Turkish Journal of Clinical Research

Turk J Clin Res. 2026;2(1):15-21
https://doi.org/10.63909/1453039

RESEARCH ARTICLE

Surgical outcomes of intracranial aneurysms: A single-center experience with 90 patients

İntrakraniyal anevrizmaların cerrahi sonuçları: 90 hastalık tek merkez deneyimi

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Abstract

Aim: Intracranial aneurysms are a major cause of subarachnoid hemorrhage (SAH) and remain associated with substantial morbidity and mortality. This study aimed to evaluate surgical outcomes of patients with intracranial aneurysms treated at our institution and to interpret these results in the context of the published literature.

Methods: This retrospective, single-center study included 90 consecutive patients who underwent microsurgical treatment for intracranial aneurysms between January 2008 and June 2012. Clinical status on admission was assessed using the Hunt–Hess and World Federation of Neurosurgical Societies (WFNS) grading systems, and radiological severity was graded according to the Fisher scale. Outcomes were in-hospital mortality, postoperative complications, and functional status at discharge measured by the Glasgow Outcome Scale (GOS). Associations between admission grades and mortality were assessed using univariate analyses.

Results: Of the 90 patients, 54 (60%) were female and 36 (40%) were male. Mean age was 59 years in females and 52.5 years in males. SAH was present in 94.4% of patients. The most common aneurysm location was the anterior communicating artery (43.3%), followed by the middle cerebral artery (22.2%). Overall survival was 80%, and in-hospital mortality was 20%. Higher Fisher and Hunt–Hess grades were strongly associated with mortality. A favorable functional outcome (GOS 5) at discharge was achieved in 63.3% of patients.

Conclusion: Higher admission clinical grades and greater hemorrhage burden were associated with increased in-hospital mortality in this surgical series. Early aneurysm securing was frequently performed; however, causal conclusions regarding timing cannot be drawn due to the retrospective design. Larger, contemporary, multicenter studies incorporating multivariable modeling are needed to identify independent predictors of outcome and to better define the role of microsurgery alongside endovascular approaches.

Keywords: Intracranial aneurysm, subarachnoid hemorrhage, surgical clipping, Hunt–Hess.

Özet

Amaç: İntrakraniyal anevrizmalar subaraknoid kanamanın (SAK) başlıca nedenlerinden biridir ve önemli düzeyde morbidite ve mortalite ile ilişkisini sürdürmektedir. Bu çalışmanın amacı, kurumumuzda intrakraniyal anevrizma nedeniyle tedavi edilen hastaların cerrahi sonuçlarını değerlendirmek ve bu sonuçları yayımlanmış literatür bağlamında yorumlamaktır.

Yöntemler: Bu retrospektif, tek merkezli çalışmaya Ocak 2008–Haziran 2012 tarihleri arasında intrakraniyal anevrizma nedeniyle mikrocerrahi tedavi uygulanan ardışık 90 hasta dahil edildi. Başvuru anındaki klinik durum Hunt–Hess ve Dünya Nöroşirürji Dernekleri Federasyonu (DNDF) derecelendirme sistemleri kullanılarak değerlendirildi; kanamanın radyolojik şiddeti ise Fisher ölçeğine göre sınıflandırıldı. Sonuç ölçütleri hastane içi mortalite, postoperatif komplikasyonlar ve taburculuk sırasındaki fonksiyonel durum Glasgow Sonuç Ölçeği (GSÖ) ile belirlendi. Başvuru semptomları ile mortalite arasındaki ilişkiler tek değişkenli analizlerle değerlendirildi.

Bulgular: Doksan hastanın 54'ü (%60) kadın, 36'sı (%40) erkekti. Ortalama yaş kadınlarda 59, erkeklerde 52,5 yıldı. Hastaların %94,4'ünde SAK mevcuttu. En sık anevrizma lokalizasyonu anterior komünikan arterdi (%43,3); bunu orta serebral arter (%22,2) izledi. Genel sağkalım %80, hastane içi mortalite %20 idi. Daha yüksek Fisher ve Hunt–Hess dereceleri mortalite ile güçlü biçimde ilişkiliydi. Taburculukta iyi fonksiyonel sonuç (GSÖ) hastaların %63,3'ünde elde edildi.

Sonuç: Bu cerrahi seride, başvuru anındaki klinik derecenin yüksek olması ve kanama yükünün fazla olması, hastane içi mortalitenin artmasıyla ilişkiliydi. Anevrizmanın erken dönemde güvence altına alınması sıklıkla uygulanmış olmakla birlikte, retrospektif tasarım nedeniyle zamanlamaya ilişkin nedensel çıkarımlar yapılamaz. Bağımsız sonuç belirleyicilerini saptamak ve endovasküler yaklaşımların yanı sıra mikrocerrahinin rolünü daha iyi tanımlamak için çok değişkenli modellemeyi içeren, daha büyük ve güncel çok merkezli çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: İntrakraniyal anevrizma, subaraknoid kanama, cerrahi klipleme, Hunt–Hess.

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Cite as: Aydin O, Yurt A. Surgical outcomes of intracranial aneurysms: a single-center experience with 90 patients. Turk J Clin Res. 2026;2(1):15-21

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Received: 15 April 2026 | **Accepted:** 13 May 2026 | **Published:** 31 May 2026

Turk J Clin Res. 2026;2(1):15-21
https://doi.org/10.63909/1453039

INTRODUCTION

Intracranial aneurysms are a leading cause of non-traumatic subarachnoid hemorrhage (SAH), a critical neurological emergency associated with substantial morbidity and mortality worldwide (1). Aneurysmal SAH constitutes a major subset of hemorrhagic stroke and remains a devastating condition despite advances in microsurgery, endovascular therapy, and neurocritical care (2). Epidemiological studies report an annual incidence of approximately 6–10 per 100.000 individuals, with marked geographic variation (3). Mortality remains high; nearly one-third of patients die within the first month, and many survivors experience long-term neurological disability (4).

The pathogenesis of intracranial aneurysms is multifactorial and reflects an interplay between intrinsic vessel-wall vulnerability and acquired hemodynamic stressors (5). Degeneration of the internal elastic lamina, loss of smooth muscle cells, and extracellular matrix remodeling contribute to progressive weakening of the arterial wall (6). Hemodynamic stress at arterial bifurcations promotes endothelial dysfunction and inflammation, facilitating aneurysm initiation and growth (7). In addition, genetic susceptibility has been increasingly recognized, and several chromosomal loci have been linked to aneurysm development (8).

Several factors influence aneurysm formation and rupture. Key modifiable risks include hypertension, cigarette smoking, and excessive alcohol consumption (9). Non-modifiable risks include older age, female sex, and inherited predisposition, particularly in connective tissue disorders such as Ehlers–Danlos syndrome and autosomal dominant polycystic kidney disease (10). These factors contribute to aneurysm development and may also affect growth and rupture propensity.

Clinically, aneurysmal rupture typically presents with sudden, severe headache—often described as the "worst headache of life"—and may be accompanied by nausea, vomiting, photophobia, and varying degrees of neurological impairment (11). Severity at presentation is commonly assessed using the Hunt–Hess and World Federation of Neurosurgical Societies (WFNS) grading systems, both of which have prognostic value (12). Early neurological status remains one of the strongest determinants of outcome.

Radiological evaluation is central to diagnosis and treatment planning. Non-contrast computed tomography (CT) is typically the first-line modality because of its availability and high sensitivity for acute SAH (13). When CT is nondiagnostic and clinical suspicion remains high, lumbar puncture may be required. Digital subtraction angiography (DSA) remains the reference standard for defining aneurysm morphology, size, and relationships to adjacent vessels (14). Computed tomography angiography (CTA) and magnetic resonance angiography (MRA) are widely used non-invasive alternatives with high diagnostic accuracy in appropriate settings (15).

The primary goal of aneurysm treatment is prevention of rebleeding, which is associated with very poor outcomes, particularly during the first days after rupture (16). Rebleeding risk is highest within 24–48 hours and remains clinically relevant throughout the early post-hemorrhagic period (17). Accordingly, early aneurysm occlusion is recommended whenever feasible.

Microsurgical clipping has long been a definitive treatment option, achieving exclusion of the aneurysm from the circulation while preserving the parent artery and adjacent perforators (18). The development of endovascular techniques, particularly coil embolization, has expanded therapeutic options, especially for patients at high surgical risk or with anatomically complex aneurysms (19). Treatment selection depends on aneurysm location and morphology, patient age and clinical status, and institutional expertise.

Despite therapeutic advances, aneurysmal SAH remains associated with frequent complications, including vasospasm, hydrocephalus, rebleeding, and delayed cerebral ischemia (20). These complications substantially affect prognosis and functional recovery, underscoring the need for early diagnosis, timely intervention, and comprehensive perioperative and neurocritical care.

In this study, we evaluated surgical outcomes of patients with intracranial aneurysms treated at our institution, examined the relationship between clinical/radiological grading systems and outcomes, and compared our findings with the current literature.

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METHODS

This retrospective, single-center cohort study included consecutive patients who underwent microsurgical treatment for intracranial aneurysms at İzmir Bozyaka Training and Research Hospital between January 2008 and June 2012. Patients were eligible if they presented with aneurysmal subarachnoid hemorrhage (SAH) confirmed on computed tomography (CT) with an aneurysm demonstrated by vascular imaging, or had an incidentally detected intracranial aneurysm that was electively treated using microsurgical methods. Patients managed exclusively with endovascular techniques and those with non-aneurysmal SAH were excluded. Clinical, imaging, operative, and in-hospital outcome data were extracted from medical records.

Patient selection reflected routine clinical decision-making during the study period. Specifically, the cohort represents patients selected for microsurgical clipping (or, rarely, wrapping) at our center and does not include patients treated endovascularly or patients who were not offered intervention. As a result, the retrospective design is subject to selection bias (e.g., referral patterns, surgeon preference, aneurysm morphology, clinical grade, and resource availability), which may limit the generalizability of the observed outcomes to an unselected aneurysm population.

On admission, neurological severity was graded using the Hunt–Hess and World Federation of Neurosurgical Societies (WFNS) scales, and level of consciousness was documented with the Glasgow Coma Scale (GCS). Perioperative management included close neurological monitoring, blood pressure control, and measures to mitigate secondary brain injury; patients were managed in a high-dependency or intensive care setting according to clinical grade and institutional practice during the study period. Surgical timing was determined by the treating neurosurgical team based on clinical grade, radiological findings, and operating room availability, with a preference for early aneurysm securing when feasible.

All patients underwent non-contrast CT on presentation to evaluate for SAH. The extent of subarachnoid blood was graded using the Fisher classification on the initial CT scan. Digital subtraction angiography (DSA) was the primary modality used to confirm the diagnosis and characterize aneurysm morphology and cerebrovascular anatomy; computed tomography angiography (CTA) and/or magnetic resonance angiography (MRA) were used in selected patients as complementary or preliminary studies. Aneurysms were categorized by number (single vs multiple) and anatomical location (e.g., AComA, MCA, ICA, and posterior circulation).

All procedures were performed under an operating microscope using standard microsurgical techniques. The pterional approach was used most frequently; orbitozygomatic or posterior fossa approaches were selected when dictated by aneurysm location and the required surgical corridor. The primary strategy was clip occlusion using titanium clips to achieve complete aneurysm exclusion while preserving the parent vessel and perforators. Wrapping was reserved for anatomically complex lesions in which safe clip application was not feasible.

The primary endpoints were in-hospital mortality and functional outcome at discharge assessed with the Glasgow Outcome Scale (GOS). Secondary outcomes included postoperative complications recorded during the index hospitalization. Associations between categorical variables (e.g., Fisher grade, Hunt–Hess grade, admission GCS category) and mortality were evaluated using univariate analyses; p-values reported in Table 3 reflect these comparisons, with statistical significance set at $p<0.05$. Given the retrospective dataset and the limited number of outcome events, no multivariable model was constructed; therefore, the analyses are descriptive and exploratory and do not establish independent predictors.

RESULTS

A total of 90 patients were included; 54 (60%) were female and 36 (40%) were male (female-to-male ratio, 1.5). Age ranged from 26 to 84 years, with the highest frequency in the sixth decade (30%), followed by the fifth (24.4%) and seventh decades (23.3%). Demographic characteristics, presenting features, and comorbidities are summarized in Table 1.

SAH was present in 85 patients (94.4%); 4 patients (4.4%) had incidentally detected unruptured aneurysms,

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and 1 patient (1.1%) had a residual aneurysm. Headache was the most common presenting symptom (51.1%), followed by loss of consciousness (24.4%). Headache with altered consciousness occurred in 22.2% of patients, whereas motor and cranial nerve deficits were uncommon (1.1% each) (Table 1). Comorbidities were documented in 66.7% of patients, with hypertension being the most prevalent (Table 1).

Table 1. Demographic and clinical characteristics of patients (n=90)

Variable	n (%)
Gender	
Female	54 (60%)
Male	36 (40%)
Age Distribution	
21–30 years	4 (4.4%)
31–40 years	4 (4.4%)
41–50 years	22 (24.4%)
51–60 years	27 (30%)
61–70 years	21 (23.3%)
71–80 years	10 (11.1%)
81–90 years	2 (2.2%)
Clinical Presentation	
Subarachnoid hemorrhage	85 (94.4%)
Incidental aneurysm	4 (4.4%)
Residual aneurysm	1 (1.1%)
Presenting Symptoms	
Headache	46 (51.1%)
Loss of consciousness	22 (24.4%)
Headache + altered consciousness	20 (22.2%)
Motor deficit	1 (1.1%)
Cranial nerve deficit	1 (1.1%)
Comorbidities	
Any comorbidity	60 (66.7%)
Hypertension	41 (68.3% of comorbid group)

According to the Fisher grading system, 2.2% of patients were Grade 1, 36.7% Grade 2, 27.8% Grade 3, and 27.8% Grade 4. DSA was the primary imaging modality and was performed in 93.3% of cases; MRA with DSA and CT alone were used in a minority. Single aneurysms were observed in 86.7% of patients, while multiple aneurysms were present in 13.3% (Table 2). The anterior communicating artery (AComA) was the most common location (43.3%), followed by the middle cerebral artery (MCA) (22.2%) and internal carotid artery (ICA) (8.9%); posterior circulation aneurysms were less frequent (Table 2).

Table 2. Radiological findings, treatment characteristics, and outcomes

Variable	n (%)
Fisher Grade	
Grade 1	2 (2.2%)
Grade 2	33 (36.7%)
Grade 3	25 (27.8%)
Grade 4	25 (27.8%)
Imaging Modality	
DSA	84 (93.3%)
MRA + DSA	4 (4.4%)
CT only	2 (2.2%)
Aneurysm Number	
Single	78 (86.7%)
Multiple	12 (13.3%)
Aneurysm Localization	
AComA	39 (43.3%)
MCA	20 (22.2%)
ICA	8 (8.9%)
Others	Remaining
Surgical Timing (SAH patients)	
1–3 days	61 (67.8%)
4–7 days	17 (18.9%)
>7 days	7 (7.8%)
Outcomes	
Survival	72 (80%)
Mortality	18 (20%)
GOS Score	
GOS 5 (Good recovery)	57 (63.3%)
GOS 4 (Moderate disability)	12 (13.3%)
GOS 3 (Severe disability)	3 (3.4%)
Death	18 (20%)
Complications	
Present	28 (31.1%)
Absent	62 (68.9%)

Among patients with SAH, 67.8% underwent surgery within 1–3 days, 18.9% between days 4–7, and 7.8% after day 7 (Table 2). Overall in-hospital mortality was 20% (18 patients), and 80% (72 patients) survived. Mortality increased with higher radiological and clinical grades: mortality was 48% in Fisher Grade 4 and 16% in Fisher Grade 3. Similarly, mortality rose with increasing Hunt–Hess grade, reaching 100% in Grade 5, 42.9% in Grade 4, and 37.5% in Grade 3 (Table 3).

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https://doi.org/10.63909/1453039

Table 3.	Association between clinical/radiological grades and mortality			
Variable	**Total (n)**	**Mortality n (%)**	**Survival n (%)**	**p-value**
Fisher Grade				**<0.001**
Grade 1	2	0 (0.0%)	2 (100.0%)	
Grade 2	33	1 (3.0%)	32 (97.0%)	
Grade 3	25	4 (16.0%)	21 (84.0%)	
Grade 4	25	12 (48.0%)	13 (52.0%)	
Hunt–Hess Grade				**<0.001**
Grade 0	5	1 (20.0%)	4 (80.0%)	
Grade 4	25	12 (48.0%)	13 (52.0%)	
Hunt–Hess Grade				**<0.001**
Grade 0	5	1 (20.0%)	4 (80.0%)	
Grade 1	38	2 (5.3%)	36 (94.7%)	
Grade 2	15	2 (13.3%)	13 (86.7%)	
Grade 3	24	9 (37.5%)	15 (62.5%)	
Grade 4	7	3 (42.9%)	4 (57.1%)	
Grade 5	1	1 (100.0%)	0 (0.0%)	
GCS at Admission				**<0.01**
13–15	73	12 (16.4%)	61 (83.6%)	
8–12	14	4 (28.6%)	10 (71.4%)	
3–7	3	2 (66.7%)	1 (33.3%)	

On univariate analysis, Fisher grade and Hunt–Hess grade were significantly associated with mortality ($p<0.001$ for each), and lower admission GCS categories were associated with increased mortality ($p<0.01$) (Table 3). Postoperative complications occurred in 31.1% of patients. The most frequent complications were cerebral vasospasm, brain edema, and neurological deterioration; less common events included hydrocephalus, seizures, electrolyte imbalance, hematoma formation, and cranial nerve deficits (Table 2).

At discharge, 63.3% of patients had good recovery (GOS 5), 13.3% had moderate disability (GOS 4), and 3.4% had severe disability (GOS 3) (Table 2).

DISCUSSION

This single-center surgical series reports in-hospital outcomes after microsurgical management of intracranial aneurysms and examines how admission severity scales relate to mortality and discharge functional status. Although the analyses are univariate, the findings consistently indicate that initial neurological condition and hemorrhage burden are the dominant determinants of early outcome after aneurysmal SAH.

The demographic profile (female predominance and a peak incidence in the sixth decade) aligns with prior epidemiological reports (3–5). Clinically, this supports maintaining a high index of suspicion for SAH in middle-aged and older adults particularly women presenting with sudden severe headache and/or impaired consciousness. However, because this is a surgically treated cohort, these distributions may also reflect referral pathways and treatment selection during the study period.

Hypertension was the most common comorbidity, supporting its established role in aneurysm formation and rupture through chronic hemodynamic stress (6). The high prevalence observed here may reflect regional cardiovascular risk profiles and the likelihood that comorbidities are more consistently documented during hospitalization for severe SAH. Because comorbidity variables were not evaluated in a multivariable model, these findings should not be interpreted as indicating independent effects.

Most patients presented with aneurysmal SAH and typical symptoms (headache with or without altered consciousness), emphasizing that early recognition of classic warning signs remains essential for timely diagnosis and aneurysm securing (7). Radiologically, the predominance of Fisher Grades 2–4 indicates a cohort with moderate-to-severe hemorrhage burden. In our univariate analysis, higher Fisher grade was associated with markedly increased mortality (Table 3), which is clinically plausible given the association between subarachnoid blood load, vasospasm, delayed cerebral ischemia, and early neurological deterioration reported in prior studies (8,9).

Clinical severity at admission remained closely linked to mortality. Increasing Hunt–Hess grade was strongly associated with worse outcomes (Table 3), consistent with the concept that this scale reflects early brain injury and the systemic impact of hemorrhage. Admission GCS also correlated with mortality and remains useful for rapid stratification, although it overlaps with Hunt–Hess/

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https://doi.org/10.63909/1453039

WFNS measures. Because multivariable adjustment was not performed and patient numbers were small in the highest grades, these associations should be interpreted as descriptive rather than as independent effects.

The distribution of aneurysm locations, with AComA and MCA predominance, mirrors patterns commonly reported in surgical series (12). Most SAH patients underwent surgery within 72 hours, reflecting an institutional preference for early aneurysm securing (Table 2). Nevertheless, in retrospective cohorts, surgical timing is confounded by baseline clinical grade and logistical factors; therefore, these data do not support causal inferences regarding the effect of timing on outcome. Future studies using contemporary cohorts and time-dependent or multivariable methods are needed to better assess the independent relationship between treatment timing and outcomes.

Complications occurred in approximately one-third of patients, most commonly vasospasm and brain edema (Table 2). This pattern is consistent with the natural history of aneurysmal SAH and highlights the value of standardized neurocritical care pathways to prevent and treat secondary injury. Because detailed perioperative management variables (e.g., specific vasospasm prophylaxis and monitoring strategies) could not be uniformly extracted from retrospective records, we could not evaluate how management differences influenced complication rates or outcomes. Nevertheless, most survivors achieved good recovery at discharge (GOS 5 in 63.3%), although the in-hospital mortality of 20% underscores the severity of this condition.

Several limitations should be considered. First, the retrospective, single-center design introduces risks of selection bias, information bias, and unmeasured confounding, and limits external validity. Second, the study period (2008–2012) predates several contemporary endovascular devices and modern neurocritical care protocols; therefore, the results may not fully reflect current practice. Third, because the cohort comprises surgically treated patients, the findings may not be generalizable to all patients with intracranial aneurysms or aneurysmal SAH, particularly those treated endovascularly or deemed unsuitable for intervention. Finally, the absence of multivariable modeling precludes identification of independent predictors of mortality and functional outcome. Prospective, multicenter studies with standardized perioperative protocols and contemporary case mix, coupled with multivariable and time-dependent statistical methods, are warranted to validate and extend these observations.

CONCLUSION

Microsurgical treatment of intracranial aneurysms remains an effective strategy to prevent rebleeding and to improve patient outcomes in appropriately selected cases. In this cohort, admission clinical status (Hunt–Hess/WFNS and GCS) and radiological hemorrhage severity (Fisher grade) were strongly associated with in-hospital mortality. Because treatment timing and modality were determined by clinical judgment in a retrospective setting, the observed associations should be interpreted as descriptive rather than causal. The anterior communicating artery was the most common aneurysm location, consistent with the literature. Despite advances in microsurgical techniques, neuroimaging, and perioperative care, aneurysmal SAH continues to carry substantial morbidity and mortality, underscoring the need for early recognition and coordinated multidisciplinary management.

Clinical implications: In current neurosurgical practice, these findings reinforce the importance of rapid triage using admission grading scales, early definitive aneurysm occlusion when feasible, and vigilant prevention/management of secondary injury (e.g., vasospasm, hydrocephalus, and delayed cerebral ischemia). In centers where both clipping and endovascular options are available, objective assessment of initial clinical/radiological grade can help prioritize resources, guide family counseling, and support individualized selection of the most suitable aneurysm-securing strategy.

Acknowledgement: None.

Ethical Approval: Ethical approval was not required for this study since it is a research article.

Author Contributions: Idea/Concept: O.A., A.Y.; Design: O.A., A.Y.; Supervision: O.A., A.Y.; Resources: O.A., A.Y.; Materials: O.A., A.Y.; Data Collection and/or Processing: O.A., A.Y.; Analysis and/or Interpretation: O.A., A.Y.;

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https://doi.org/10.63909/1453039

Literature Review: O.A., A.Y.; Written by: O.A., A.Y.; Critical Review: O.A., A.Y.

Conflict of Interest: The authors declared no conflict of interest.

Financial Disclosure: The authors declared that this study has received no financial support.

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