Original Research

Bagcilar Medical Bulletin 2017;2(1):19-24
DOI: 10.5350/BMB20170218032850

Microsurgical Clipping of Anterior Circle of Willis Aneurysms: A Retrospective Study

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ABSTRACT

Objective: The surgical outcomes of anterior circle of Willis aneurysms were evaluated.

Material and Methods: Between March 2015 and December 2016, 38 patients were operated and followed up for aneurysms. There were 15 female and 23 male patients with a mean age of 47 years (range: 17-78). Of the patients, 35 were diagnosed with subarachnoid hemorrhage (SAH). Of these patients, 54.2% (n=19) were operated within the first 24 hours. All patients were operated by the same surgeon with sylvian dissection. All clinical data in the hospital charts and outpatient records and radiological investigations stored in the archive were evaluated retrospectively.

Results: The most commonly seen aneurysm was on the anterior communicating artery (44.8%). After that, aneurysms on the middle cerebral artery (31.6%), posterior communicating artery (13.2%), internal cerebral artery bifurcation (7.8%), and distal anterior cerebral artery were seen, respectively. There was a significant correlation between the location of the aneurysm and the mean age (p=0.009). All patients were followed in the intensive care unit after operation. After surgery, vasospasm was observed in 26.3% of patients. Patients with high SAH grade developed vasospasm significantly more frequently (p=0.03). Neurological examinations at discharge were normal in 17 patients with SAH and 3 patients without SAH. Four patients were discharged with minimal neurological deficit and 2 patients with severe deficit. Eight patients with World Federation of Neurosurgical Societies (WFNS) grade 4-5, 2 patients with grade 3, and 2 patients with grade 1-2 were lost. Postoperative Glasgow Coma Scale and SAH WFNS grades were found to be determinants for dying.

Conclusion: Despite the development of endovascular techniques in the treatment of aneurysm, microsurgical clipping remains the first choice method to treat anterior system aneurysms. Closure of the aneurysm is the treatment priority. It is well known that early surgery reduces mortality and morbidity.

Keywords: aneurysm, clip, aneurysm surgery, microsurgical clipping, subarachnoid hemorrhage, circle of Willis

ÖZET

Willis poligonu anterior dolaşım anevrizmalarının mikroşirurjikal yöntemle klipslenmesi: Retrospektif çalışma

Amaç: Willis poligonu anterior sistem anevrizmalarının cerrahi sonuçlarının değerlendirilmesi.

Yöntem ve Gereçler: Mart 2015-Aralık 2016 arasında intrakranyal anevrizma nedeniyle kliniğimizde ardı ardına 38 hasta ameliyat edildi. On beş kadın ve 23 erkek hastanın yaş ortalaması 47 (aralığı: 17-78) idi. Otuz beş hastada subaraknoid kanama (SAK) vardı ve bunların %54,2'si (n=19) ilk 24 saatte ameliyata alındı. Hastalar aynı cerrah tarafından silviyan diseksiyon yöntemi kullanılarak opere edildi. Çalışmamız klinik kayıt ve radyolojik görüntü arşivleri kullanılarak retrospektif olarak gerçekleştirildi.

Bulgular: En fazla anterior komminikan arter anevrizması görüldü (44.8%). Sonra sırasıyla middle serebral arter (31.6 %), posterior komunikan arter (13.2 %), internal serebral arter (7.8%) ve distal anterior serebral arter (2.6%) anevrizması vardı. Anevrizma yeri ve ortalama görülme yaşı arasında anlamlı farklılık vardı (p=0.009). Tüm hastalar ameliyat sonrası yoğun bakım ünitesinde takip edildiler. Vazospazm %26.3 oranında görüldü. SAK olan hastalarda vazospazm anlamlı derecede fazlaydı (p=0.003). Hastaneden çıkarken SAK olan 17 hasta ve kanamamış 3 hastanın nörolojik muayeneleri normaldi. Dört hasta minimal nörolojik defisitle, 2 hasta ise ağır nörolojik defisitle taburcu edildi. SAH WFNS (World Federation of Neurosurgical Societies) grade 4-5 olan sekiz hasta, grade 3 olan 2 hasta ve grade 1-2 olan 2 hasta kaybedildi. Ameliyat öncesi Glasgow koma skalası skoru düşük olması ve SAH WFNS grade yüksek olması ölen hastalar için belirleyici oldu.

Sonuç: Anevrizma tedavisinde endovasküler tekniklerin gelişmesine rağmen anterior sistem anevrizmalarında cerrahi ile klipsleme hala önemini korumaktadır. Öncelikli tedavi anevrizmanın kapatılmasıdır. Erken cerrahi ile morbidite ve mortalitenin azaldığı bilinmektedir.

Anahtar kelimeler: anevrizma, klips, anevrizma cerrahisi, mikroşirurjikal klipsleme, subaraknoid kanama, Willis poligonu

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Date of submission: February 5, 2017
Date of acceptance: February 17, 2017

Introduction

Non-traumatic subarachnoid hemorrhage (SAH) is most commonly caused by the rupture of an intracranial saccular aneurysm (1). Most intracranial aneurysms develop secondary to hemodynamic stress and acquired degenerative changes of the arterial wall (2). In addition, there must be some family characteristics because there is a higher incidence of aneurysms in first-degree relatives (3). Of the saccular aneurysms, 85-90% develop in the terminal portion of the internal carotid artery and on the main vessels of the circle of Willis. Because of the vessel branching characteristics of the circle of Willis region, hemodynamic stress in this region provides the appropriate condition for aneurysm formation (4). Closure of the aneurysm is the priority for the treatment. Microsurgical clipping and endovascular coiling are the treatment choices.

In this study, 38 patients operated and followed up for anterior circle of Willis aneurysms were evaluated retrospectively.

Material and Methods

Study Design

In our clinic, 38 consecutive cases were treated with the diagnosis of anterior circulation saccular aneurysm between March 2015 and December 2016. Ten patients undergoing endovascular treatment were not included in the study. All clinical data in the hospital charts and outpatient records and radiological investigations held in the archive were evaluated retrospectively. The cases were examined by age, gender, clinical and neuroradiological findings, treatment, and outcome.

Neurological state on admission was evaluated using the Glasgow Coma Scale (GCS) and graded according to the Federation of Neurosurgical Societies (WFNS). Computerized tomography (CT) was used for SAH diagnosis. CT angiography (CTA) or digital subtraction angiography (DSA) was used for aneurysm diagnosis. All patients were operated by the same surgeon using sylvian dissection. Yasargil titanium clips (Aesculap AG & Co., Tuttlingen, Germany) were used to clip the aneurysms.

Statistical Analysis

In this study, statistical analysis was carried out using the NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) package. In order to analyze the data, in addition to descriptive statistical methods (mean, standard deviation), single-direction variance analysis for comparisons of normally distributed variables, Kruskal-Wallis test for comparisons of non-normally distributed variables, Dunn's multicomparative test for comparisons of subgroups, as well as chi-square and Fisher exact tests for comparisons of qualitative data were used. The outcomes were evaluated with a significance level of $p<0.05$.

Results

There were 15 female and 23 male patients with a mean age of 47 years (range: 17-78), of whom 35 (92%) were diagnosed with SAH. Of these patients, 54.2% (n=19) were operated within the first 24 hours and 25.7% between 24-72 hours. Preoperative rebleeding was seen in 2 patients. The mean GCS score just before entering surgery was 12.5±2.5 (3-15). When the patients were evaluated, 21 patients were WFNS grade 1, 5 patients were grade 2, 4 patients were grade 3, 3 patients were grade 4 and 5 patients were grade 5. Thirty-six patients were operated with DSA and 2 patients with CTA. In all 38 cases, the aneurysms were successfully clipped from the neck and the aneurysm domes were checked by puncturing. Temporary clips were needed in 18 patients.

The most common aneurysm was one located on the anterior communicating artery (ACoA) (44.8%). After that, aneurysms on the middle cerebral artery (MCA) (31.6%), posterior communicating artery (PCoA) (13.2%), internal cerebral artery (ICA) bifurcation (7.8%), and distal anterior cerebral artery (A2), respectively, were seen. Four patients with ACoA aneurysm (23.5%) had suffered an intraventricular hematoma (IVH) and two of them had developed an intracerebral hematoma (ICH). Four patients (33.3%) with MCA aneurysm had ICH. The ACoA aneurysm frequency was higher in males and the MCA aneurysm frequency was higher in females. However, aneurysm location and size were not significantly different between males and females (Table 1). There was no significant difference between aneurysm size and mean age, either ($p=0.42$). However, there was a significant correlation between the location of the aneurysm and the mean age ($p=0.009$). The mean age of the patients with ICA bifurcation aneurysms was significantly lower than that of the ones with ACoA and MCA aneurysms ($p=0.03$ and $p=0.004$, respectively) (Table 2).

After operation, all patients were followed in the intensive care unit (ICU) for 1-150 days (12±26.3, mean±SD). After

Table 1: Correlation of sex and aneurysm location and size

		Male (n=23)		Female (n=15)		p
Location of aneurysm	**ACoA**	14	(60.9%)	3	(20%)	0.069
	MCA	4	(17.4%)	8	(53.4%)	
	PCoA	2	(8.7%)	3	(20%)	
	A2	1	(4.3%)	0	(0%)	
	ICA bifurcation	2	(8.7%)	1	(6.6%)	
Aneurysm size	**1-5 mm**	6	(26.1%)	6	(40%)	0.765
	5-10 mm	13	(56.6%)	7	(46.7%)	
	10-25 mm	3	(13%)	2	(13.3%)	
	>25 mm	1	(4.3%)	0	(0%)	

Data are presented with %. Significant p values are shown in bold characters. (n: number, ACoA: Anterior communicating artery, MCA: Middle cerebral artery, PCoA: Posterior communicating artery, ICA: Internal cerebral artery, A2: Distal anterior cerebral artery)

Table 2: Mean age distribution with aneurysm location

Location of aneurysm	n	Age	p
ACoA	17	46.6±14.9	**0.009**
MCA	12	54.2±11.7	
PCoA	5	48.0±13.6	
A2	1	51	
ICA bifurcation	3	22.6±2.3	

Data are presented with means±standard deviations. Significant p values are shown with bold characters. (n: number, ACoA: Anterior communicating artery, MCA: Middle cerebral artery, PCoA: Posterior communicating artery, ICA: Internal cerebral artery, A2: Distal anterior cerebral artery)

surgery, vasospasm was observed in 26.3% of patients. Patients with a high SAH grade developed vasospasm significantly more frequently (p=0.03). There was no correlation between vasospasm and GCS, day of surgery, aneurysm size, and aneurysm location (Table 3). External ventricular drainage (EVD) was used in six patients; subsequently, 2 of them needed a ventriculoperitoneal (VP) shunt.

Neurological examinations at discharge were normal in 17 patients with SAH and 3 patients without SAH. Four patients were discharged with minimal neurological deficit and 2 patients with severe deficit. In total, 12 patients died, including 8 patients with WFNS grade 4-5 (88.8%), 2 patients with grade 3 (50%), and 2 patients with grade 1-2 (7.7%). Postoperative GCS and SAH WFNS grades were found to be determinant for death (p=0.0001 and p=0.022, respectively).

Table 3: Comparison of clinical characteristics of patients with vasospasm

		Vasospasm (+) (n=10)		Vasospasm (-) (n=28)		p
Preoperative GCS score		11.8±3.2		14.3±0.7		0.097
Operation day		3.9±8.3		2.1±1.7		0.518
Temporary clip	**Yes**	5	(50%)	13	(46.4%)	0.846
	No	5	(50%)	15	(53.6%)	
Aneurysm size	**1-5 mm**	2	(20%)	10	(35.7%)	0.061
	5-10 mm	5	(50%)	15	(53.6%)	
	10-25 mm	2	(20%)	3	(10.7%)	
	>25 mm	1	(10%)	0	(0%)	
Location of aneurysm	**ACOM**	3	(30%)	14	(50%)	0.617
	MCA	5	(50%)	7	(25%)	
	PCOA	1	(10%)	4	(14.3%)	
	A2	0	(0%)	1	(3.6%)	
	ICA bifurcation	1	(10%)	2	(7.1%)	
SAH Grade WFNS	**Grade 1**	1	(10%)	20	(71.4%)	**0.034**
	Grade 2	2	(20%)	3	(10.7%)	
	Grade 3	1	(10%)	3	(10.7%)	
	Grade 4	2	(10%)	1	(3.6%)	
	Grade 5	4	(20%)	1	(3.6%)	

Preoperative GCS score and operation day data are presented with mean±standard deviation; the other values are presented with %. Significant p values are shown in bold characters. (n: number, GCS: Glasgow Coma Scale, SAH: Subarachnoid hemorrhage, WFNS: Federation of Neurosurgical Societies, ACoA: Anterior communicating artery, MCA: Middle cerebral artery, PCoA: Posterior communicating artery, ICA: Internal cerebral artery, A2: Distal anterior cerebral artery)

Discussion

Spontaneous SAH accounts for 3-4% of all strokes, and in 85% of cases it is caused by ruptured intracranial saccular aneurysms (5). The risk of rupture of unruptured aneurysms is on average 1-2% per year (6).

Intracranial aneurysms occur more frequently between the fourth and sixth decades. The peak age for rupture is 50 (7). We have seen similar results in our series. However, all patients with ICA bifurcation aneurysms were under 30 years of age. Conversely, Miyazawa et al. (8) reported an average age of 51 years for 25 ICA bifurcation aneurysm patients.

Aneurysms are more common in women, while ACoA aneurysms are more common in men (9). In our study, as expected, MCA and PCoA aneurysms were more common in women. There was a male preponderance in our study, probably due to a higher incidence of ACoA aneurysms.

Anterior communicating aneurysms are the most common aneurysms of the circle of Willis (10), and it is reported that they constitute 30-37% of all intracranial aneurysms (11,12). Third ventricle and ACoA are anatomically closely related. For this reason, ACoA aneurysm rupture causes IVH, either alone or in combination with parenchymal hematomas. Similar to the rates in our study, Hernesniemi et al. (12) reported that IVH was associated with ACoA aneurysm rupture in 19% of their cases.

The probability of ICH in MCA aneurysms is 30-50% (13). In our series, there was an association of MCA aneurysm with ICH in similar ratios. In addition, giant aneurysms (>25mm) are most commonly seen on MCA after the ICA paraclinoid segment (14). In our study, there was a giant MCA aneurysm in one patient.

There are two main methods to treat intracranial aneurysms. Endovascular treatment is preferred in posterior circulation (vertebrobasilar) aneurysms, while microsurgical clipping is preferred in anterior circulation aneurysms. In ruptured aneurysms, early treatment is usually preferred. The main goals of early treatment are the prevention of rebleeding, the prevention and management of vasospasm, and the treatment of other neurologic and medical complications (5). Increased survival rates have been reported with early treatment of ruptured aneurysms (14,15). In our study, almost all of the patients were operated in the early posthemorrhagic period. Nevertheless, in 2 patients the neurological condition was worse after preoperative rebleeding. Only 1 patient was treated too late after hemorrhage, having been referred to our clinic after 45 days at another hospital's intensive care unit.

The incidence of hydrocephalus after SAH has been reported to be about 20% (15). In our series, this ratio was found to be 15.8%. In 6 patients, EVD was performed. Two of them were the patients with preoperative rebleeding, and they died in the first week postoperatively. Two patients required a VP shunt during their follow-up. In the other 2, EVD was removed without VP shunt requirement.

Vasospasm occurs most frequently between 3-14 days after SAH. The incidence of symptomatic vasospasm after SAH has been reported to be 46% (15). Vasospasm can also occur without SAH. Tsyben et al. (17) reported 2 patients with delayed ischemic deficit due to vasospasm after non-ruptured aneurysm surgery. Clipping is an independent risk factor for the development of early cerebral infarcts, whereas delayed cerebral infarcts are associated with angiographic vasospasm (18). In a study dealing with the prevention of vasospasm, Kawahara et al. (19) recommended to perform early lumbar drainage in patients with SAH. In another study, it was reported that delayed ischemic neurological deficits decreased in patients treated with clazosentan (20). However, Velat et al. (21) reported in their meta-analysis that successful treatment for vasospasm was only achieved with nimodipine. In our series, we routinely used nimodipine in vasospasm treatment, but we did not perform lumbar drainage. Instead, we used cerebrospinal fluid drainage with lumbar puncture in cases with clinical vasospasm.

Subarachnoid hemorrhage is a disease with a high mortality and morbidity. Mortality is seen in the first 24 hours at a rate of 25%, of which 10% do not receive any medical help. The total mortality rate of all SAH cases was reported at 31-42% (22). WFNS Grade 4-5 patients constitute a quarter of all patients, and in these patients the mortality is increased to 60% (approximately half before clipping) (23,24). In our study, the mortality rate of grade 4-5 patients was also very high. In addition, presence of IVH is a poor prognostic criterion in SAH (12). In our series, 3 of the cases with IVH died and the other one was discharged from hospital with severe neurological deficits.

With the advances in imaging modalities, it is possible to diagnose aneurysms with CTA without an invasive procedure. Koc et al. (25) reported that an aneurysm was found by DSA in only 1 patient out of 22 who were angiographically negative with 3D CTA. They reported that 3D CTA is a reliable and fast

method for aneurysms ≥3 mm. We used this method in only 2 patients who were operated in a very early period after hemorrhage because of their large ICH.

Most non-ruptured intracranial aneurysms are asymptomatic, and clipping is easier and safer in these cases. However, mortality and morbidity are high in ruptured aneurysm patients. There are new studies to introduce surgical advantages for these cases. Kockro et al. (26) reported that they significantly lowered their mortality and morbidity rates by conducting preoperative 3D planning in a virtual reality environment. In another study, intraoperative monitoring of somatosensory-evoked potentials has been shown to reduce ischemic complications (27). Such studies using new sophisticated technology may contribute to a reduction of operation risks in the future.

Conclusion

Despite the development of endovascular techniques in the treatment of aneurysms, microsurgical clipping remains the method of first choice to treat anterior system aneurysms. Treatment morbidity is determined by numerous factors associated with patient, aneurysm, and institution. There is still no success in the treatment of vasospasm. However, it is well known that early surgery reduces mortality and morbidity.

Contribution Categories	Name of Author
Development of study idea	E.D., B.E., F.K.G., M.Y,
Methodological design of the study	E.D., B.E., O.Y.A., A.T.
Data acquisition and process	M.O., E.D., F.K.G., M.Y., O.Y.A.
Data analysis and interpretation	I.G., O.Y.A., A.T., A.T.
Literature review	M.O., I.G., A.T., A.T., M.S.V.
Manuscript writing	M.S.V., B.E., F.K.G., M.Y.
Manuscript review and revisation	M.O., A.T., M.S.V., I.G.

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

Financial Disclosure: The authors declared no financial support.

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