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ORIGINAL RESEARCH

Large and Giant Intracranial Aneurysm: Surgical Management and Outcomes in a Tertiary Hospital

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Background: Large and giant intracranial aneurysms, exceeding 10 mm and 25 mm in diameter, respectively, are rare in neurosurgery. These lesions carry substantial morbidity and mortality risks, often causing mass effects, intracranial hemorrhage, stroke, or seizures.

Methods: We present our experience with 54 patients diagnosed with these aneurysms. We conducted neurological assessments and preoperative evaluations using the modified Rankin Scale. Individualized treatment strategies, employing surgical techniques or endovascular embolization, were tailored to each patient.

Results: The cohort included 28 females and 26 males, averaging 46.9 years. Aneurysms were predominantly in the anterior circulation (80.6%), with initial symptoms including mass effect (78.7%), cerebral ischemia (8.3%), intracranial hemorrhage (3%), and seizures (2.8%). Surgical interventions, including direct clipping, aneurysmal wall resection, aneurysmorrhaphy with clipping, and cross-clamping (average duration: 20 minutes), were performed in 32 cases (59.2%). Endovascular coiling was utilized in 22 patients (40.8%), with 10 requiring flow diverter stents. Of the cases, 32 were giant aneurysms, and 22 were large aneurysms. Outcomes ranged from favourable to excellent in 70.4% of patients, while 18.5% experienced poor outcomes, primarily in posterior circulation aneurysms or due to poor preoperative conditions. The overall mortality rate was 11.1%, with eight fatalities.

Conclusion: Management of giant intracranial aneurysms remains challenging, with higher morbidity and mortality rates compared to other neurosurgical conditions. No universally effective technique exists, emphasizing the importance of meticulous perioperative planning and surgical expertise. Further research and treatment advancements are needed to enhance the management of these complex aneurysms.

Keywords: large aneurysm, giant intracranial aneurysm, modified rankin scale, clipping, coiling

Introduction

Despite multiple advances in microsurgical and endovascular techniques, the treatment of large and giant intracranial aneurysms poses a significant challenge for vascular neurosurgeons. These rare lesions, accounting for approximately 5% of all intracranial aneurysms, predominantly occur in the anterior circulation and affect females more frequently than males.[1–3] Patients with large and giant aneurysms often present with subtle symptoms, including slow cranial nerve dysfunction, particularly involving the optic and oculomotor nerves, progressive neurological dysfunction, chronic headache, or slowly progressive dementia.[1–3] Intracranial hemorrhage, encompassing subarachnoid or intraventricular hemorrhage (SAH or IVH), is the second most common presenting symptom. Some patients may experience a sentinel headache before a major bleeding event, while others may deteriorate due to acute hydrocephalus.[1–3] Seizures or ischemic strokes secondary to thrombus formation within the giant aneurysm, subsequent embolus, or vascular compromise due to aneurysm bulkiness are also observed in a few cases. Incidental discovery of these lesions is rare.[3–13] The pathogenesis of giant intracranial saccular aneurysms remains poorly understood. It is believed that these aneurysms evolve from smaller saccular aneurysms, which may or may not rupture. The continual hemodynamic changes and blood

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flow turbulence within the sac contribute to the enlargement of these small aneurysms, leading to wall vibration, degeneration, and further expansion. Repeated minor hemorrhages also contribute to the thickening of the aneurysmal wall through fibrin or calcium deposition. Moreover, giant aneurysms often contain multi-laminated thrombus.[3,7,14–20] In contrast, fusiform giant aneurysms affect the entire arterial wall, extending over a substantial length of the artery. This pathology is likely a consequence of atherosclerotic ectasia or dissection.[4,10,14,21–23]

The management strategy for large or giant intracranial aneurysms varies.[1,3–7,9–12,20,22–25] Ideally, the treatment aims to isolate the neck of the aneurysm from blood flow and its hemodynamic forces without sacrificing the main artery or the perforators, decompress the neural tissue, and ultimately restore adequate blood flow.[3] Treatment methods can be categorized as direct or indirect. Direct clipping of the aneurysm is the preferred technique when feasible, offering favourable short and long-term outcomes.[5,11] However, direct clipping alone may not be possible in cases where the neck is large or heavily calcified. In such instances, alternative techniques are employed. Although these alternatives are considered substandard to direct clipping, they become necessary to avoid sacrificing the parent vessel, which could lead to devastating infarction or incomplete debulking of the aneurysmal mass.[5,11] These options include microsurgical resection of the aneurysmal mass, aneurysmorrhaphy with arterial reconstruction through suturing the sac, or using a wrapping reinforcement technique. Indirect approaches involve trapping the aneurysm using clips or ligature above and below the aneurysm or obliterating the internal carotid artery (ICA) in the neck using the Hunterian technique if the patient can tolerate parent artery occlusion.[4,10,21] Alternatively, extracranial-intracranial revascularization surgery utilizing a long saphenous vein graft bypass (JSVG),[2,26] or superficial temporal artery to middle cerebral artery anastomosis (STA-MCA) may be necessary to restore blood flow.[16,27]

In this study, we focused on this variety of management strategies used by the senior author when treating giant aneurysms in different locations to improve the outcome and to reduce the morbidity and mortality rate related to the complexity of these lesions that can be attained by selecting the most suitable technique for a particular location.

Materials and Methods

Patient Demographics and Clinical Materials

This retrospective study was conducted at King Abdullah University Hospital and was approved by the Institutional Research Board (IRB) committee at Jordan University of Science and Technology (JUST). The study group comprised 54 cases who were treated for large and giant aneurysms between December 2005 and December 2020.

Inclusion Criteria

Patients with ruptured or unruptured large aneurysms measuring between 10 and 25 mm or giant unruptured aneurysms measuring more than 25 mm were included in the study. Only cases that received surgical or radiological interventions were included.

Exclusion Criteria

Patients with small aneurysms (less than 10 mm in diameter) were excluded from the study. Additionally, cases with large or giant aneurysms that remained untreated were also excluded.

Patient Assessment

Each patient was individually assessed, considering factors such as age, presenting symptoms, exact size and location of each aneurysm, and the patient's pre-operative neurological condition. The Modified Rankin Scale (MRS) provided in Table 1 was utilized to determine the most suitable surgical approach for each patient. Table 2 provides information on the preoperative Modified Rankin Scale (MRS) grades of patients.

Table 1 Modified Rankin Scale (MRS)

Modified Rankin Scale (MRS)	
0	Asymptomatic
1	No significant disability despite symptoms, able to perform all routine tasks
2	Slight disability, cannot perform all previous tasks but can look after own affairs without help.
3	Moderate disability needs some help but can walk unaided
4	Moderate-severe disability, cannot walk without help, cannot attend to body needs without help
5	Severe disability, bedridden, incontinent, needs a constant nursing care
6	Dead

Table 2 Preoperative Modified Rankin (MRS) Scale Grades of Patients

MRS	Pre-Operative (n = 54)	%
Grade 0	13	23.4
Grade 1	19	34.6
Grade 2	14	26.2
Grade 3	3	3.7
Grade 4	2	1.9
Grade 5	3	5.6
Grade 6	0	0

Preoperative Investigations and Procedure Selection

Preoperative investigations were conducted for all patients, except in cases requiring emergency interventions, following the established protocol in our institution. These investigations included various imaging modalities and tests to gather essential information:

Computed Tomography (CT): CT scans were performed without and with contrast to obtain a detailed understanding of the aneurysms. These scans helped determine their size, shape, and location, as well as identify any calcifications or recent hemorrhage.

Digital Subtraction Angiogram (DSA): A four-vessel DSA with a 3D study was conducted to provide comprehensive information about the aneurysm's site and morphology. DSA also facilitated the evaluation of adjacent arteries, the anatomy of the area, the condition of distal branches, the presence of collaterals, and the identification of laminated thrombus in giant aneurysms. DSA was performed when CT was negative with a high susception of the presence of aneurysm or the presence of SAH.

Magnetic Resonance Imaging (MRI): MRI scans from different angles were utilized to assess the relationship between the aneurysms and surrounding brain structures. This imaging technique also aided in identifying the layers of thrombus with varying ages of hemorrhage.

Patients with non-thrombosed large or giant aneurysms underwent additional elective tests, including internal carotid artery (ICA) balloon occlusion tests with single-photon emission computerized tomography (SPECT) scans, electro-encephalography (EEG), and neuro-psychiatric consultations. These tests were performed to assess the cerebral blood flow (CBF) and cerebral perfusion state preoperatively, particularly when temporary or permanent occlusion of the parent artery was anticipated.

Regarding procedure selection, either operative or endovascular, interdisciplinary approach was adopted for every case and a comprehensive discussion was carried out for every single case. The interdisciplinary team included consultant neurosurgery, interventional neuro-radiologist, diagnostic radiologists and an intensive-care internal medicine team. In general, the decision on whether to surgically operate or to coil depended on two major factors: first: patient factors such as age, comorbidity, presence of ICH, SAH grade, aneurysm size, location and configuration. Second: the procedure factors which included the competence and availability of the staff at that time. Factors in favor of operative surgery are younger age, presence of space occupying ICH, middle cerebral artery and pericallosal aneurysm, wide aneurysm neck, and arterial branches existing directly out of the aneurysmal sac. Factors in favor of endovascular intervention (coiling) are age above 70 years, non-space occupying ICH, posterior circulation, small aneurysm neck and unilobar shape. However, for patients with aneurysms judged to be technically amenable to both endovascular and surgical approaches, endovascular approach was considered.

Operative Approaches

For anterior circulation and posterior cerebral artery large and giant aneurysms, the cranial pterional or orbito-zygomatico -pterional transsylvian approach was selected. This approach provided a wide exposure, minimized brain retraction, and offered a direct route to the objective. Vertebral artery and PICA aneurysms were managed using the far lateral suboccipital craniectomy approach. Out of the 32 cases that underwent surgical intervention for large or giant aneurysms, 22 cases (64%) were directly clipped using SKS (Sundt-Kees) clips. In 11 patients (36%), resection of the aneurysmal wall and suturing of the aneurysm with clipping technique were performed.

Endovascular Embolization Techniques

Endovascular embolization was performed in 22 cases. The procedure involved the patient lying supine on the X-ray table The anesthesia administered varied based on the patient's medical condition, ability to follow instructions and the complexity of the case. Heparin, an anti-clotting medication, was administered to prevent blood clots during the procedure. To ensure stability, the patient's head is positioned securely to minimize movement during the endovascular embolization procedure.

Femoral artery access is obtained to perform endovascular embolization. Once the catheter is optimally placed, the neuro-interventionalist administers contrast dye while capturing X-ray images in multiple dimensions. Dye injections are repeated until all necessary arteries are visualized, allowing for accurate measurements of the aneurysm, particularly the neck and aneurysm dome, as well as their relationship with the parent artery.

A microcatheter is then advanced through the standard catheter and into the aneurysm lumen. With continuous contrast injection, the microcatheter enables precise coil delivery and better assessment of the coils. Coiling was performed in four cases using this technique.

In cases where the aneurysm exhibits a wide neck or irregular shape, a stent may be utilized to assist in holding the coils in place. The stent is advanced through the catheter and positioned in the normal artery adjacent to the aneurysm.

In recent developments, a flow-diverter stent has been employed to isolate arterial blood flow from the intraluminal flow within the aneurysm. This leads to clot formation and subsequent shrinkage of the aneurysm. The flow-diverter stent was utilized in five patients with positive results.

Statistical Analysis

The extracted data were presented as frequency (percentage) for nominal data and mean ± standard deviation of the mean (SD) for normally distributed continuous variables. Limited statistical tests were applied due to the small sample size.

Results

General Characteristics

A total of 54 patients were included in this study. Table 3 provides information on the patients' demographics and location of aneurysms. The mean age of the patients was 46.9 years, ranging from 33 to 68 years. Out of the 54 patients, 26 (48%) were male, and 28 (52%) were female. The location of aneurysms was categorized into anterior circulation and posterior circulation. A total of 43 patients (79.6%) had aneurysms in the anterior circulation. Among these, the majority were located in the internal cerebral artery (ICA), accounting for 30 cases (55.6%). Within the ICA, the most common subtypes were ICA cavernous, with 17 cases (56.7%), followed by ICA paraclinoid with 8 cases (26.7%). Other subtypes included ICA p-com (3 cases, 10%), and ICA terminal (2 cases, 6.7%). ACA had 3 cases (5.6%), and MCA had 10 cases (18.5%). Within the ACA subtype, 1 case (33.3%) involved the A1 segment, and 2 cases (66.7%) were related to the

Table 3 Patients' Demographics and Location of Aneurysms

	All Patients (n = 54)
Age, mean	46.9
Gender, n (%)	
Male	26 (48)
Female	28 (52)
Location, n (%)	
Anterior Circulation	43 (79.6)
ICA	30 (55.6)
ICA cavernous	17 (56.7)
ICA paraclinoid	8 (26.7)
ICA p-com	3 (10)
ICA terminal	2 (6.7)
ACA	3 (5.6)
A1 segment	1 (33.3)
A-com	2 (66.7)
MCA	10 (18.5)
Posterior Circulation	11 (20.4)
PICA	1 (1.9)
BASA	6 (11.1)
BASA trunk	4 (66.7)
BASA caput	2 (33.3)
VA	2 (3.7)
PCA	2 (3.7)

Abbreviations: ICA, internal cerebral artery; MCA, middle cerebral artery; ACA, anterior cerebral artery; PCA, posterior cerebral artery; BASA, basilar artery; VA, vertebral artery; PICA, posterior inferior cerebellar artery; A-com, anterior communicating artery.

anterior communicating artery (A-com). A total of 11 patients (20.4%) had aneurysms in the posterior circulation. Among these, the most common location was the basilar artery (BASA), accounting for 6 cases (11.1%). Within the BASA subtype, 4 cases (66.7%) were located in the trunk, and 2 cases (33.3%) were located in the caput. Other locations in the posterior circulation included the posterior inferior cerebellar artery (PICA) with 1 case (1.9%), vertebral artery (VA) with 2 cases (3.7%), and posterior cerebral artery (PCA) with 2 cases (3.7%).

Relation Between Aneurysm Site and Symptoms

Table 4 presents the relationship between aneurysm location and initial presenting symptoms. Among patients with aneurysms in the ICA 26 (86.7%) presented with symptoms related to mass effect, 2 cases (6.7%) presented with ICH, 1 case (3.3%)

Table 4 Relationship of Aneurysm Location with Initial Presenting Symptoms

Initial Presenting Symptom, n (%)	Location of Aneurysm						
	ICA (n = 30)	MCA (n = 10)	ACA (n = 3)	PCA (n = 2)	BASA (n = 6)	VA (n= 2)	PICA (n = 1)
Mass Effect	26 (86.7)	5 (50)	1 (33.3)	1 (50)	5 (83.3)	1 (50)	0 (0)
ICH	2 (6.7)	2 (20)	1 (33.3)	0 (0)	0 (0)	1 (50)	0 (0)
Stroke	1 (3.3)	2 (20)	0 (0)	1 (50)	1 (16.7)	0 (0)	1 (100)
Seizure	0 (0)	1 (10)	1 (33.3)	0 (0)	0 (0)	0 (0)	0 (0)
Incidental	1 (3.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Abbreviations: ICA, internal cerebral artery; MCA, middle cerebral artery; ACA, anterior cerebral artery; PCA, posterior cerebral artery; BASA, basilar artery; VA, vertebral artery; PICA, posterior inferior cerebellar artery; ICH, intracranial hemorrhage.

presented with stroke, and 1 case (3.3%) was incidentally discovered. No cases of seizures were reported for ICA aneurysms. In patients with aneurysms in MCA, 5 (50%) presented with symptoms related to mass effect, 2 cases (20%) presented with ICH, 2 cases (20%) presented with stroke, and 1 case (10%) presented with seizures. No incidental findings were reported for MCA aneurysms. Among patients with ACA aneurysms, 1 case (33.3%) presented with symptoms related to mass effect, 1 case (33.3%) presented with ICH, and 1 case (33.3%) presented with seizures. No seizures or incidental findings were reported for ACA aneurysms. Among PCA aneurysms 1 case (50%) presented with symptoms related to mass effect, and 1 case (50%) presented with stroke. No cases of ICH, seizures, or incidental findings were reported for PCA aneurysms. Among cases with BASA aneurysms, 5 cases (83.3%) presented with symptoms related to mass effect, and 1 case (16.7%) presented with stroke. No cases of ICH, seizures, or incidental findings were reported for BASA aneurysms. Among VA aneurysms, 1 case (50%) presented with symptoms related to mass effect, 1 case (50%) presented with ICH, and no cases of stroke, seizures, or incidental findings were reported. There was only 1 case of PICA aneurysm, and the case presented with symptoms related to mass effect, and no other symptoms were reported. The distribution of initial presenting symptoms varied depending on the aneurysm location. Mass effect was the most common symptom observed across multiple locations, followed by ICH, stroke, seizures, and incidental findings.

Treatment and Outcomes

Surgical interventions were performed in 59.2% (32 cases) of patients, either through direct clipping or resection of the aneurysmal wall and aneurysmorrhaphy with clipping. Endovascular coiling was conducted in 40.8% (22 cases) of patients, with 10 of them requiring a flow diverter stent.

In this study, all patients underwent post-operative angiogram on the first or second day to ensure complete obliteration of the aneurysm. Additionally, cerebral CT scans were performed on all patients on the first day after the operation. Two patients required reoperation due to incomplete occlusion of the aneurysm. One patient underwent a redo procedure with direct clipping, resulting in successful aneurysmal stability. Another patient initially underwent endovascular coiling but had a large residual neck, leading to subsequent direct clipping after neurological improvement.

Although multi-modality techniques were employed to address large and giant aneurysms in different locations, the results still demonstrated a higher mortality and morbidity rate compared to smaller lesions. Among the patients, 70.4% achieved excellent to good results, with 33.3% being asymptomatic and classified as grade 0, 14.8% classified as grade I, and the rest falling into grade II. Poor outcomes were observed in 17.6% of patients, ranging from grade III to V. The overall mortality rate was 11.1%, with most deaths occurring in patients with basilar or posterior communicating giant aneurysms.

Ten patients experienced a poor neurological status, either due to devastating initial presentation or deterioration following treatment. Among these, eight patients developed ischemic changes, with four of them showing improvement and minor deficits. One patient who underwent excision of an MCA giant aneurysm experienced postoperative severe vasospasm, which responded well to angiographic intra-arterial nicardipine injection, leading to improvement without deficits. The remaining four patients ended up with a poor neurological condition. For instance, one patient with a left giant MCA aneurysm had right hemiplegia and aphasia that did not improve despite aggressive treatment due to MCA artery occlusion. Another patient with a right ICA cavernous aneurysm developed cavernous sinus syndrome and continued to decline without improvement. Four cases did not exhibit any neurological improvement after endovascular intervention, likely due to their poor preoperative status.

There was a case of a patient who experienced a fall in the hospital, resulting in a small intracerebral hemorrhage. However, this patient recovered well from the hemorrhage. Another patient presented with SAH grade V from a large ICA posterior communicating aneurysm. Initially, coiling of the aneurysm was performed, but one of the coils herniated through the dome, requiring surgical intervention. During the operation, the ICA was trapped for arteriotomy, and the herniated coil was successfully removed. The patient underwent craniotomy for clipping and eventually recovered with minimal hemiparesis, although the course was complicated.

Six patients in the study, unfortunately, passed away. Among them, two had BASA trunk or tip aneurysms treated with endovascular embolization. These patients had a stormy post-operative course and poor recovery, and complications such as massive pulmonary embolus and basilar thrombosis leading to pontine infarction were observed on angiogram and CT scan. Another patient with a left ICA paraclinoid aneurysm developed extensive infarction after endovascular embolization.

Additionally, one patient experienced ICA dissection and diffuse bilateral cerebral infarction during the operation for clipping of a right ICA posterior communicating aneurysm, resulting in a worsened condition and eventual death.

Among the patients in the study, two individuals experienced an intracerebral hemorrhage. The first patient initially presented with headache and double vision, which was attributed to right abducent palsy. Unfortunately, the patient's condition worsened, and they bled in the ICU, resulting in a Glasgow Coma Scale (GCS) score of 3. An urgent endovascular embolization procedure was performed to address the BASA trunk aneurysm, but regrettably, the patient did not recover and passed away shortly thereafter. The second patient, who had a large ICA posterior communicating aneurysm, also had a poor recovery following coiling and subsequently succumbed to the condition at a later stage.

In terms of surgical outcomes, our results indicate a tendency for better outcomes in patients with anterior circulation giant aneurysms. Among these patients, 75.6% achieved good outcomes, while 14% had poor outcomes. The mortality rate in this group was 5.9%. In contrast, for patients with posterior circulation giant aneurysms, 33.3% achieved excellent to good results, 33.3% had poor outcomes, and the mortality rate was notably higher at 28.6%.

When analyzing the outcomes based on aneurysm location, the best results were observed in patients with PCA, MCA, and ICA aneurysms, with success rates of 90%, 80%, and 72.9% respectively. Respectable outcomes were also achieved in patients who underwent clip and suture with debulking as well as direct clipping and endovascular embolization, with success rates of 80.5%, 66.7%, and 62.1% respectively. Patients with basilar aneurysms suffered from a higher morbidity and mortality rate, with 36.7% experiencing severe disability and a matching death rate. Interestingly, patients with PCA giant aneurysms displayed favorable outcomes in this study.

Discussion

In recent years, the endovascular procedure has gained popularity in the treatment of large or giant aneurysms. Balloon trapping techniques, previously used by placing balloons above and below the aneurysm endovascularly,[13,28] have been replaced by GDC embolization or flow diverter stent and coiling techniques due to the high morbidity associated with balloon trapping.[5,29–33] The long-term efficacy of these endovascular techniques is still under evaluation. In certain cases, a combined surgical and endovascular approach may be employed as an alternative, with the endovascular technique serving as part of a multimodal treatment plan.[11,18,25]

Large and giant intracranial aneurysms are relatively rare, comprising only 5% of all intracranial aneurysms.[1–3] They are more commonly observed in females in most series.[4,9,10,14,21,24,34] These aneurysms typically present with symptoms related to compression of local neural structures due to their size.[13,28] Unlike smaller aneurysms, they have a lower tendency to rupture. However, in some series, subarachnoid hemorrhage (SAH) has been reported as the initial presenting symptom in 25% of cases.[8,13,23,34] The annual risk of bleeding in large and giant aneurysms is estimated to be around 3%, which is higher than that of smaller aneurysms, and this risk increases with the size of the aneurysm.[24,27] Recent reports have shown that rebleeding from these aneurysms is common, with an incidence of 18.4% within 2 weeks and a high mortality rate of 33%, which is comparable to smaller aneurysms.[32,35] Therefore, early identification and intervention are recommended for better outcomes.[12,20,25,36]

Two types of giant intracranial aneurysms are recognized: saccular and fusiform. Saccular aneurysms are more common and predominantly affect the anterior circulation, often located at arterial bifurcations. These aneurysms may arise from the growth of smaller aneurysms that continue to expand due to blood pressure changes. Alternatively, they can develop from repeated minor bleeds that cause thickening of the arterial walls through fibrin deposits.[3,7,14–20] Fusiform aneurysms, on the other hand, are less common and typically arise from the posterior circulation. They involve pathological changes affecting all layers of the arterial wall and can extend along the length of the artery. The etiology of fusiform aneurysms remains uncertain, although some authors propose atherosclerosis or arterial dissection as possible causes.[14,21–23] Pathogenesis studies by Drake et al demonstrated this type in only nine out of 120 patients with fusiform giant aneurysms.[14,21]

The prognosis of untreated giant aneurysms is poor.[1–3] If left untreated, these aneurysms continue to enlarge due to turbulence and wall vibration, leading to hemorrhage or progressive compression of blood vessels and neural structures. The mortality rate can be high within a few years after discovery of the aneurysm, reaching approximately 85% in some reports.[7,12]

Thromboembolic stroke or cerebral compression can cause death, but subarachnoid hemorrhage is the most common contributing factor to the high mortality rate,[1–3,6,7] although rare cases of spontaneous remission have been reported.[3]

The treatment of giant aneurysms has significantly improved with advancements in microvascular neurosurgical techniques and approaches. These advancements have led to substantial results, with the majority of patients achieving excellent or good outcomes and a much lower mortality rate compared to the natural course of unoperated giant aneurysms in most series.[1,4,6,9,10,14,21,23,24,34] Nevertheless, there are still a few patients who experience poor outcomes.

When dealing with these complex lesions, the treatment strategy aims to achieve several goals. Firstly, it involves isolating the aneurysm from the circulation. Secondly, it focuses on preserving the parent arteries and their perforators. Lastly, it aims to decompress the adjacent structures affected by the aneurysm. These goals can be accomplished through the utilization of appropriate surgical techniques by skilled and experienced surgeons, along with thorough preoperative planning.[7,8,12,13]

In the past, Hunterian ligation was a commonly used method to treat giant aneurysms. This technique involved suturing the parent vessel to reduce blood flow to the aneurysm, relying on collateral circulation for nourishment.[4,8,10,13,21] While effective in some cases, there were risks associated with this approach, including the possibility of delayed hemodynamic stroke or continued expansion and bleeding of the aneurysm, potentially caused by retrograde blood flow from opposite or posterior circulation or the external carotid artery.[10,14,21,26,37,38]

Yasargil et al introduced the extracranial-intracranial bypass technique by anastomosing the superficial temporal artery to the middle cerebral artery (STA-MCA).[16,27] Surgeons began combining STA-MCA anastomosis with Hunterian occlusion of the internal carotid artery (ICA) to treat giant aneurysms. Another technique involved using a long saphenous vein graft bypass (LSVGB) to restore blood flow between the common carotid artery and the intracranial segment of the ICA in cases of complete ICA occlusion.[2,26] These techniques and their variants have proven effective in treating occlusive vascular diseases and giant aneurysms, particularly when parent vessel trapping is not tolerated by the patient.[6,26,33,36,37,39–42] Revascularization procedures should be considered when reserve capacity is compromised, and the decision can be based on clinical aspects and preoperative physiological studies.[26,43,44]

Direct surgical neck occlusion through clipping the aneurysm while preserving the original artery is considered the ideal treatment method, but its feasibility varies in different series due to factors such as a broad, bulbous, firm, or calcified neck.[1,4–6,8,10,11,13] Additional clips may be required to reinforce the closing tension, with longer clips being less effective at the tip compared to shorter clips.[4,10,22,23]

The basic principles of aneurysm surgery apply to giant aneurysms as well. Proximal and distal control of the parent artery, sharp dissection, and temporary clipping when necessary are crucial. Decompression of the aneurysm through thrombus removal or blood aspiration is important before applying the clip. Total excision of the aneurysm wall is unnecessary since these lesions are not neoplastic and do not recur once the sac is isolated from the bloodstream. The focus is on decompressing the aneurysm and isolating the neck from circulation.[1,3,6]

Wrapping reinforcement has been successfully used by encasing the aneurysm with surgical gauze or plastic and applying purse string sutures around the base and dome to restrain it. However, concerns exist regarding the need for extensive dissection around the base of the brain and the possibility of continued aneurysm growth.[4,5,8,11,13]

Trapping the aneurysm can be an effective technique in selected cases where sufficient collateral circulation is present and direct clipping is not feasible. Care must be taken to consider the branches arising from the trapped segment, and the sacrificed portion should be minimized by applying clips close to the aneurysm.[1,4,6,8,10,13] Excision of the aneurysm with primary reconstruction could be an alternative for MCA aneurysms whereby this vessel can be repaired easily. It might be impossible to repair if the artery is friable.

Endovascular techniques have shown promising results in the treatment of inoperable giant aneurysms. Serbinenko introduced the detachable balloon occlusion method for carotid cavernous fistula and aneurysms, preserving the internal carotid artery.[13,28] However, this approach is suitable only for selected cases. In 1989, Hilal reported successful endovascular occlusion of inoperable intracranial aneurysms using platinum coils with Dacron fibers, inducing intra-aneurysmal thrombotic occlusion.[5,31] More recently, Guglielmi introduced intra-aneurysmal electro-thrombosis by injecting thrombogenic detachable platinum coils via an endovascular approach.[29,30] While effective for smaller aneurysms, this technique is unsuitable for giant aneurysms due to their size, irregular shape, and presence of thrombus.[25,29] However, there are varying reports on its efficacy.[9,18,32,33]

According to a review by Campos et al, flow diversion is a newly developed endovascular technique that has shown success in treating giant aneurysms. Among 22 patients who underwent endovascular embolization, 10 required flow diverters. Previous studies have demonstrated that endovascular embolization with flow diversion is a safe and effective solution for large or giant, wide-neck internal carotid artery (ICA) aneurysms, with a primary effectiveness rate of 62.8%. The major complications or neurological death rate was found to be 8.3%, consistent with our own series.[4]

In certain cases, a combined surgical and endovascular approach may be beneficial.[11,35] Some reports suggest endovascular ICA occlusion following extracranial-intracranial bypass for inoperable ICA aneurysms.[1] Additionally, Lin et al identified ACA aneurysms with recurrences after microsurgical clipping that were subsequently treated with flow diversion using PED, resulting in complete occlusion in 83% of cases. Therefore, flow diversion with PED is a viable option for treating recurrences after surgical clipping.[4] However, the use of a combined technique requires careful evaluation, individualized treatment planning, and close follow-up.

The selection of the explicit operative surgical technique is influenced by the aneurysm's anatomy, its relationship to adjacent brain structures, and the perioperative neurological state. The chosen operative approach aims to optimize field exposure with minimal brain retraction and increased bone removal, allowing for direct and unobstructed access to the aneurysm. The widely utilized orbitozygomatic-pterional trans-sylvian approach is commonly employed for treating anterior circulation and certain posterior circulation giant aneurysms.[28,30,39,43] This approach offers multiple access points in various directions within the sylvian fissure, and in specific cases, additional bone removal, such as clinoidectomy, may be necessary to enhance exposure of the ICA giant aneurysms. The removal of the zygomatic arch provides a reasonable subtemporal access, with inferior retraction of the temporalis muscle. For addressing the tip of the basilar aneurysm and its branches, the subtemporal approach can provide appropriate access.[8,45]

For lower basilar, vertebral artery, and PICA giant aneurysms, the far lateral suboccipital approach is considered a standard technique.[31,44] This procedure requires removal of the rim of the foramen magnum, a portion of the occipital condyle, and the C1 arch up to the sulcus arteriosus to achieve ideal access.

Intraoperative cerebral protection plays a crucial role in the management of these complex lesions and can be facilitated prior to the commencement of the operation. Proper head positioning, extensive bone exposure, and minimal brain retraction can be achieved through CSF drainage and administration of Mannitol. Additional protection during the procedure involves maintaining mildly elevated blood pressure to enhance cerebral perfusion pressure, administering barbiturates, and implementing patient cooling techniques.[26,46]

Barbiturate-induced EEG burst suppression is an effective method during cross-clamping. Barbiturates have the ability to reduce neuronal metabolic rate and increase brain tolerance to focal ischemia by mitigating substrate supply shortages. However, their role in global ischemia is not well-established.[26,38,45,47] Administering barbiturates before applying the clip has proven to be particularly beneficial, as evidenced by Spetzler et al's animal model study, which confirmed adequate brain protection from focal ischemia.[45,47]

Hypothermia serves as an adjunctive therapy with significant value in preventing ischemia by reducing cerebral metabolic rate of oxygen consumption through decreased cellular oxygen requirement for enzymatic reactions. Attention must be given to the patient's clotting factors.[22,40] The author believes that maintaining a hypothermia level of 32 degrees Celsius is efficient in neural protection with fewer complications. Furthermore, minimizing temporary clamping time and preserving existing collaterals from the external carotid artery are crucial for preventing ischemic insults.[26]

The surgical outcomes for the management of large and giant aneurysms exhibit variability across different series.[1,4,6,7,9,10,21,24,34] However, with meticulous perioperative planning, excellent to good outcomes can be achieved in the majority of patients, surpassing 80% success rates, and with a relatively low mortality rate ranging from approximately 5% to 15%.[1,5,6,11,34,41,48] When comparing these surgical outcomes to the natural course of untreated giant aneurysms, it becomes evident that surgery offers superior results and significantly impacts the prognosis.

The introduction of flow diverters for treatment of intracranial aneurysms represents a major paradigm shift in the treatment of these lesions. The theoretical hallmark of flow diverters is the treatment of the diseased segment harboring the aneurysm instead of treating the aneurysm itself. Flow diverters are designed to induce disruption of flow near the aneurysm neck while preserving flow into parent vessel and adjacent branches. After flow diversion, intra-aneurysmal thrombosis occurs, followed by shrinkage of the aneurysmal sac as the thrombus organizes and retracts. Preliminary clinical series document effective treatment of wide-neck and/or large and giant aneurysms with acceptable complication rates.[49] Despite the improvement in technology, endovascular treatment of bifurcation intracranial wide-neck aneurysms remains challenging, mainly due to the difficulty of maintaining coils within the aneurysm sac without compromising the patency of bifurcation arteries. The Woven EndoBridge (WEB) device is a recent intrasaccular braided device specifically dedicated to treating such aneurysms with a wide neck by disrupting the flow in the aneurysmal neck and promoting progressive aneurysmal thrombosis. Endovascular treatment of bifurcation wide-neck aneurysms with the WEB device is feasible and allows an acceptably adequate aneurysm occlusion rate; however, the rate of neck remnants is not negligible.[50]

We firmly believe that the chosen technique for aneurysm occlusion, along with its location and the preoperative neurological status of the patient, greatly influences the overall outcome. It is our conviction that the best results can be achieved when a suitable surgical technique is selected for effectively isolating the giant aneurysm, accompanied by comprehensive perioperative planning.

This study has several limitations. First, the retrospective nature of the study is one of the major limitations and decreases our ability to obtain several important parameters such as long-term postoperative data and detailed intraoperative complications. Second, the relatively small sample size limits the utilization of more advanced statistical analyses tests.

Conclusion

The management of giant intracranial aneurysms necessitates an individualized approach, as there is no universally effective technique to address the complexity of these lesions. With the recent advancements in the field and comprehensive preoperative planning, coupled with the selection of an appropriate surgical technique and the implementation of adequate intraoperative brain protection measures, a favorable outcome can be achieved. By adhering to these principles, the overall prognosis for patients with giant intracranial aneurysms can be significantly improved. Clipping is, when possible, the golden standard for giant aneurysms and that should be mentioned. However, further research and advancements in surgical techniques are necessary to continue enhancing the management and outcomes of these challenging lesions.

Data Sharing Statement

The data used in this study is available upon request from the corresponding author.

Ethical Approval

This study has been performed in accordance with the 1964 Declaration of Helsinki and its later amendments. This research has obtained ethical approval from the institutional review board at Jordan University of Science and Technology and King Abdullah University Hospital, Irbid, Jordan (667/2021). The authors confirm that the patients' privacy was saved, and the data was anonymized and kept confidential. The institutional review board waived the need for consent due to the study's retrospective nature.

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This paper has been uploaded to ResearchSquare as a preprint: https://www.researchsquare.com/article/rs-3654403/v1.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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