicating artery	5	26.08.2022	Right pterional	-	0.16	-	-	-	-	N	-	-
36	M	1	2	Middle cerebral artery (bifurcation)	5	25.09.2022	Left pterional	-	0.19	-	-	-	-	N	-	-
57	F	3	3	Anterior communicating artery	1	16.11.2022	Right pterional	-	0.16	+	-	-	-	Na ↓	-	-
58	F	4	4	Anterior cerebral artery (A1)	1	21.12.2022	Right pterional	-	0.15	+	-	-	-	N	+	-
48	M	1	2	Middle cerebral artery (bifurcation)	5	17.02.2023	Left pterional	-	0.26	-	-	-	-	N	-	-
42	F	2	3	Posterior communicating artery	1	12.04.2023	Right pterional	-	0.15	+	-	-	-	Na ↑	-	-
48	F	4	4	Middle cerebral artery (bifurcation)	1	14.06.2023	Left pterional	-	0.16	+	-	-	-	Na ↓	+	-
34	M	1	2	Anterior communicating artery	5	26.06.2023	Right pterional	-	0.28	-	-	-	-	Na ↓	-	-
46	M	4	4	Distal right anterior choroidal artery	4	06.09.2023	Transcortical	+	0.34	-	+	-	-	N	+	+
30	F	3	2	Middle cerebral artery (bifurcation)	4	01.11.2023	Left pterional	-	0.27	+	-	-	-	N	-	-
85	F	2	2	Anterior communicating artery	1	06.11.2023	Right pterional	+	0.31	-	-	+	-	N	-	-
62	M	1	3	Anterior communicating artery	4	05.04.2023	Right pterional	-	0.29	-	-	-	-	N	-	-

Patient names and protocol numbers were removed for anonymization; Values are presented at the patient level; The signs "+" and "–" indicate presence and absence of the relevant finding, respectively, and "N" indicates normal findings; ACom+MCA cases were classified as ACom when the ruptured aneurysm was accepted as ACom; WFNS: World Federation of Neurosurgical Societies, GOS: Glasgow Outcome Score, EVD: external ventricular drainage, ICH: intracerebral hematoma, IVH: intraventricular hemorrhage, MCA: middle cerebral artery, ACom: anterior communicating artery, PICA: posterior inferior cerebellar artery, AICA: anterior inferior cerebellar artery, SCA: superior cerebellar artery, Na: sodium

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Table 2. Aneurysm operation table (Anonymized)

Age	Sex	WFNS	Fisher	Aneurysm	GOS	Op. date	Craniotomy	Hydrocephalus	Evans	Vasospasm	EVD	Shunt	Rebleed	Metabolic	ICH	IVH
58	M	4	4	Posterior communicating artery	1	06.12.2023	Right pterional	+	0.31	-	+	-	+	Na ↑	+	-
55	M	1	2	Anterior communicating artery	5	19.12.2023	Left pterional	-	0.29	-	-	-	-	N	-	-
62	F	2	2	Anterior cerebral artery (A2-A3 junction)	5	29.12.2023	Interhemispheric	-	0.28	-	-	-	-	N	-	-
48	M	5	4	Middle cerebral artery (bifurcation)	1	23.01.2024	Left pterional	-	0.15	-	-	-	+	N	+	+
79	M	4	3	SCA	1	24.01.2024	Left subtemporal	+	0.33	-	+	-	-	Na ↑	-	+
50	M	3	3	Anterior communicating artery	5	21.02.2024	Left pterional	-	0.29	+	-	-	-	N	-	-
55	M	5	4	Middle cerebral artery (bifurcation)	1	02.03.2024	Left pterional	-	0.25	-	-	-	+	N	+	+
44	M	2	2	Posterior communicating artery	4	22.05.2024	Right pterional	-	0.14	-	-	-	-	Na ↑	-	-
55	M	3	2	Anterior communicating artery	5	11.10.2024	Left pterional	-	0.16	-	-	-	-	N	-	-
77	F	2	4	PICA	1	06.11.2024	Right median suboccipital	-	0.12	-	-	-	-	Glucose ↑	-	+
54	F	2	3	Anterior communicating artery	5	10.02.2025	Left pterional	+	0.32	-	-	+	-	N	-	-
70	F	3	2	Anterior communicating artery* and middle cerebral artery	1	30.11.2022	Right pterional	+	0.31	-	+	-	-	N	-	-
65	M	2	4	AICA	4	13.10.2023	Right retrosigmoid	-	0.18	-	-	-	-	N	-	+
67	F	2	2	Middle cerebral artery (bifurcation)	5	15.11.2023	Right pterional	-	0.17	-	-	-	-	N	-	-
58	F	5	4	Middle cerebral artery (bifurcation)	1	04.03.2025	Right pterional	-	0.19	-	-	-	+	Na ↑	+	-
30	M	2	3	Anterior communicating artery	5	17.03.2025	Left pterional	-	0.20	+	-	-	-	N	-	-
55	F	3	4	SCA	4	05.05.2025	Right subtemporal	-	0.24	-	-	-	-	N	-	+
45	M	1	1	Anterior communicating artery	4	21.08.2024	Right pterional	-	0.25	+	-	-	+	N	-	-
56	M	4	4	Anterior communicating artery	5	20.05.2025	Left pterional	-	0.25	+	-	-	-	N	-	+
44	M	4	4	Basilar tip	2	01.08.2025	Right subtemporal	-	0.30	+	+	+	-	N	-	+
46	M	1	3	Middle cerebral artery (bifurcation)	5	21.10.2025	Right pterional	-	0.29	-	-	-	-	N	-	-
70	M	1	2	Anterior cerebral artery (A2-A3 junction)	5	14.02.2026	Interhemispheric	-	0.24	-	-	-	-	N	-	-
58	F	4	4	Anterior communicating artery* + middle cerebral artery	1	14.04.2026	Right pterional	-	0.34	-	+	-	+	N	-	+

Patient names and protocol numbers were removed for anonymization; Values are presented at the patient level; The signs "+" and "–" indicate presence and absence of the relevant finding, respectively, and "N" indicates normal findings; ACom+MCA cases were classified as ACom when the ruptured aneurysm was accepted as ACom; WFNS: World Federation of Neurosurgical Societies, GOS: Glasgow Outcome Score, EVD: external ventricular drainage, ICH: intracerebral hematoma, IVH: intraventricular hemorrhage, MCA: middle cerebral artery, ACom: anterior communicating artery, PICA: posterior inferior cerebellar artery, AICA: anterior inferior cerebellar artery, SCA: superior cerebellar artery, Na: sodium

Discussion

In this retrospective clipping series, unfavorable early functional outcome was mainly linked to higher WFNS score, higher Fisher grade, EVD requirement, rebleeding, metabolic disturbance, ICH, and ventricular enlargement defined by Evans index ≥ 0.30. This pattern agrees with previous reports highlighting the roles of initial clinical severity, hemorrhage burden, ventricular-system involvement, and systemic-laboratory deterioration in determining outcome after aSAH [1,2,5].

Admission neurological status emerged as one of the clearest outcome-related variables in our cohort. The higher median WFNS score among patients with unfavorable outcome reinforces the importance of baseline clinical grade in the early functional course. Contemporary prognostic models and clinical series have also reported a close association between higher neurological grade and unfavorable outcome [5,13,14]. Evidence that early risk factors may worsen outcome even in patients with initially favorable neurological status further supports the importance of admission clinical grading [13].

The parallel increase in Fisher grade among patients with unfavorable outcome indicates that subarachnoid blood load has clinical relevance beyond descriptive imaging. Increased

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hemorrhage burden has been associated with delayed cerebral ischemia and unfavorable functional outcome in both pathophysiological reviews and modern volume-based imaging studies [4,8]. Therefore, the association between Fisher grade and unfavorable outcome in our series is clinically meaningful.

For ventricular-system assessment, we prioritized variables that were objective and clinically time-dependent: Evans index, Evans index ≥ 0.30, IVH, EVD, and shunt requirement. In our study, continuous Evans index values were not associated with outcome, whereas Evans index ≥ 0.30 was significantly associated with unfavorable outcome. This pattern suggests that Evans index may be more informative as a threshold-based marker than as a strictly linear outcome variable [9,15].

The fact that most patients with Evans index ≥ 0.30 required EVD demonstrates a close relationship between this ventricular enlargement threshold and acute CSF drainage need. However, not every patient with Evans index ≥ 0.30 underwent EVD. This observation indicates that EVD placement should be interpreted as a clinical-radiological decision rather than a response to ventricular size alone. In other words, Evans index ≥ 0.30 may serve as a warning radiological parameter for acute EVD requirement but should not be considered a sufficient indication on its own.

An important observation was that every patient who required shunt placement belonged to the Evans index ≥ 0.30 subgroup. Previous studies have also emphasized the inclusion of ventricular measurements and radiological features in prognostic models for permanent CSF diversion requirement [9,15]. In contrast, our series showed no significant association between EVD and shunt requirement. At first glance, the finding that only 1 of 7 EVD-treated patients later underwent shunting may appear to indicate a low rate of permanent CSF diversion after temporary drainage. This interpretation requires caution because 5 EVD-treated patients had GOS 1/death, and many may not have survived long enough to develop a clinically apparent shunt requirement.

Accordingly, the low shunt rate in the EVD group should not be interpreted as evidence that EVD reduced permanent shunt requirement. A more plausible explanation is that EVD requirement reflected a more severe acute clinical condition and that early mortality in this group created a potential competing-risk or survival bias for subsequent shunt dependency. Thus, EVD may represent acute clinical-radiological decompensation, whereas shunt requirement may indicate a later form of persistent CSF circulation disorder. Although these outcomes are located on the same pathophysiological axis, their timing and clinical meaning differ.

The observed relationship between IVH and EVD use is clinically plausible. Intraventricular blood can obstruct the ventricular system, impair CSF circulation, and increase the need for acute drainage. In our series, EVD was markedly more frequent among patients with IVH, whereas IVH was not significantly associated with shunt requirement. Mortality was also numerically higher in patients with IVH than in those without IVH, but this difference did not reach statistical significance. In this cohort, IVH therefore appears to represent acute CSF drainage demand more than a reliable indicator of later shunt dependence or death. A competing-risk mechanism may still be relevant: if a subgroup of patients with IVH experienced early death or severe early unfavorable outcome, subsequent shunt dependency could have been underestimated because these patients may not have survived long enough to develop a clinically apparent need for permanent CSF diversion. However, this interpretation should remain cautious because the association between IVH and mortality did not reach statistical significance in the present analysis.

Recent imaging studies also support the relationship of IVH and other imaging scores with complications, mortality, and functional outcome [15].

Rebleeding was another clinically relevant variable associated with poor early outcome. Current guidelines and contemporary reviews clearly state that one of the main reasons for securing the ruptured aneurysm as early as possible is to prevent rebleeding [1,2]. In our cohort, rebleeding was markedly more frequent in the unfavorable outcome group, emphasizing the importance of both aneurysm treatment and treatment timing. Recent prognostic studies also support the association between rebleeding and ischemic complications or poor clinical course [16].

The relationship between ICH and unfavorable outcome also aligns with prior imaging-outcome literature. Parenchymal hemorrhage accompanying aSAH may produce mass effect, local tissue injury, and cerebral edema, thereby contributing to a more severe brain injury pattern. Recent imaging and outcome studies have shown that increased intracranial blood burden and early computed tomography findings are associated with functional deterioration [8,17]. In this context, the association between ICH and unfavorable outcome in our series is expected.

The association between metabolic disturbance and unfavorable outcome deserves particular attention. Systemic and laboratory abnormalities are increasingly recognized as contributors to the clinical course and outcome after aSAH. Prognostic models incorporating hemoglobin level, inflammatory markers, complement components, renal function, acid-base status, and cardiac electrophysiological parameters demonstrate the importance of systemic physiological balance in outcome prediction [18-23]. In our study, metabolic disturbance was analyzed as a combined variable defined by hyponatremia, hypernatremia, or hyperglycemia. Future studies with larger samples should evaluate sodium and glucose abnormalities separately rather than as a combined metabolic category. Therefore, this finding should be interpreted as an indicator of overall systemic metabolic dysregulation rather than the independent prognostic effect of a single sodium or glucose abnormality.

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Age was numerically higher in the unfavorable outcome group but did not reach statistical significance. Although advanced age is often reported as a predictor of unfavorable functional outcome in the literature, the strength of this association varies across series [1,2,14]. In our study, the lack of statistical significance may reflect the limited sample size or the stronger influence of early complications. Similarly, the absence of statistically significant associations for variables such as vasospasm and IVH in univariate outcome comparisons may be related to limited event numbers, small sample size, or variability in diagnostic and therapeutic practices over time [4,24,25].

This study is limited by its retrospective design, small cohort size, single-center setting, early outcome endpoint, and lack of multivariable modeling. The relatively small sample size reduces statistical power, particularly in subgroup analyses, limits the generalizability of the findings, and may have contributed to the lack of statistical significance observed for vasospasm and IVH. Because functional outcome was assessed at the first post-discharge month or according to the final in-hospital status in patients who died earlier, the results should be interpreted as reflecting early functional outcome rather than long-term neurological recovery. Accordingly, the first-month or final in-hospital GOS assessment may not fully capture subsequent neurological recovery and should not be considered representative of long-term functional outcome. In addition, the small number of events in some subgroups requires cautious interpretation of the relationships among EVD, shunt requirement, IVH, and GOS 1/death. Nevertheless, assessment of ventricular-system involvement through Evans index, IVH, EVD, and shunt requirement allowed a clinically differentiated evaluation of CSF circulation-related variables

Conclusion

In this microsurgical clipping series of ruptured intracranial aneurysms, unfavorable early functional outcome was associated mainly with higher admission severity, increased hemorrhage burden, EVD requirement, rebleeding, metabolic disturbance, and ICH. Although continuous Evans index values were not significant, the Evans index ≥ 0.30 threshold was associated with unfavorable outcome, EVD requirement, and shunt requirement, suggesting that ventricular enlargement may become clinically relevant after a defined threshold is exceeded. IVH was not directly associated with unfavorable outcome or shunt requirement, but it was strongly associated with EVD requirement. Mortality was numerically higher in patients with IVH, although this difference was not statistically significant. The low shunt rate among EVD-treated patients should not be interpreted as a protective effect, because 5 of 7 patients in this group had GOS 1/death, and early mortality may have shortened the time needed for later shunt dependency to become apparent. Overall, these findings indicate that early outcome after aSAH should be interpreted through the combined influence of clinical grade, hemorrhage severity, acute CSF diversion need, rebleeding, parenchymal hemorrhage, and systemic-metabolic deterioration rather than through any single radiological measure.

Ethical Approval

Ethical approval was obtained from the İzmir Bakırçay University Non-Interventional Clinical Research Ethics Committee, dated April 28, 2026, with decision number 2908.

Patient Consent

Written informed consent was obtained from the patients. Additionally, this was a retrospective study based on archived medical records. All patient data were analyzed anonymously without including any personally identifiable information.

Conflict of Interest

The authors confirm the absence of any conflicts associated with this work.

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