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Endovascular treatment of brain arteriovenous malformations: Our clinical experience

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Abstract

Aim: The aim of this study is to evaluate the preoperative characteristics and post-operative results of cerebral arteriovenous malformations (cAVM) cases that we treated endovascularly. Endovascular embolization has started to be used as an adjuvant therapy to other treatments in the treatment of cAVM. However, with the increase of technical developments and professional experience over time; endovascular techniques have started to be the primary treatment method in the treatment of AVMs.

Materials and Methods: Complaints, angiographic evaluation and treatment data of 12 patients with cAVM who were treated with endovascular methods between January 2018 and December 2020 were retrospectively reviewed.

Results: Eight of the patients (66.6%) were male and 4 (33.3%) were female. AVM localizations were cerebral in eleven (91.6%) patients and cerebellar in one (8.3%) patient. According to the Spetzler-Martin grading system; 5 cases (41.6%) were classified as grade 2, 4 cases (33.3%) as grade 3, 2 cases (16.6%) as grade 4 and 1 case (8.3%) as grade 5. During the endovascular treatment procedure, iatrogenic rupture occurred in the AVM nidus in one patient. No other intraoperative or postoperative complications developed in any of the other cases. Total thrombosis was achieved in 5 cases (41.6%) and partial thrombosis in 7 cases (58.3). These 7 cases with partially thrombosis achieved (58.3%), were referred to radiosurgery after endovascular procedure. Total thrombosis was seen in 3 of these 7 patients (42.8%) after radiosurgery. The total thrombosis rate in all cases was 66.6% (n:8). The mean follow-up period was 23.8 months (12-40).

Conclusion: Therapeutic embolization may be a viable option for cAVMs in selected cases. In complex cAVM cases, embolization is thought to provide a high rate of thrombosis or excision of the lesions, reducing the risks of bleeding and other complications before surgical treatment or radiosurgery.

Introduction

Cerebral arteriovenous malformations (cAVMs) are high-flow vascular malformations with abnormal feeding arteries and drainage veins connected by a plexus [1, 2]. Brain AVMs are most commonly diagnosed in patients presenting with intracranial hemorrhage [3]. Most cAVMs are sporadic and are thought to be congenital, although the exact etiology is unknown [4].

Although most of the cases are asymptomatic, its incidence is thought to be in the range of 5-600/100.000 [5]. The most common clinical presentations of AVMs are bleeding, seizures, headache, and progressive neurological deficits [6]. Intracranial hemorrhage is a symptom that occurs in 38-73% of patients with AVM and is the most common cause of morbidity and mortality [7].

Computed tomography (CT) and magnetic resonance imaging (MRI) help to detect the localization of AVM, relations with parenchymal structures, evaluation of complications and post-treatment follow-up in patients with cAVM [8]. However, digital subtraction angiography (DSA) is the gold standard radiological method for imaging and treatment planning of AVMs [9]. In cAVMs, the Spetzler-Martin (SM) grading system is used to evaluate the risk of microsurgical resection and to plan the treatment strategy [10, 11]. The primary goal of cAVM treatment is to eliminate the risk of prospective bleeding [12]. Theoretically, complete removal of the AVM with microsurgery is the ideal treatment of cAVMs [13]. Current treatment options include microsurgery, stereotactic radiosurgery (SRS), and endovascular embolization alone or as

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combination therapies [14-16]. Endovascular embolization has been established as an adjuvant treatment strategy to reduce the size of cAVMs and to eliminate the high risk of bleeding in preparation for microsurgery [17, 18]. With the recent developments in endovascular equipment and techniques, therapeutic embolization of cAVMs is practically applied in many centers.

In this study, we evaluated the preoperative characteristics and postoperative results of cAVM cases that we treated with endovascular methods in our clinic.

Materials and Methods

Ethics committee approval was obtained for this study (03.06.2021/257).

Patient population

In this study, we retrospectively analyzed 12 patients who received endovascular treatment for cerebral arteriovenous malformation (cAVM) in our clinic between January 2018 and December 2020.

Demographic factors, localization, nutrition, grade, postoperative obliteration rates and complications of cAVM cases treated with endovascular methods in our clinic between the dates given in the study were analyzed retrospectively through the files.

cAVM cases treated with endovascular methods between the specified dates were included in the study. Cases treated with craniotomy or only with stereotactic radiosurgery were not included in the study.

The clinical features, radiological grading and postoperative results of the cases are given in Table-1.

Table 1. Clinical, radiological and postoperative characteristics

Characteristics	Number	%
Sex		
Male	8	66.6
Female	4	33.3
Symptoms		
Headache	9	75
Seizure	2	16.6
Unbalance	1	8.3
Localization		
Cerebral	11	91.6
Cerebellar	1	8.3
Feeder		
1	5	41.6
1 >	7	58.3
S-M Grade		
II	5	41.6
III	4	33.3
IV	2	16.6
V	1	8.3
Obliteration		
Total	5	41.6
Partial	7	58.3
Complication		
Nidus rupture	1	8.3

Clinical and radiological evaluation

Preoperative neurologic examination was normal in all cases. Brain tomography (CT) and magnetic resonance imaging (MRI) were performed in all cases. Then, Digital Subtraction Angiography (DSA) was performed in all cases to confirm the diagnosis of AVM, to reveal possible feeding arteries and drainage veins, to detect accompanying prenidal or intranidal aneurysms and to determine the treatment strategy. All of the cases applied in an unruptured state. Appropriate antiepileptic drug treatment was started for the cases who presented with seizures.

Endovascular procedure

Endovascular intervention was performed by a multidisciplinary team including an interventional neuroradiologist and at least one neurosurgeon. All embolizations were performed under general anesthesia. Systolic blood pressure was maintained between 80-120 mmHg. All embolization cases were applied transarterially from one side. After the femoral sheats were placed, 4000-7500 U heparins was administered as an intraarterial bolus for prophylactic purposes. Long vascular sheats were then placed into the common carotid artery using a guidewire. The feeding arteries of the AVM were visualized by angiography. Feeding arteries were catheterized with the aid of a microcatheter. Then Onyx was started to be injected. Forward and backward movements of the embolization agents were closely followed while Onyx was injected. The injection was stopped when any reflux was noticed. After waiting 15-30 seconds, the injection was continued. In cases when reflux flow started to occur, the injection was stopped again. This cycle was repeated continuously to ensure safe occlusion of the nidus of the AVM and the feeding artery. Venous escape was also noted during the injection of the embolization agent. When there was a possibility of venous leakage, the injection was stopped and the procedure was resumed after waiting for a while. In order to prevent clogging of the microcatheter, the stopping times of the injections were not exceeded 1 minute. It was ensured that the AVM nidus was filled as much as possible and that the feeding arteries were thrombosed without disturbing the normal parenchymal vascular feeding. Embolization of suspected nutrient arteries, which are thought to feed normal parenchymal tissue, was avoided. A control CT scan was performed in all cases after the procedure. In the first 24 hours postoperatively, all patients were kept in the intensive care unit for close monitoring of blood pressure and other vital parameters. Antiepileptic drugs were continued in the postoperative period for those patients with a history of seizures. Heparin or antiaggregant-anticoagulant support was not given to any patient in the postoperative period. Afterwards, the patients were followed up in the neurosurgery clinic for 2-3 days. Patients without any complications were discharged on the fourth postoperative day on average. Emergency CT and MRI were performed to evaluate possible ischemia or bleeding in patients who experienced neurological fluctuations during the clinical follow-up period. In patients who would undergo a reembolization session, approximately 3 months was waited in between sessions.

Results

Eight of the patients (66.6%) were male and 4 (33.3%) were female. The mean age was 40.5 months [19-70). The most common reason for admission was headache (n:9, 75%). Other reasons for admission were seizure (n:2, 16.6%) and loss of balance (n:1, 8.3%).

AVM localizations were cerebral (n:11, 91.6%) and cerebellar (n:1, 8.3%). When the feeding arteries were examined according to DSA, there was only one feeding artery in 5 cases (41.6%) and more than one feeding artery in 7 cases (58.3%). According to the Spetzler-Martin grading system, 5 cases (41.6%) were classified as grade 2, 4 cases (33.3%) as grade 3, 2 cases (16.6%) as grade 4 and 1 case (8.3%) as grade 5.

Iatrogenic rupture of the AVM nidus occurred in one patient during the endovascular procedure. A control CT scan was performed after the procedure, and subarachnoid hemorrhage at the AVM localization and an image consistent with an intracerebral hematoma of approximately 3x4 cm were detected. The patient was taken to the intensive care unit. The patient with a Glasgow Coma Score of 11 had paresis of 3/5 at the left upper and lower extremities. This case was grade 5 according to the Spetzler-Martin grading system. The patient was discharged with 2/5 left sided loss of strength after clinical follow-up period. No intraoperative or postoperative complications developed in any of the other cases.

A total of 18 embolization sessions were performed in all cases. Total obliteration was achieved in 5 cases (41.6%) and partial obliteration was achieved in 7 cases (58.3%) (Figure 1-2).

After the embolization sessions, 7 cases (58.3%) whose interventional occlusion seemed risky for the patient were referred to radiosurgery after endovascular procedure. Total thrombosis was seen in 3 patients (42.8%, 7 patients in total) after radiosurgery. The total thrombosis rate in all cases resulted as 66.6% (n:8).

Patients were called for follow-up angiography at 3, 6, 12 months in the first year and then annually. One case dropped out of follow-up after the first control. The mean follow-up period in other cases was 23.8 months [12-40].

Discussion

Intracranial AVMs can be in any localization at the brain. It has been reported in studies that it is most commonly found in the cerebral and then cerebellar localization, and cases with brain stem localization have also been reported [2, 7, 18]. In our study, cAVM localizations of patients were cerebral (n:11, 91.6%) and cerebellar (n:1, 8.3%).

AVM cases may present with lesion localization-related or general symptoms. In a study; Weber et al. reported the distribution of symptoms in 94 patients with AVM as follows: seizures in 48%, bleeding from the nidus in 20%, headaches in 17%, and neurological disorders in 4.3% [19]. In our cases, the most common reason for admission was headache (n:9, 75%). Other reasons for admission were seizure (n:2, 16.6%) and loss of balance (n:1, 8.3%).

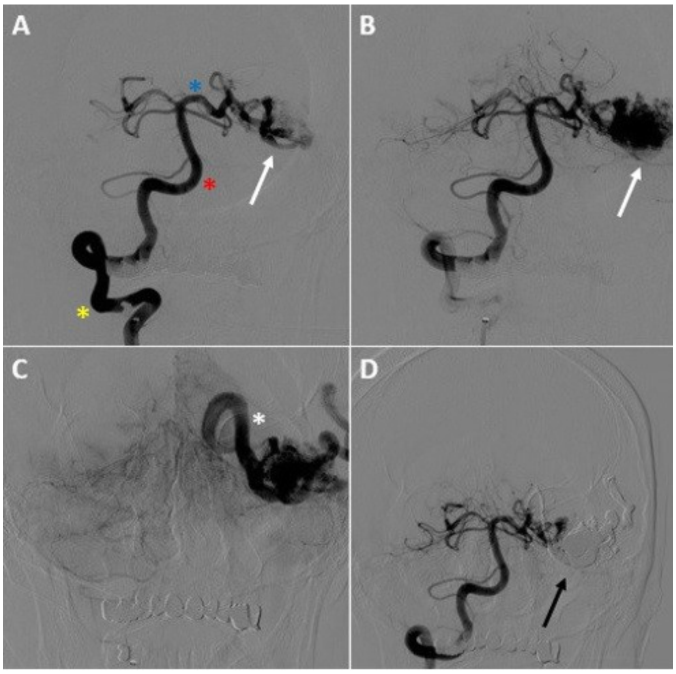

Figure 1. 55-year-old male patient, unruptured S-M grade 4 AVM in the left parietooccipital region, A-C: Pre-embolization anteroposterior VA injections, D: Postembolization anteroposterior VA injection. White arrows: AVM nidus, Black arrow: AVM appearance after embolization, Yellow asterisk : right vertebral artery, Red asterisk : Basilar artery, Blue asterisk: Left posterior cerebral artery, White asterisk: Drainage vein,

In the treatment of cerebral AVMs, treatment modalities such as surgery, embolization and stereotactic radiosurgery (SRS) alone or in combination are applied [3]. Despite unresolved controversies regarding the choice of treatment modality, unruptured obliteration of AVM feeders and venous drainage remains the common goal of all interventions. Early venous occlusion or ligation can cause nidus engorgement and serious hemorrhagic complications. Cutting the arterial supply of the AVM with microsurgery before coagulation of the drainage vein is the basic principle of AVM resection [11]. Similarly, progressive AVM devascularization through occlusion of arterial feeders and nidal penetration with fluid embolizers can be achieved by endovascular embolization traditionally performed with a transarterial approach [20].

Microsurgical resection is the traditional standard method for the treatment of AVM, but requires careful planning and patient selection, rather than routinely performed in all patients. Surgical excision provides a viable therapeutic option for cAVMs, but should be the treatment of choice for surgically accessible and low-risk lesions according to the grading systems [21, 22]. The most widely used grading system to classify surgical risk is the Spetzler-Martin grading system [11, 22]. This system is evaluated based on three key factors including AVM size, venous drainage location (superficial/deep) and eloquent site location. Spetzler-Martin grades I and II are ideal for microsurgical resection [10, 11, 21, 22]. Spetzler-Martin grade

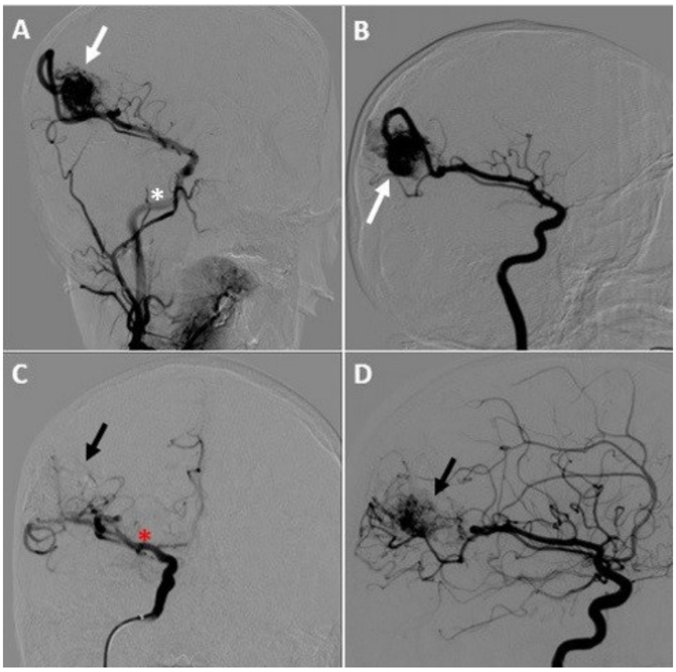

Figure 2. 24-year-old male patient, unruptured S-M stage 3 AVM in the right temporoparietal region, A-B: Preembolization anteroposterior and lateral ICA injections, C-D: Postembolization anteroposterior and lateral ICA injections. White arrows: AVM nidus, Black arrows: partially thrombosed AVM after embolization, White asterisk: right ICA, Red asterisk: right MCA

III AVMs are usually managed with multimodal therapeutic options [22, 23]. In general, ruptured grade IV or V AVMs should not be managed surgically [22]; in some cases, they may be initially treated with embolization or radiosurgery to reduce the size of the lesion and make the lesion potentially amenable for microsurgical resection [24].

Recent advances in endovascular techniques have increased the role of endovascular embolization in the treatment of cerebral AVMs [12, 17, 18]. It is known that with embolization, the size of the AVM is reduced, the risk of bleeding is reduced, and then the mortality and morbidity associated with microsurgical treatment are reduced [25]. However, it should not be forgotten that surgical intervention increases the length of hospital stay and may cause cosmetic problems, especially in young patients. In addition, microsurgical resection carries a very high risk of postoperative morbidity [21, 22].

Embolization therapy was initially used for high grade risky pathologies suitable for microsurgical intervention [9,25]. However, in recent years, endovascular approaches have been used as primary treatment in most of the cases. The most important angiographic features associated with embolization include AVM size, location, associated aneurysms, and perforator supply. Small AVMs in surgically inaccessible locations that require an immediate therapeutic approach (ruptured lesions) may be considered for endovascular treatment [12, 24, 26]. Embolization can also be considered primarily in cases with prenidal or intranidal aneurysms and therefore a very high risk of bleeding for microsurgical intervention [26].

Conventional embolic agents used in AVM embolization are polyvinyl alcohol particles, coils, silk sutures, and ethanol. All of these, Onyx is one of the most frequently used embolizing agent for the endovascular treatment of AVM [20, 27]. We used onyx as embolic agent in all of our cases.

Endovascular treatments are usually performed transarterially, but transvenous approaches are also available. A transvenous approach is mostly used for deeply located AVMs or AVMs in the terms of non-viable safe transarterial access of cAVMs [28, 29]. We used the transarterial approach in all of our cases.

In studies, total obliteration rates in cAVMs treated with endovascular embolization are between 16-86% [18, 30, 31]. However, when embolization is used as the primary treatment option in selected patients, the rate of complete obliteration can be greater than 90% according to the studies [18]. Saatci et al., in their study of 350 cases showed that the rate of recovery with embolization alone was 98% in Spetzler-Martin (SM) Grade I and II cases, while this rate was 12.5% in S-M Grade III and IV patients. In this study, complete obliteration with embolization resulted in 51% of patients [20]. In our clinical study, after embolization, total obliteration was achieved in 5 cases (41.6%) and partial obliteration was achieved in 7 cases (58.3%).

Embolization has an important role in the multimodal treatment of cerebral AVMs, and embolization has also been used as adjuvant therapy prior to stereotactic radiosurgery (SRS) for large-volume AVMs [32]. Embolization is also a good option for small, deep, ruptured AVMs that are considered to be at high risk of rupture when radiosurgery is delayed [32]. The role of pre-SRS embolization is to reduce the volume of the nidus and treat high-risk lesions such as AVM-related aneurysms and high-flow arteriovenous shunts [32]. In our study, 7 cases with partial obliteration after embolization were sent to radiosurgery. Total thrombosis was achieved in 3 of these cases in angiographic control after radiosurgery. Therefore, total thrombosis was achieved in 8 (66.6%) cases, including embolization and subsequent SRS.

In studies, the overall complication rate related to endovascular procedures has been reported as 9-30% [4, 28, 31, 33]. The most common complications are bleeding due to vessel perforation, extravasation of the embolic agent, rupture of vessel with the guide wire, and adhesion of the catheter to the embolizing agent. The risk of bleeding increases in cAVMs with prenidal and intranidal aneurysms, intraventricular or periventricular localization, and high S-M grade [34]. In our cases, intracerebral and subarachnoid hemorrhage occurred due to nidus rupture during endovascular procedure in a patient with S-M Grade 5 (8.3%). The patient was discharged with 2/5 hemiparesis after clinical follow-up. No intraoperative or postoperative complications developed in any of the other cases.

In general, morbidity rates after endovascular treatment ranged from 8-19.5% in some studies [35], while in Saatcı et al. series, this rate was 7.1% [20]. In our study, it was evaluated as 8.3%.

In a review study, mortality due to endovascular procedure was reported as 1.5% [36]. In another study, mortality rate was reported as 2.7% after endovascular treatment of cerebellar AVMs [37]. This rate has been reported as 1.4-4% in some other studies [18, 20, 35]. There was no mortality in our cases.

In the literature, the mean follow-up period in cases after endovascular procedure has been reported as at least 3 months and the longest is 23.7 years [18, 20]. In our study, the mean follow-up period was 23.8 months.

Considering our morbidity (8.3%) and mortality (0%) rates in our study, endovascular treatment of AVMs may be preferred in selected cases.

In conclusion, therapeutic embolization is a viable option for AVMs in selected cases. Endovascular treatment method may be preferred in AVMs with a risk of rupture, deeply located, accompanied by prenidal or intranidal aneurysms, in terms of providing safer treatment efficiency in a shorter time compared to other treatments. However, there is still a need for a large number of studies in order to clearly evaluate the effectiveness of different treatment modalities. In addition, considering the reported complications, it would be beneficial to apply the appropriate treatment strategy after a multidisciplinary evaluation.

Limitations

Our study presents several limitations. First, there are natural selection biases arising from the observational design of this study, and the monocentric nature of the study may also affect the results.

In addition, due to the fact that the study is a single center and the number of cases is low, the effectiveness of different treatment modalities will be clarified with many similar studies.

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