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Outcomes of Surgical and Endovascular Treatment of Intracranial Aneurysms: A Single-Center Analysis of 1183 Patients

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ABSTRACT

AIM: To compare the treatment outcomes of surgical and endovascular methods in patients with intracranial aneurysms.

MATERIAL and METHODS: A total of 1183 patients [722 (61%)] female and 461 [(39%) male] with intracranial aneurysms, including 615 with subarachnoid hemorrhage (SAH) and 568 without hemorrhage, were retrospectively reviewed.

RESULTS: The mean age of patients was 51.3 ± 12.4 years. Male patients were significantly more likely to have aneurysmal hemorrhage at admission ($p<0.001$). Surgical intervention was performed in 462 (39.1%) patients, and endovascular methods were used in 541 (45.7%) patients. Sixty-five (5.5%) patients were treated with both methods. The World Federation of Neurosurgical Societies grade was found to have a strong negative effect on the Glasgow Outcome Scale (GOS) score (Wald = 21.81). The GOS scores were significantly higher in the surgical treatment group than in the endovascular treatment group for aneurysms in the anterior communicating artery. Based on follow-up digital subtraction angiography, the complete occlusion rate of the aneurysm was significantly higher with the surgical method than with the endovascular method ($p<0.001$). The complete closure rate of aneurysms following endovascular treatment was significantly lower than that after surgical treatment ($p<0.001$). However, we found no significant difference between the two methods in terms of residual aneurysms requiring reintervention.

CONCLUSION: Treatment of intracranial aneurysms should be decided jointly by an experienced team of neurovascular surgeons, neuroradiologists, and anesthesiologists.

KEYWORDS: Endovascular intervention, Intracranial aneurysm, Neurovascular surgery, Subarachnoid hemorrhage

ABBREVIATIONS: DSA: Digital subtraction angiography, **GOS:** Glasgow outcome scale, **SAH:** Subarachnoid hemorrhage, **WFNS:** World Federation of Neurosurgical Societies

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INTRODUCTION

Aneurysmal subarachnoid hemorrhage (SAH) is associated with high mortality and morbidity rates. Approximately 66% of survivors have impaired functional status after SAH treatment (12). Therefore, surgical or endovascular closure of incidentally discovered unruptured aneurysms is recommended, considering the patient's age, comorbidities, neurological status, and type of aneurysm (23).

A combination of both methods can also be used to treat SAH (7). The surgical intervention aims to close the aneurysm by controlling blood flow in the adjacent vessels and intervening from outside the vessel using special filtered surgical microscopes, clips, intraoperative Doppler ultrasound, and injections of indocyanine green (2,21). Endovascular therapy entails intravascular intervention for the closure of the aneurysm using materials such as coils or stents, alone or in combination (4,23). As intracranial aneurysms can be treated by two different specialties using different methods, many studies have compared the outcomes of treatment methods (23).

In the present study, we aimed to compare the outcomes of surgical and endovascular treatment methods for patients with intracranial aneurysms treated at a single center in Turkey.

MATERIAL and METHODS

The Institutional Review Board of Istanbul University, Istanbul Faculty of Medicine reviewed and approved the study protocols and steps (154510/31.03.2021).

We retrospectively reviewed 1183 patients with intracranial aneurysms, including 615 with SAH and 568 without hemorrhage, who were treated at the Istanbul University Department of Neurosurgery between 2001 and 2018. Surgical treatment was performed at the Istanbul University Department of Neurosurgery, while endovascular treatment was performed at the Department of Neuroradiology.

The outcomes of surgical and endovascular treatments were compared in terms of the patient's age, aneurysm location, World Federation of Neurosurgical Societies (WFNS) grades, symptoms at hospital admission, pre-treatment and post-treatment neurological findings, comorbid conditions, complications, mortality, transient and permanent neurological deficits, presence of residual filling in the follow-up digital subtraction angiography (DSA) scan, and Glasgow Outcome Scale (GOS) score at discharge.

Descriptive statistics were generated for comparison between surgical and endovascular treatment groups. In the statistical evaluation, the mean WFNS grade and GOS scores were compared using the t-test, analysis of covariance, and Mann–Whitney U test. The numerical values of other results were compared using the chi-squared test. p-values < 0.05 indicated statistical significance.

Logistic regression analysis was used to identify the factors affecting poor outcomes in patients with SAH. GOS scores of 1–3 and 4–5 indicated poor and good outcomes, respectively. Furthermore, the β coefficient, standard deviation, p-value, odds ratio, Wald statistic, and 95% confidence intervals were calculated. Statistical analysis was performed using the IBM SPSS Statistics 24.0 program.

RESULTS

Age and Sex

The mean age of 1183 participants, including 722 (61%) females and 461 (39%) men, was 51.3 ± 12.4 years. The mean age of patients with subarachnoid hemorrhage (50.6 ± 12.6 years) was significantly lower than that of patients without hemorrhage (52.0 ± 12.2 years) (p=0.05). The age distribution of patients with and without hemorrhage is shown in Figure 1.

The percentages of female and male patients with hemorrhagic aneurysms were 51.1% and 48.9%, respectively, whereas the corresponding rates in patients without SAH were 71.8% and 28.2%, respectively. In addition, 43.5% and 65.3% of hospitalized female and male patients had a hemorrhage, respectively. Therefore, there was a significantly higher proportion of males among patients with SAH compared to patients without hemorrhage (p<0.001). In other words, aneurysms in most female patients (56.5%) were not associated with hemorrhage, whereas most male patients (65.3%) were hospitalized with hemorrhage (p<0.001) (Table I).

Treatment Methods

Out of 1183 patients in this study, 462 (39.1%) underwent surgery and 541 (45.7%) underwent endovascular treatment. Sixty-five (5.5%) patients were treated with both methods. Notably, 115 (9.7%) patients did not undergo any intervention.

The mean age of patients in the surgical treatment group (50.0 ± 11.6 years) was significantly lower than that in the endovascular treatment group (51.7 ± 12.5 years; p=0.035). The WFNS grade in the surgical treatment group (1.3 ± 1.3) was significantly higher than that in the endovascular treatment group (0.7 ± 1.2; p=0.009) (Table II).

Factors Affecting the Outcome in Patients Hospitalized with Subarachnoid Hemorrhage

At hospital discharge, we analyzed the factors that adversely affected the neurological status of 615 patients with hemorrhagic aneurysms. A GOS score of ≤3 was defined as a poor outcome, and a GOS score of ≥4 was defined as a good outcome. The significance levels of the variables that affect the GOS score were examined using the chi-squared test (Table III).

The WFNS grade was the most vital factor negatively affecting the GOS score (Wald = 21.81). However, the development of postoperative cerebral infarction contributed to the poor outcome of the aneurysm, as assessed by the GOS.

The treatment method, loss of consciousness at admission, preoperative neurologic deficit detection, hydrocephalus, and intracerebral hematoma did not affect the GOS score.

Comorbidities

Of 1183 patients, 223 had comorbid conditions that affected mortality and morbidity. Analysis of the follow-up results of the group with comorbidities revealed that 17 patients died,

Table I: Subarachnoid Hemorrhage Rate by Sex

		Without hemorrhage	With hemorrhage	p-value
Females	**n**	408	314	**<0.001**
	%	56.5	43.5	
Males	**n**	160	301	
	%	34.7	65.3	

41 developed new neurological deficits in the post-treatment period, and 62 developed other complications. The mean GOS scores of the groups with and without comorbidities were very similar, whereas the WFNS grade was higher in patients without comorbidities.

Evaluation of aneurysms in terms of years and treatment methods

The number of surgically closed aneurysms gradually decreased, whereas the number of aneurysms treated with en-

Table II: Distribution of Patients in Terms of Their WFNS Grades

		WFNS						Age	WFNS	GOS	Total
		0		1–3		4–5					
		n	%	n	%	n	%				
Surgery	2001–2006	47	49.5	126	68.9	16	40	49.13 ± 12.41	1.48 ± 1.36	4.16 ± 1.45	189
	2007–2012	58	31.0	98	50.3	10	50	51.23 ± 10.48	1.09 ± 1.2	4.57 ± 1.1	166
	2013–2018	43	15.0	53	35.8	11	37.9	49.72 ± 11.81	1.07 ± 1.34	4.64 ± 0.99	107
	Total	**148**	**26.1**	**277**	**52.7**	**37**	**41.6**	**50.02 ± 11.62**	**1.25 ± 1.31**	**4.42 ± 1.25**	**462**
Endovascular	2001–2006	28	29.5	35	19.1	14	35	52.73 ± 9.73	1.53 ± 1.62	4.08 ± 1.54	77
	2007–2012	98	52.4	72	36.9	5	25	50.89 ± 12.51	0.74 ± 1.1	4.42 ± 1.25	175
	2013–2018	219	76.6	62	41.9	8	27.6	51.82 ± 13.22	0.42 ± 0.94	4.82 ± 0.72	289
	Total	**345**	**60.7**	**169**	**32.1**	**27**	**30.3**	**51.65 ± 12.54**	**0.68 ± 1.17**	**4.59 ± 1.09**	**541**
S + E	2001–2006	6	6.3	13	7.1	0	0	44.47 ± 10.72	1.16 ± 1.07	4.74 ± 0.81	19
	2007–2012	11	5.9	12	6.2	2	10	52.92 ± 8.37	1 ± 1.32	3.76 ± 1.71	25
	2013–2018	6	2.1	13	8.8	2	6.9	47.95 ± 14.53	1.29 ± 1.45	4 ± 1.45	21
	Total	**23**	**4.0**	**38**	**7.2**	**4.0**	**4.5**	**48.85 ± 11.70**	**1.14 ± 1.29**	**4.12 ± 1.45**	**65**
No Intervention	2001–2006	14	14.7	9	4.9	10	25	54.36 ± 13.31	1.76 ± 1.98	3.73 ± 1.68	33
	2007–2012	20	10.7	13	6.7	3	15	61.14 ± 12.59	1.08 ± 1.48	4.08 ± 1.46	36
	2013–2018	18	6.3	20	13.5	8	27.6	53.43 ± 15.28	1.39 ± 1.73	4.24 ± 1.49	46
	Total	**52**	**9.2**	**42**	**8.0**	**21**	**23.6**	**56.11 ± 14.22**	**1.4 ± 1.74**	**4.04 ± 1.54**	**115**

GOS: *Glasgow Outcome Scale,* ***WFNS:*** *World Federation of Neurosurgical Societies,* ***S:*** *Surgery, and* ***E:*** *Endovascular treatment.*

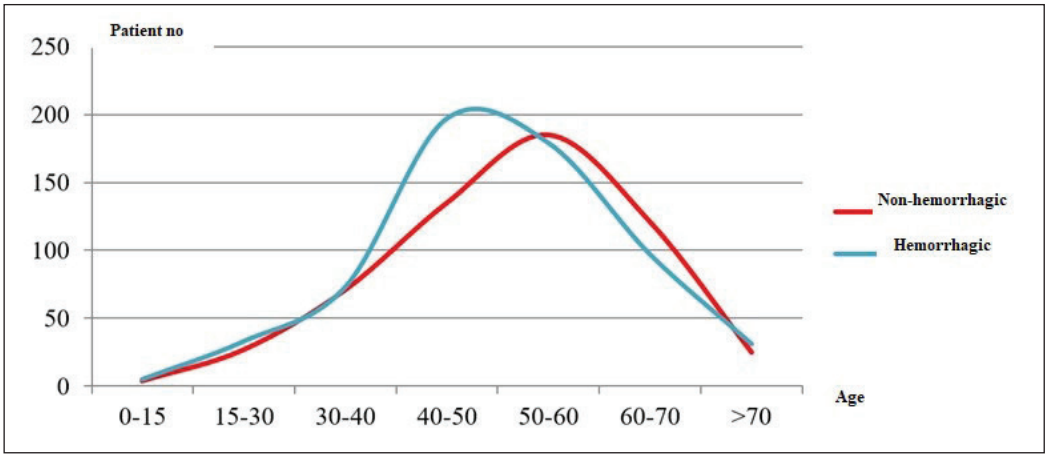

Figure 1: Age distribution of patients with and without hemorrhage.

Table III: Analysis of Variables Considered to Affect the GOS Score

Variable	p-value
Age distribution	**0.002**
Sex	0.56
Treatment method	0.861
Time to intervene in a patient with subarachnoid hemorrhage	0.363
Loss of consciousness	**<0.001**
Seizure	0.204
Comorbidities affecting morbidity and mortality	0.055
WFNS grade	**<0.001**
Anatomical location of the aneurysm	0.079
Intracerebral hematoma	**<0.001**
Intraventricular hematoma	**<0.001**
Vasospasm	0.6
Postoperative cerebral infarction	**<0.001**
Central nervous system infection	**<0.001**

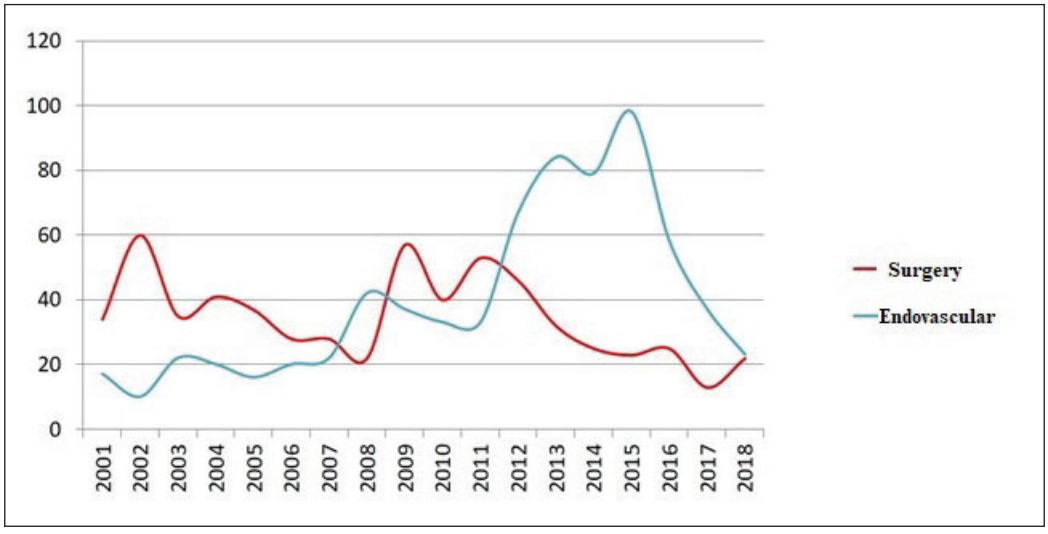

Figure 2: Distribution of aneurysms according to treatment methods and years

dovascular procedures increased. Up to 2008, most aneurysms were treated with surgical methods, but after 2012, the number of endovascular treatments was significantly higher than that of surgical treatments (Figure 2).

In endovascular treatment, the simultaneous use of stents and coils has been observed more frequently, especially since 2009. Moreover, stenting and coiling were found to have been used together, particularly in patients without SAH, because anticoagulant therapy is administered after stenting. However, because anticoagulant therapy must be avoided in the early stages of SAH, primary coiling was more frequently performed in these patients.

Comparison of Aneurysm Outcomes in Terms of Their Localization

The location of the cerebral aneurysm plays an essential role in the treatment choice. For the evaluation of the GOS scores after surgical and endovascular treatments of aneurysms in the middle cerebral artery, internal carotid artery and its branches, anterior cerebral artery, and the vertebrobasilar system, an analysis of covariance in terms of WFNS grades was performed. No significant difference was observed between

the two treatment methods. However, on performing an analysis of covariance for the WFNS grades of aneurysms in the anterior communicating artery, GOS scores were significantly higher in patients who underwent surgical treatment than in those who underwent endovascular treatment (Table IV).

Evaluation of Follow-up Cerebral DSA Results

Of the 1068 patients treated in our study, 434 (40.6%) underwent follow-up DSA. Of these 434 patients, 121 (40.6%) had a residual aneurysm and 62 (51.2%) underwent surgical or endovascular reoperation.

Of 462 patients who underwent surgical treatment, 191 (41.3%) underwent follow-up DSA and 169 (88.5%) had complete aneurysm occlusion. Furthermore, 22 (11.5%) patients had a residual filling in the neck of the aneurysm. Two (9.0%) patients underwent endovascular and surgical reoperations.

Of the 541 patients who underwent endovascular treatment, 226 (41.8%) underwent follow-up DSA and 132 (58.4%) had complete aneurysm occlusion. Overall, 94 (41.6%) patients had a residual filling in the neck of the aneurysm. During follow-up, 25 (23.5%) of these patients underwent endovascular reoperation and 2 (2.1%) underwent surgery.

Analysis of follow-up DSAs performed after the initial procedures for aneurysms revealed that the aneurysm's complete occlusion rate was significantly higher with the surgical method than with the endovascular method (p<0.001).

DISCUSSION

The mean age of the participants in this study was 51.2 ± 12.4 years. The mean age of patients with SAH was 50.6 ± 12.6 years, whereas that of patients with nonhemorrhagic aneurysms was 52.0 ± 12.2 years. Based on the relevant literature, the mean age range varies between 40 and 60 years, and the results of our study are consistent with those of previous studies (8–12).

Several studies have found that intracranial aneurysms are detected more frequently in females and that the female sex is a risk factor for SAH (2,13-18). In the present study, although intracranial aneurysms were more common in females, aneurysms with SAH were found in 65.3% of male patients, suggesting that the male sex is a risk factor for hemorrhagic aneurysms in patients with aneurysms (p<0.001), consistent with the findings of studies in the relevant literature (19,20).

Regarding the comparison between surgical and endovascular methods, there was no significant difference in the mean WFNS grades of patients between 2001 and 2006. In contrast, the WFNS grades of patients treated with endovascular methods between 2013 and 2018 were significantly lower than those of patients who underwent surgery (p<0.001) (8,13). This result can be attributed to the increasing popularity of endovascular treatment in recent years due to advances in technology and technique and the fact that the endovascular method is often preferred over craniotomy for patients with WFNS grade 1.

The mean GOS scores of the surgical and endovascular treatment groups were 4.39 and 4.57, respectively. Given the significant difference between the patient groups regarding the WFNS grades, no significant difference was found when the GOS scores of the patient groups were compared by analysis of covariance (p=0.542). In the Barrow ruptured aneurysm trial, no significant difference was found between the outcomes of the two treatment groups at 1-year follow-ups (19).

In our study, 115 patients received no intervention owing to the high risk of treatment for the majority of patients in this group (28 patients, 24.3%). The mean age of patients who did not receive any intervention (56.1 ± 14.2 years) was significantly higher than that of patients who received the intervention (50.7 ± 12.1 years; p<0.001). This finding of higher mean age and comorbidities in patients who had not undergone an intervention is consistent with previous studies (16).

Table IV: Comparison of Surgical and Endovascular Treatment Methods According to the Anatomical Location of Aneurysms

		WFNS	GOS score at discharge	p-value
ACA	Surgery	1.41 ± 1.33	4.53 ± 1.33	0.292
	Endovascular	0.63 ± 0.89	4.63 ± 1.09	
ACoA	Surgery	1.25 ± 1.10	4.58 ± 1.12	**0.004**
	Endovascular	1.15 ± 1.28	4.50 ± 1.09	
ICA	Surgery	1.06 ± 1.29	4.11 ± 1.47	0.614
	Endovascular	0.31 ± 0.90	4.66 ± 1.04	
MCA	Surgery	1.22 ± 1.43	4.41 ± 1.22	0.368
	Endovascular	0.36 ± 0.90	4.80 ± 0.80	
VBS	Surgery	1.36 ± 1.16	4.25 ± 1.43	0.345
	Endovascular	0.91 ± 1.35	4.46 ± 1.24	

ACA: *Anterior cerebral artery,* ***ACoA:*** *Anterior communicating artery,* ***ICA:*** *Internal carotid artery,* ***MCA:*** *Middle cerebral artery,* ***VBS:*** *Vertebrobasilar system,* ***WFNS:*** *World Federation of Neurosurgical Societies,* ***S:*** *Surgery, and* ***E:*** *Endovascular.*

Several studies have investigated the factors that may affect the outcome during hospital discharge after intracranial aneurysm treatment (5,18). Age, WFNS grade, presence of intracerebral or intraventricular hematoma, development of vasospasm, central nervous system infection, and cerebral infarction were found to negatively affect the outcome; however, on logistic regression analysis, only the WFNS grade and presence of cerebral infarction showed a significant effect on the outcome. Treatment modality, presence of epileptic seizures, localization of the aneurysm, and development of hydrocephalus were not found to affect the GOS score at discharge.

The endovascular method is typically preferred for aneurysms in patients with comorbid diseases. Of the 223 patients with comorbidities, 119 (53.4%) received endovascular treatment and only 52 (23.3%) received surgical treatment. Notably, 43 (19.3%) patients received no intervention. The preference for endovascular treatment over other methods in patients with high comorbidity was statistically significant ($p<0.001$); this finding is consistent with that in the literature (6).

The present study also examined the preference rate for treatment methods over the years. Although surgical clipping was more widely used in the early 2000s, endovascular treatments increased significantly after 2008, surpassing surgery and becoming the preferred method for aneurysms after 2011. Endovascular treatment has become more common following the development of flow-diverter stent technology and the more widespread use of the stent-assisted coil method (1). According to Leake et al., in hospitals in the United States treating more than 20 patients with cerebral aneurysms annually, the number of patients receiving endovascular treatment exceeded the number of surgically treated patients after 2003 (11). The increasing applicability of coil, stent-assisted coil, and stent treatments with developing technology is the reason for the increased frequency of endovascular treatment in recent years (9).

The complete closure rate in patients treated with the endovascular method was significantly lower ($p<0.001$) than that in patients treated with the surgical method. In the international subarachnoid aneurysm trial, the rate of aneurysm residuals in the endovascular and surgical treatment groups was 34% and 18%, respectively (14). However, in our study, there was no significant difference between the two methods in terms of aneurysm residuals that required reintervention.

CONCLUSION

Treatment of intracranial aneurysms should be decided jointly by an experienced team comprising neurovascular surgeons, neuroradiologists, and anesthesiologists. Moreover, age, comorbidities, location, orientation, shape, and size of aneurysms should be evaluated individually for each patient.

Declarations

Funding: No research or industry funding was obtained for this study.

Availability of data and materials: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Disclosure: Authors declare no conflict of interest.

AUTHORSHIP CONTRIBUTION

Study conception and design: BP, MSS, EA
Data collection: BP, MSO, MO
Analysis and interpretation of results: BP, MSS, EA
Draft manuscript preparation: BP, CIG, DS
Critical revision of the article: ID, TCU, GA, OO, ANI, YA
Other (study supervision, fundings, materials, etc...): PAS, AA, AS, ANI, YA
All authors (BP, ID, TCU, CIG, DS, MSO, MO, MSS, EA, GA, OO, PAS, AA, AS, ANI, YA) reviewed the results and approved the final version of the manuscript.

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