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Research

Results of Microsurgical Clipping of Anterior Circulation Aneurysms Secondary to Subarachnoid Hemorrhage: 107 Cases

Subaraknoid Kanama ile Prezente Anterior Sistem Anevrizmalarının Mikrocerrahi Klipleme Cerrahi Sonuçları: 107 Olgu

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ABSTRACT

Objective: Spontaneous subarachnoid hemorrhage (sSAH) is a significant disease requiring urgent intervention. It may develop because of the rupturing of intracranial aneurysms and has high mortality and morbidity rates. This study was conducted at a hospital that serves as a reference center in the region in which it is located with the aim of evaluating patient characteristics, patient preferences, and complication management among patients with aneurysmal subarachnoid hemorrhage (aSAH) and presenting the results of these intracranial aneurysm clipping surgeries.

Methods: Cases of 261 patients who were admitted with a diagnosis of sSAH were retrospectively examined. Subsequently, 107 patients with aSAH who were treated with 117 microsurgical aneurysm clippings were included in the study. The effects of patient demographics, Glasgow coma scale (GCS) scores, clinical World Federation of Neurological Surgeons scale and Hunt/Hess scale scores, and radiological modified Fisher scale gradings on modified Rankin scale (mRS) scores were examined. The management of complications such as rebleeding, cerebral vasospasm (CV), and delayed cerebral ischemia and surgical results were compared according to clinical and radiological data.

Results: Of the patients, 52 were female (48%) and 55 were male (52%). Their average age was 50.4 years (range: 29-78 years), and the mean follow-up period was 13.8 months or 414 days (range: 30-892 days). The most common complaint of the patients at admission was headache (75.8%). Approximately 72.9% of patients had GCS scores of 14 or 15 at first admission. Twenty-eight (26.1%) patients had multiple aneurysms. Thirteen (12%) patients required a permanent cerebrospinal fluid drainage system. Rebleeding occurred in 7 (6.5%) patients before treatment. Thirty-six (33.6%) patients had a clinical CV. Delayed cerebral ischemia occurred in 25 (23.3%) patients. At the end of the mean follow-up period of 13.8 months, 82.3% of the patients had slight or no disabilities (mRS: 0-2), whereas 11.2% had severe disabilities (mRS: 3-5). Seven (6.5%) patients died, thus having an mRS score of 6 (exitus). Five (4.6%) patients had residual aneurysms. Six (5.6%) patients had parent or perforating artery occlusion.

Conclusion: Poor prognosis at admission, rebleeding, and CV complications remain the most important causes of mortality and morbidity related to aSAH. Evaluations of the diagnoses, treatments, and complication management of patients with sSAH and the multidisciplinary approaches of experienced endovascular and neurosurgical teams are important for better understanding and management of this disease.

Keywords: Cerebral vasospasm, rebleeding, modified Fisher scale, mortality, morbidity

ÖZ

Amaç: Spontan subaraknoid kanama (sSAK) acil müdahale gerektiren önemli bir hastalıktır. İntrakraniyal anevrizmaların yırtılmasına bağlı olarak gelişebilir ve yüksek mortalite ve morbidite oranlarına sahiptir. Bu çalışma, bulunduğu bölgenin referans bir merkez hastanesinde olup, başvuran anevrizmal subaraknoid kanama (aSAK) hastalarının özelliklerini, hastaların seçim ve komplikasyon yönetimini tartışmayı ve intrakraniyal anevrizma kliplenmesi cerrahisi sonuçlarını literatüre sunmayı amaçlamaktadır.

Gereç ve Yöntem: sSAK ile gelen 261 hasta retrospektif olarak incelendi. Yüz on yedi mikrocerrahi anevrizma klipleme operasyonu ile tedavi edilen 107 aSAK hastası çalışmaya dahil edildi. Hastaların demografik verileri, Glasgow koma skalası (GKS) skorları, klinik World Federation of

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Neurological Surgeons ve Hunt/Hess skalası skorları ve radyolojik modifiye Fisher sınıflamalarının modifiye rankin skalası (mRS) skorları üzerine olan etkileri incelendi. Tekrar kanama, serebral vazospazm, gecikmiş serebral iskemi gibi komplikasyonların yönetimi literatür ışığında tartışılmış ve cerrahi sonuçlar klinik ve radyolojik verilerle karşılaştırılmıştır.

Bulgular: Hastaların 52'si kadın (%48), 55'i erkekti (%52). Ortalama yaşları 50,4 (dağılım: 29-78 yıl), ortalama takip süresi 13,8 ay veya 414 gündü (dağılım: 30-892 gün). Hastaların başvuru anında en sık şikayeti baş ağrısıydı (%75,8). Hastaların %72,9'unun ilk başvuruda GKS skorları 14 veya 15'ti. Yirmi sekiz (%26,1) hastada çoklu anevrizma saptandı. On üç (%12) hastada kalıcı beyin omurilik sıvısı drenaj sistemi gerekti. Tedavi öncesinde 7 (%6,5) hastada tekrar kanama meydana geldi. Otuz altı (%33,6) hastada serebral vazospazm kliniği vardı. Gecikmiş serebral iskemi 25 (%23,3) hastada görüldü. Ortalama 13,8 aylık takip süresi sonunda hastaların %82,3'ü hafif engelli veya engelsiz (mRS: 0-2), %11,2'si ağır engelli (mRS: 3-5) seyretti. mRS skoru 6 (eksitus) olan 7 (%6,5) hasta mevcuttu. Beş (%4,6) hastada rezidü anevrizma tespit edildi. Altı (%5,6) hastada parent veya perforan arter oklüzyonu görüldü.

Sonuç: Başvuru anında kötü prognoz olması, tekrar kanama, serebral vazospazm gibi komplikasyonlar, aSAK'ye bağlı mortalite ve morbiditenin en önemli nedenleri arasında olmaya devam etmektedir. sSAK'lı hastaların tanı, tedavi ve komplikasyon yönetiminin deneyimli endovasküler ve nöroşirürji ekiplerinin multidisipliner yaklaşımları ile değerlendirilmesi bu hastalığın daha iyi anlaşılması ve yönetilmesi için önemlidir.

Anahtar Kelimeler: Serebral vazospazm, rebleeding, modifiye Fisher skalası, mortalite, morbidite

INTRODUCTION

Spontaneous subarachnoid hemorrhage (sSAH) is a clinical entity that causes high rates of mortality and morbidity, although it is responsible for only 1-7% of all strokes (1). In the past few decades, new diagnostic techniques, advances in neuroanesthesia, and technical developments in surgical clipping and endovascular methods have revolutionized the treatment of aneurysmal subarachnoid hemorrhage (aSAH), decreasing the annual mortality rates by 0.5-0.8% (2,3). Although mortality rates have decreased in developed countries over the last 25 years, this group of patients still experiences mortality rates of 32% to 67%, while one-third of survivors become permanently disabled (2-7).

Despite alternative methods devised by interventional radiologists for the treatment of aSAH secondary to intracranial aneurysms, such as coiling and stenting, microsurgical clipping remains a precise and permanent treatment method. The aim of this treatment is to completely close the aneurysm dome and protect the parent and perforating arteries (8-10).

On the other hand, treatment modalities for managing complications related to aSAH have still not been elucidated (11). The most common complication of aSAH is rebleeding. For untreated aneurysms, the risk of rebleeding is 20-30% in the first month and 3% per year in the following years. aSAH significantly increases mortality and morbidity. It is associated with mortality at a rate of approximately 67% (12,13). Cerebral vasospasm (CV) and delayed cerebral ischemia secondary to CV, which are observed in the middle and late stages of aSAH, are among the foremost complications. CV is responsible for 50% of the morbidity and mortality of patients who survive the first hemorrhage (14). The pathophysiology, prophylaxis, and treatment of CV are still major topics of discussion (11).

This study was conducted at a hospital that serves as a reference center in the region in which it is located with the aim of evaluating patient characteristics, patient preferences, and complication management of patients with aSAH and presenting the results of these intracranial aneurysm clipping surgeries.

METHODS

Patient Group

This study was conducted in a single center and included the results of operations performed by a single surgical team. A total of 107 patients operated on due to aSAH between September 2020 and November 2022 were included in the study. After obtaining approval for the study from the Ethics Committee of University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital (decision no: 358, date: 16.08.2023), all data were retrospectively compiled and reviewed. All patients underwent non-contrast brain computed tomography (CT) scanning and digital subtraction angiography (DSA) before treatment for diagnostic purposes. Patients with internal carotid artery aneurysms were also scanned with contrast brain CT angiography to evaluate the relationship of the aneurysms with bones. All patients consulted interventional radiologists and were scheduled to undergo microsurgical clipping or endovascular treatment according to factors such as the morphology of the aneurysm and its placement, the preferences of patients and/or their representatives, and the center's caseload.

During the study period, 261 patients diagnosed with sSAH were treated in our clinic. No vascular pathology was detected in the first DSA examinations of 53 patients (20.3%), whereas 39 patients (15%) had pathologies not associated with intracranial aneurysms (e.g., arteriovenous malformation, arteriovenous fistula, and sinus vein

thrombosis). Intracranial aneurysm was the cause of sSAH in 169 (64.7%) patients. While 62 (23.7%) patients were treated for aSAH with endovascular methods by interventional radiologists, 107 (41%) patients underwent microsurgical aneurysm clipping as the first treatment for aSAH.

Patients treated for unruptured intracranial aneurysms, patients who were admitted because of sSAH but had no vascular pathologies or had intracranial aneurysms and/or non-aneurysm pathologies, and patients whose primary treatment and long-term follow-up were overseen by interventional radiologists as per the decision of the council were excluded from the study.

Patient demographics, comorbidities, clinical World Federation of Neurological Surgeons (WFNS) scale scores (15), Hunt/Hess scale (H/HS) scores (16), and radiological modified Fisher scale (mFS) scores (17) were analyzed considering modified Rankin scale (mRS) scores (18) and patient records.

Surgical Procedure

Traditional pterional craniotomy was used as the surgical technique for anterior circulation aneurysms, whereas median craniotomy, which allows an interhemispheric approach, was used as the surgical technique for distal anterior cerebral artery aneurysms. In accordance with microsurgical principles, the chiasmatic cisterns, carotid cisterns, and, if necessary, lamina terminalis cisterns of the patients were opened, sylvian fissures were dissected, proximal arteries were explored starting from around the aneurysm and perforating arteries, and, especially in cases of large aneurysms, venous structures adhered to the aneurysm dome were dissected from the neck of the aneurysm. The proximal parent arteries of most patients, not including patients with small aneurysms, were temporarily clipped. Temporary clipping reduced the internal pressure of the aneurysm dome and made it suitable for dissection from the surrounding environment (Figures 1,2). Temporary clipping was applied in areas where perforating arteries would be least affected and were suitable for repetitive manipulations. Placing a pilot clip helped in elucidating the relationship of the aneurysm with the surrounding anatomical structures in thorough explorations of the dome, especially in cases of large aneurysms, and minimized the risk of rupture until the final clipping (Figure 3). The active presence of a second surgeon in the room facilitated dynamic retraction and manipulation with a third hand and allowed clip repositioning and placement of multiple clips when necessary (Figure 4). The technical details of these procedures have been discussed in previous studies (19).

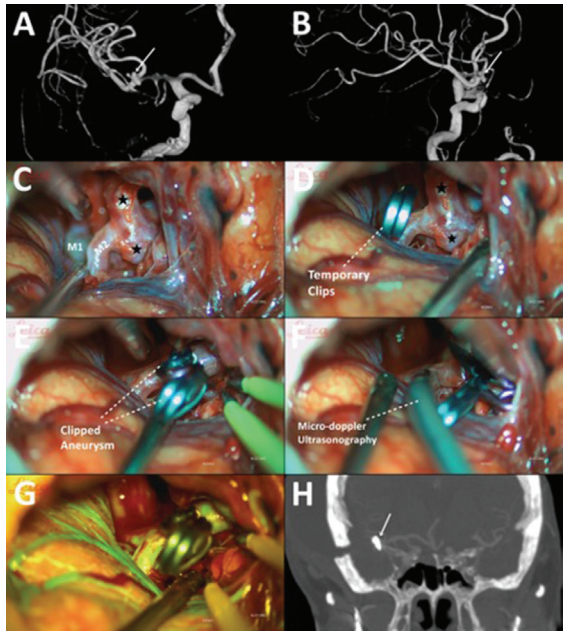

Figure 1. A 71-year-old female patient who underwent surgery due to an aneurysm in the hemorrhaging bifurcation of the right middle cerebral artery (MCA). A,B. Three-dimensional anterior-posterior and lateral images from preoperative digital subtraction angiography showing a saccular aneurysm (arrow) involving both trunci with a small bleb in the right MCA bifurcation, measuring 6×4 mm. C. Image of the aneurysm dome (star) and the right MCA M1 and M2 segments. D. Image of the temporary clip placed on the aneurysm dome and right MCA M1 segment. E. Image of the aneurysm dome being closed with two permanent clips. F. Image of the flow in the aneurysm dome and right MCA branches being explored by micro-Doppler ultrasonography. G. Videoangiography mode image after sodium fluorescein injection showing that the aneurysm dome is not filled. H. Postoperative computed tomography brain angiography image, coronal section, showing the aneurysm clip (arrow), no residual aneurysmal embolization, and no parent artery loss

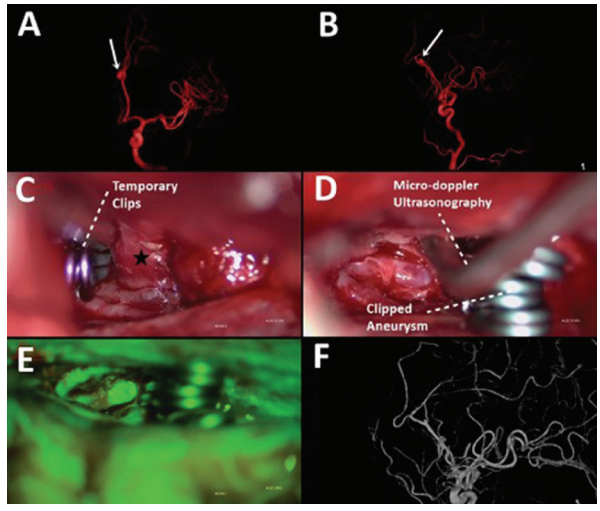

Figure 2. A 55-year-old female patient who underwent surgery due to an aneurysm in the hemorrhaging left pericallosal artery. A,B. Three-dimensional anterior-posterior and lateral images from preoperative digital subtraction angiography (DSA) showing an anterosuperiorly oriented saccular aneurysm with a narrow neck (arrow) in the left pericallosal artery, measuring 6.5×5.2 mm. C. Image of the aneurysm dome (star) and a temporary clip placed proximally to the aneurysm. D. Image of the aneurysm dome being closed with three permanent clips. The distal aneurysm is being explored by micro-Doppler ultrasonography. E. Videoangiography mode image after sodium fluorescein injection showing that the aneurysm dome is not filled. F. Postoperative 3-dimensional DSA image showing millimetric residual aneurysmal filling

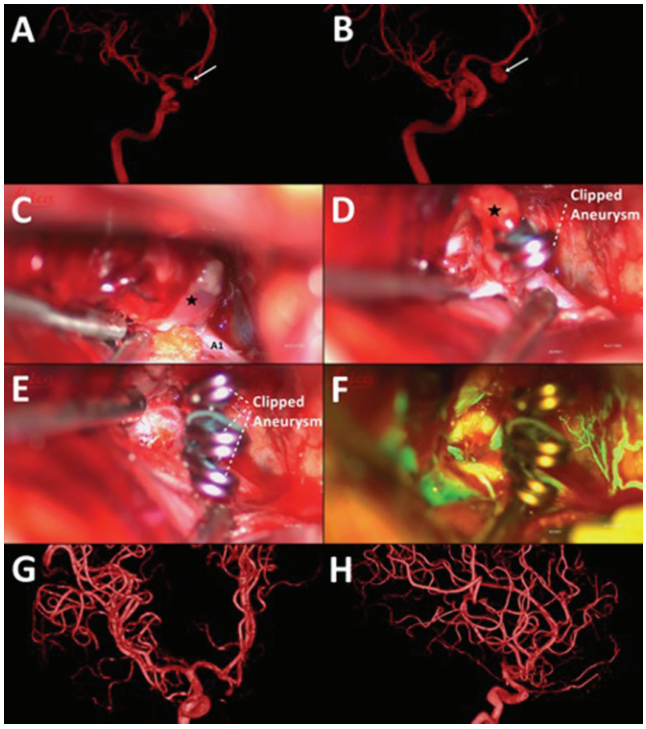

Figure 3. A 30-year-old male patient who underwent surgery due to an artery aneurysm in the hemorrhaging anterior communicating segment (Acom). A,B. Three-dimensional anterior-posterior and lateral images from preoperative digital subtraction angiography (DSA) showing an anteroinferiorly oriented, narrow-necked, irregularly contoured saccular aneurysm (arrow) filling from the right at the Acom level, measuring 8.5×6.1 mm. C. Image of the aneurysm dome (star) and the A1 segment of the right anterior cerebral artery. D. Image of the aneurysm dome (star) and the pilot clip placed on the hemorrhaging component. E. Image of the aneurysm dome being closed with serial clipping. F. Videoangiography mode image after sodium fluorescein injection showing that the aneurysm dome is not filled. G,H. Anterior-posterior and lateral images from postoperative DSA showing no residual aneurysmal filling and no loss of parent arteries

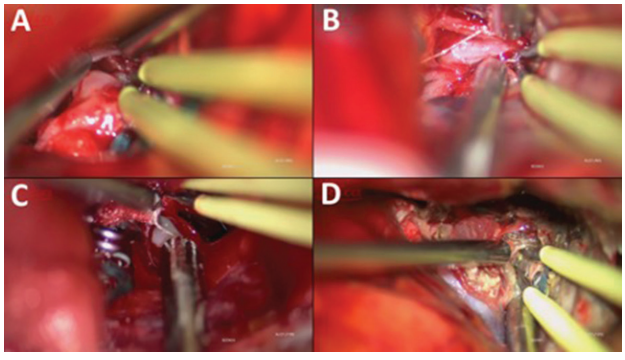

Figure 4. A-D. Images of retraction and aspiration performed in four different cases before aneurysm clipping with the help of the aspirator used by the second surgeon with the third-hand technique

Following the clipping of the aneurysm and ensuring optimal clip positioning via surgical observation and microvascular Doppler sonography (Hadeco Inc., Japan, and Koven Technology Inc., USA), sodium fluorescein videoangiography was performed using the FL560 module of a microscope (Figures 1,2,5). The details of this procedure have been discussed in previous studies (10).

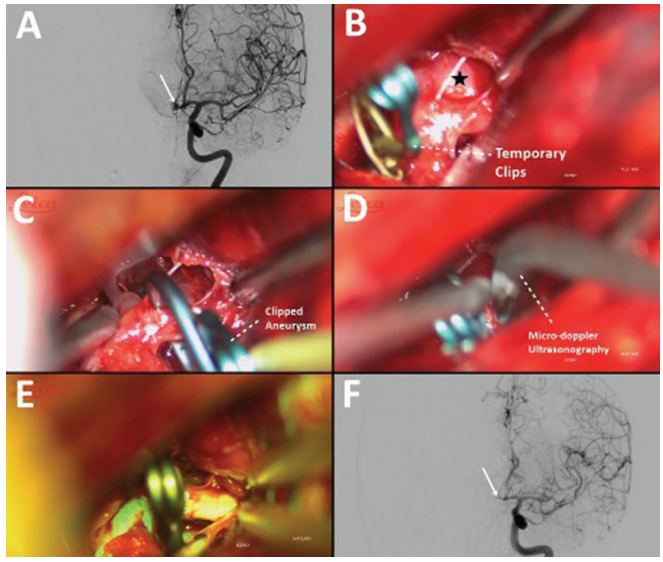

Figure 5. A 65-year-old female patient who underwent surgery due to an artery aneurysm in the hemorrhaging anterior communicating segment (Acom). A. Anterior-posterior and lateral image from preoperative digital subtraction angiography (DSA) showing a right-anterolaterally oriented saccular aneurysm (arrow) with an abnormal border at the Acom level and a narrow neck, involving the left A2 and measuring approximately 5.6×3.5 mm. B. Image of the aneurysm dome (star) and the temporary clip placed on the A1 segment of the left anterior cerebral artery. C. Image of the aneurysm being closed with a single permanent fenestrated clip. D. Image of the flow to the A1 segments of the right and left anterior cerebral artery used to explore the aneurysm dome by micro-Doppler ultrasonography. E. Videoangiography mode image after sodium fluorescein injection showing that the aneurysm dome is not filled. F. Anterior-posterior image from postoperative DSA showing an atrium-shaped residual aneurysmal filling (arrow), measuring 1.2×1 mm.

Postoperative Procedure

In the early postoperative period, all patients were screened using non-contrast brain CT to exclude possible complications secondary to surgery. Contrast brain CT angiography and/or DSA were performed for patients within a few days after the operation to evaluate whether total obliteration of the aneurysm had been achieved. Diffusion-weighted magnetic resonance imaging (DW-MRI) was performed when necessary to confirm the suspicion of delayed cerebral ischemia.

Statistical Analysis

Statistical analyzes were performed using the SPSS software.

CV Prophylaxis and Management

Hyponatremia was aggressively treated in all patients. Hemoglobin levels were maintained above 9-10 g/dL. No long-term epileptic seizure prophylaxis was administered.

All patients admitted to our hospital with a diagnosis of sSAH were administered prophylactic oral nimodipine (6×60 mg) and oral cilostazol (2×100 mg) during the postoperative period. Patients with CV symptoms who had no contraindications underwent single or serial lumbar puncture. Patients who developed delayed cerebral

ischemia and did not have cardiac contraindications were treated for hypotension with inotropes. Patients with progressive conditions who showed no response to medical treatment were treated with intraarterial vasodilators and/or balloon angioplasty after consultations with interventional radiologists (Figure 6).

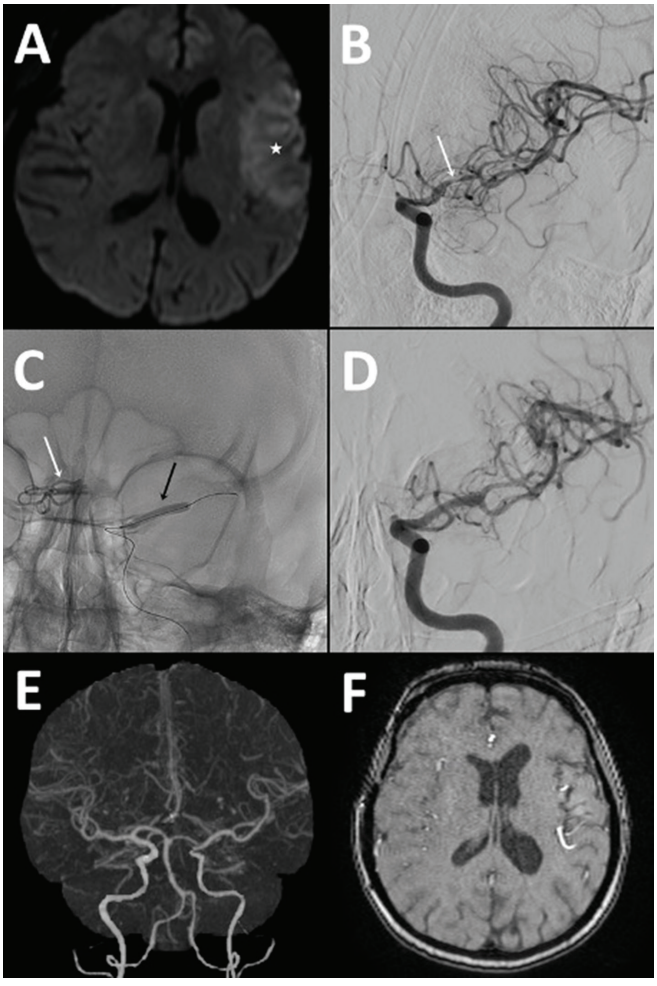

Figure 6. A 50-year-old female patient who underwent surgery due to an artery aneurysm in the hemorrhaging anterior communicating segment (Acom). A. Diffusion magnetic resonance imaging (MRI) was performed for the patient on the postoperative sixth day after the development of aphasia and paresis in the right upper limb. Image of an acute ischemic area (star) causing diffusion restriction in the watershed area of the left middle cerebral artery (MCA) in the left parietal region. B. Anterior-posterior image from preoperative digital subtraction angiography showing significant vasospasm in the left MCA (arrow) and slowed flow in the distal branches. Upon this finding, 2 mg of intraarterial nimodipine was administered to the patient. C. Upon the patient showing no response to nimodipine, balloon angioplasty was performed on the left MCA M1 segment with a compliant balloon of 4×20 mm (black arrow). Image shows clip material (white arrow) in the Acom arterial area. D. Anterior-posterior control image showing that the vasospasm was completely eliminated and the flow in the distal branches returned to normal. The patient's aphasia and paresis of the right upper extremity improved. E. Three-dimensional anterior-posterior computed tomography brain angiography image taken 1 year later showing that the left MCA and its branches have normal width and correct location. F. Axial section of MRI angiography performed 1 year later showing no infarct areas

RESULTS

The average age of the 107 aSAH patients treated with microsurgical clipping was 50.4 years (range: 29-78 years). Of the patients included in the study, 52 were female (48%) and 55 were male (52%). The main complaints of these patients upon admission to the hospital are summarized in Table 1. Headache was a significantly common complaint (75.8%) at admission. A total of 107 operations were performed for the included patients, and 117 aneurysms were clipped throughout the 107 operations (Table 2). The average follow-up time of the patients was 13.8 months or 414 days (range: 30-892 days).

Multiple aneurysms were detected in 28 (26.1%) patients with aSAH who were treated with microsurgical clipping. Ten (9.3%) patients with more than one aneurysm underwent multiple aneurysm clippings in the same session. Four (3.7%) patients required a second intervention, and their treatments were planned with the interventional radiology and neurosurgery clinics. No second interventions were planned for the aneurysms of 14 (13%) patients because of the absence of treatment indications, and these cases were followed radiologically. The Glasgow coma scale (GCS) scores of aSAH patients are presented in Table 3. It was found that approximately 72.9% of the patients had GCS scores of 14 or 15.

The clinical classifications of patients with aSAH can be determined using the WFNS classifications and H/HS scale, while their radiological classifications can be determined using mFS scores. The classification information of the 107 patients included in this study is presented in Table 4.

Among our cohort of patients with aSAH, 17 (15.8%) showed signs of hydrocephalus at admission to the hospital and required external ventricular drainage, whereas only 11 (10.2%) underwent ventriculoperitoneal (VP) shunting. In addition, 2 patients (1.8%) who did not show signs of hydrocephalus at admission to the hospital but showed signs of hydrocephalus during long-term follow-up required permanent cerebrospinal fluid drainage systems. A total of 13 (12%) patients required VP shunting.

Seven (6.5%) of the 107 patients in our cohort developed repeat bleeding. Three patients developed repeated bleeding before admission to our clinic based on epicenter non-contrast brain CT comparisons, whereas four patients developed repeated bleeding within the first 12 hours (h) after admission.

CV was detected in 36 (33.6%) patients. Twenty-five (23.3%) patients were diagnosed with delayed cerebral ischemia using DW-MRI. Lumbar puncture was performed

in 28 patients. Sixteen patients underwent intraarterial nimodipine administration and/or balloon angioplasty performed by interventional radiologists.

Morbidity

At the end of an average follow-up period of 13.8 months, 82.3% of aSAH patients treated with microsurgical clipping had no disabilities or were slightly disabled (mRS: 0-2), whereas 11.2% were severely disabled (mRS: 3-5). The mRS scores of the patients are presented in Table 5. Comparisons of mRS scores with WFNS and H/HS scores are presented in Tables 6 and 7, respectively.

Mortality

Seven (6.5%) patients died, thus having an mRS score of 6 (exitus). Three patients died because of complications that developed because of rebleeding, which occurred shortly after the patients were admitted to our center. Three patients had stable postoperative conditions for at least 24 h and then developed delayed cerebral ischemia, which was confirmed via DW-MRI and CT. CV was confirmed via DSA. In the applied medical and invasive treatment protocols for CV, which included intraarterial nimodipine and balloon angioplasty, CV complications resulted in death. A patient who had a GCS score of 7 at the start of the operation did not achieve any clinical progress in the intensive care unit (ICU) follow-up after the operation and died because of hemodynamic instability and morbidities developing during follow-up. Comparisons of the mRS scores of the patients with their WFNS and H/HS scores are presented in Tables 6 and 7.

Table 1. Complaints at the time of application

Complaints	Value	Percent
Headache	81	75.8%
Loss of consciousness	17	15.8%
Seizure	3	2.8%
Focal neurological deficit	6	5.6%
Total	107	100

Table 2. Aneurysm localizations

Aneurysms	Value	Percent
Anterior communicating artery	50	41.9%
Middle cerebral artery bifurcation/trifurcation	30	25.6%
Middle cerebral artery-M1 branches	4	2.5%
Middle cerebral artery-M2 branches	3	3.4%
Posterior communicating and anterior choroidal artery	20	17.2%
Internal carotid artery-bifurcation	5	4.3%
Anterior cerebral artery-A1 branches	2	1.7%
Anterior cerebral artery-A2 branches	3	3.4%
Total	117	100%

Surgical Complications

Residual aneurysms were detected in 5 cases (4.6%) via postoperative DSA. One of these patients was followed without intervention because the size of the residual aneurysm was 1-2 mm. The other four patients underwent endovascular treatments (flow-diverting stent or coil + flow-diverting stent) instead of repeated microsurgical interventions.

Table 3. Glasgow coma scale of aSAH patients

GCS score	Amount of patients	Percent
3	2	1.8%
4	2	1.8%
5	2	1.8%
6	1	0.9%
7	3	2.8%
8	4	3.7%
10	2	1.8%
11	1	0.9%
12	3	2.8%
13	9	8.5%
14	32	30%
15	46	43.2%
Total	107	100

GCS: Glasgow coma scale, aSAH: Aneurysmal subarachnoid hemorrhage

Table 4. International subarachnoid hemorrhage

	Classifications					
	WFNS grade		Hunt and Hess grade		M. Fisher grade	
Grade	n	%	n	%	n	%
I	46	42.9	40	37.4	37	34.6
Ia	-	-	1	0.9	-	-
II	36	33.6	37	34.6	2	1.8
III	5	4.7	13	12.2	47	43.9
IV	13	12.2	10	9.3	21	19.7
V	7	6.6	6	5.6	-	-
Total	107	100	107	100	107	100

WFNS: World Federation of Neurological Surgeons

Parent or perforating artery occlusion occurred in 6 (5.6%) patients secondary to surgery. The infarction areas detected in 3 patients were asymptomatic or had temporary symptoms. In 3 cases, permanent neurological deficits occurred. Although the aneurysm of the first patient occurred in the bifurcation of the right internal carotid artery, the right choroidal artery was observed during the operation, and the temporary clip was placed distally to the choroidal segment, 1/5 left-sided hemiparesis occurred due to right choroidal artery infarction that developed in the postoperative period. At the end of the follow-up period, the paresis of this patient improved by up to 4/5 in left lower muscle strength and 3/5 in left upper muscle strength because of physical therapy. The second patient had a widespread left large middle cerebral artery infarction, which caused right-sided hemiplegia and aphasia. After the fetal-type left posterior communicating artery aneurysm of the third patient was clipped, fragmentary infarction was observed in the left posterior cerebral artery watershed area, and the patient experienced 4/5 right-sided hemiparesis.

Rhinorrhea due to a defect opening to the sphenoid sinus occurred in one patient in the postoperative period, and the skull base of that patient was treated in a second operation. The patient did not have any further complaints during the follow-up period. Another patient had tension pneumocephalus due to a frontal sinus defect, and the skull base of that patient was treated in a second operation. One other patient underwent a second operation because of an

Table 5. Modify Rankin scale of aSAH patients

	n	%	%
0	76	71.1	
1	10	9.4	82.3
2	2	1.8	
3	3	2.8	
4	3	2.8	11.2
5	6	5.6	
6	7	6.5	6.5
Total	107	100	100

aSAH: Aneurysmal subarachnoid hemorrhage

Table 6. International subarachnoid hemorrhage classifications

	WFNS grade		mRS 0-1-2		mRS 3-4-5		mRS 6	
Grade	n	%	n	%	n	%	n	%
I	46	42.9	42	91.3	4	8.7	0	0
II	36	33.6	33	91.6	2	5.6	1	2.8
III	5	4.7	4	80	0	0	1	20
IV	13	12.2	5	38.5	3	23	5	38.5
V	7	6.6	2	28.5	5	71.5	0	0
Total	107	100	86	100	14	100	7	100

WFNS: World Federation of Neurological Surgeons, mRS: Modified Rankin scale

Table 7. International subarachnoid hemorrhage classifications

	H/HS grade		mRS 0-1-2		mRS 3-4-5		mRS 6	
Grade	n	%	n	%	n	%	n	%
I	40	37.4	36	90	4	10	0	0
Ia	1	0.9	1	100	0	0	0	0
II	37	34.6	35	95	1	2.5	1	2.5
III	13	12.2	9	70	1	7	3	23
IV	10	9.3	4	40	4	40	2	20
V	6	5.6	1	16.5	4	67	1	16.5
Total	107	100	86		14		7	

mRS: Modified Rankin scale, H/HS: Hunt/Hess scale

epidural hematoma detected in a postoperative brain CT scan. All complications are presented in Table 8.

Table 8. Surgical complications of aSAH patients

Complications	Value	Percent
Infarct (mean braches and perforans)	6	5.6%
Cerebrospinal fluid leaks	1	0.9%
Skin wound problem	2	1.8%
Epidural hematom	1	0.9%
Tension pneumocephalus	1	0.9%
Total	11	10.2%

aSAH: Aneurysmal subarachnoid hemorrhage

DISCUSSION

This study provides data on the clinical profiles, management, and outcomes of patients admitted with sSAH diagnoses to a hospital that serves as a reference center, located in a large metropolis with a population of approximately 8-10 million. Our clinic has established a rapid referral chain in coordination with emergency transport units. The treatment of admitted patients is planned as either surgical or neurovascular intervention according to the clinical condition of the patient and the location of the detected aneurysm. Because almost all patients in the large region for which the clinic provides treatment services are referred to our hospital regardless of good or poor condition, it is thought that this study is capable of accurately reflecting the morbidity and mortality rates associated with the treatment of aSAH through microsurgical clipping. Thus, it is believed that this study will make a valuable contribution to the literature.

With the exception of Japan and Finland, where the figures are doubled because of genetic factors, the overall incidence of aSAH has remained at a stable level of 9/100,000 per year worldwide (20,21). sSAH most often occurs in the age range of 40-60 years, with an average patient age of 50. It has been observed that the incidence of sSAH increases with age (22). Headaches constitute 2% of all complaints among all patients at first admission to emergency departments, and 1-3% of patients who complain of headaches are diagnosed with sSAH (23). Because headache is a common complaint, certain characteristics should be considered to avoid overlooking the possibility of sSAH, such as sudden and severe headaches with comorbid neurological deficits or patients over the age of 40. The main complaint of 75.8% of the patients included in this study was headache, and the average age of the patients was 50.4 years (range: 29-78 years).

The most important factor determining the prognosis of patients with aSAH is the initial condition of the patient. In this context, the GCS, WFNS, and H/HS scales are most frequently used for the classification of patients with aSAH (7,24,25). mFS, on the other hand, is used to predict CV (17). In this study, mortality and morbidity results based on mRS scores were compared with WFNS and H/HS scores.

The 2002 ISAT study (26) evaluating microsurgical clip treatment results reported that 36.4% of patients who underwent the procedure had mRS scores of 3-6 and 8.3% of them had mRS scores of 6 (exitus) at the second month after the procedure, while 30.6% of patients had mRS scores of 3-6 and 10.1% had mRS scores of 6 (exitus) in the first year following the procedure. An extensive meta-analysis revealed that 15% of patients who underwent the procedure had mRS scores of 6 (exitus), whereas 30.9% of them had mRS scores of 3-6 (27). The same meta-analysis showed that the complication rate of microsurgical clipping operations was 10.8%. In the present study, it was determined that 17.7% of patients who underwent the procedure had mRS scores of 3-6 and 6.5% had mRS scores of 6 at the end of an average follow-up period of 13.8 months. The surgical complication rate determined in this study was 10.2%. The lower mortality and morbidity rates of the present study compared with the literature may be explained by the fact that posterior circulation aneurysms were not included in this study and the study included fewer patients compared with the aforementioned series.

It was observed that a center with fewer than 10 annual sSAH patient admissions had a significantly lower mortality rate than a center with more than 35 annual sSAH patient admissions (28). However, multidisciplinary centers with neurointensive care units and experienced endovascular and vascular surgical teams that accept a high number of cases are recommended for patients with sSAH (7,25,29). During this study, approximately 130 sSAH patients were admitted to our center annually, and approximately 50 aSAH patients underwent microsurgical clipping. High patient admission rates help not only the surgical team but also branch practitioners such as anesthesiologists or endovascular experts, physicians, and non-physician medical personnel working in units such as in-patient departments and ICUs gain experience and contribute to improved morbidity and mortality rates.

A multidisciplinary approach assisted by an endovascular team is important for treating aSAH (7,24). The technical capabilities of the center and the experience of the

surgical team are the foremost factors that determine the treatment methods for aneurysms (29). In addition to factors such as the location, structure, and width of the aneurysm and the narrowness of the aneurysm neck, factors such as the patient's age, general condition, and presence of intracerebral hematoma are influential in the selection of aneurysm treatment methods (7,24,29). In our clinic, the indication for microsurgical clipping is decided on according to general principles with the deliberation of a council that includes an endovascular team. In centers with high caseloads, it is important for both the surgical and vascular teams to evaluate patients and plan together according to their schedules to be able to treat patients with the most appropriate decisions in the shortest possible time.

Rebleeding is one of the most important complications occurring among patients with aSAH in the period leading up to treatment (30). It tends to occur within the first 3 days after aSAH, and its incidence rate is approximately 13% on average (31). The rate of incidence of rebleeding is 3-4% within the first 24 h, and it most commonly occurs within 2-12 h (22). Rebleeding is a complication that significantly increases the risk of mortality and morbidity; the mortality and morbidity rates of patients who develop rebleeding may reach up to 80% (12,13). In the literature, it has been reported that delays in hospital admission and diagnosis vary by geographical region, but evidence suggests that these delays worsen the prognosis of patients (2). The timing of treating an aneurysm is important because of the risk of rebleeding. The consensus in the literature holds that the final treatment of patients should be planned as soon as possible within 72 h after the first hemorrhage, taking into account the technical capabilities of the center and vascular teams and the patient's condition (22,23,25,29,32). Furthermore, centers that perform extremely early surgery within 24 h have shared results that can be considered significantly positive (33,34). In this study, rebleeding was observed in 7 of 107 patients (6.5%) and 2 of those 7 patients died. Most patients who developed rebleeding in this study had that complication before reaching our center or at a time early enough to make treating the aneurysm impossible. In our center, most patients undergo final treatment within less than 24 h and a maximum of 72 h.

Approximately 70% of aSAH patients develop CV, and approximately 30% of these patients develop symptomatic CV or delayed cerebral ischemia observed in imaging. Although compounds are utilized against CV and delayed cerebral ischemia, effective medical treatments are still being researched (11). Hypervolemia, hemodilution, and hypertension, known as 3-H treatment, are no longer recommended treatment options for this condition. Induced hypertension is indicated for symptomatic patients, but its use may be limited by the patient's cardiac condition (29,35). Oral nimodipine is a compound whose efficacy has been proven in randomized controlled trials (24,25,29). Cilostazol is also a promising compound whose effectiveness against symptomatic and radiological CV has been demonstrated (36). In addition, cisternal irrigation and lumbar drainage are among the methods that have positive clinical effects on CV outcomes. Although endovascular treatment methods, including intraarterial vasodilator compound injections and balloon angioplasty, are not recommended as prophylactic treatments for CV, they produce positive results in patients with resistant clinical conditions (37). In this series, all patients were administered prophylactic oral nimodipine and cilostazol. Despite prophylactic treatment, symptomatic vasospasms were observed in 33.6% of the patients, which is a rate similar to that reported in the literature. Patients who developed CV despite prophylactic treatment were treated incrementally with lumbar puncture, induced hypertension, and endovascular treatments, such as intraarterial vasodilators and/or balloon angioplasty, in the event that they did not respond to other treatments. Hydrocephalus and hyponatremia are among the complications of sSAH. They are associated with poor clinical outcomes and should be promptly treated (29,38-40).

In the literature, the rate of parent or perforating artery occlusion secondary to surgery has been reported to be 0.3-12%. In an extensive series, the rate of residues in aneurysm domes was reported to be 5.9% (41,42). It has also been reported in the literature that the use of intraoperative auxiliary techniques such as videoangiography and microvascular Doppler sonography reduces mortality and morbidity by protecting the perforating and parent arteries and ensuring the complete closure of the aneurysm dome, which are the main aims of vascular surgery (8-10,19). Sodium fluorescein videoangiography and microvascular Doppler sonography were used in this study. The parent or perforating artery occlusion rate was 5.6%, and the residual rate in the aneurysm dome was 4.6%.

There are currently two main treatment methods for aSAH: endovascular treatment and microsurgical clipping. Discussing all possible treatment methods and their results within a single population would allow better elucidation of aSAH treatment options. However, this study has only presented the results of patients who underwent microsurgical clipping. The fact that the follow-up procedures and the results achieved by the endovascular team were not discussed is another limitation of this study.

CONCLUSION

The occurrence of aSAH continues to challenge the healthcare system in Türkiye and in other developing countries. Early detection strategies, fully equipped third-line hospitals, and effective referral systems are necessary to treat aSAH patients in a timely manner. Multidisciplinary approaches applied by experienced endovascular and neurosurgical teams are important for better understanding and management of this disease. sSAH should be considered within the framework of all aspects of its complicated management, including diagnosis, treatment, and the possibility of rebleeding or CV.

ETHICS

Ethics Committee Approval: Approval for the study from the Ethics Committee of University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital (decision no: 358, date: 16.08.2023) obtained.

Informed Consent: Retrospective study.

Authorship Contributions

Surgical and Medical Practices: B.E., E.A., L.Ş.P., Concept: B.E., S.D., O.B., O.H., F.Ş., L.Ş.P., Design: E.A., Y.K., S.D., O.B., Data Collection or Processing: B.E., E.A., Y.K., O.H., F.Ş., Analysis or Interpretation: B.E., O.B., L.Ş.P., Literature Search: B.E., Y.K., S.D., O.H., F.Ş., Writing: B.E., E.A., Y.K., S.D., O.B., O.H., F.Ş., L.Ş.P.

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