Predictive Factors for Response of Intracranial Dural Arteriovenous Fistulas to Transarterial Onyx Embolization: Angiographic Subgroup Analysis of Treatment Outcomes

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OBJECTIVE: **Endovascular treatment using Onyx has been increasingly used to treat intracranial dural arteriovenous fistulas (DAVFs). This study evaluated predictive factors for favorable treatment outcome in patients with intracranial noncavernous DAVFs treated by transarterial Onyx embolization.**

METHODS: **Between August 2008 and August 2014, 55 patients who underwent transarterial Onyx embolization for noncavernous DAVFs were retrospectively reviewed. Patients' demographic, clinical, and procedural data were analyzed to find statistically significant predictive factors for favorable treatment outcomes after Onyx embolization. Fistulas were classified angiographically according to the relationship between fistulas and dural venous sinuses and the presence of leptomeningeal venous reflux.**

RESULTS: **Sixty-eight Onyx embolizations were performed in 55 patients. Immediate angiographic cure was achieved in 28 patients, and 14 of 27 patients with residual shunts showed progressive occlusion at follow-up imaging studies. Therefore, the overall favorable treatment outcome was 76.4% (42/55). The remaining 13 patients (23.6%) showed persistent residual shunts, and 3 (5.5%) of them showed aggravation of residual lesion on follow-up studies. Of 25 patients with non-sinus fistulas, 23 patients (92%) showed favorable treatment outcomes, and 19 of 30 patients (63.3%) with sinus fistulas showed favorable outcomes. Among the evaluated variables, non-sinus DAVFs was a statistically significant predictive factor for favorable response to transarterial Onyx embolization ($P < 0.05$).**

CONCLUSIONS: **Transarterial Onyx embolization is a highly effective treatment method for non-sinus DAVFs. Careful consideration of angiographic features and multimodal embolization strategies are required for treatment of sinus DAVFs.**

Dural arteriovenous fistula (DAVF) is a subtype of arteriovenous shunts that accounts for 10%–15% of all intracranial arteriovenous malformations.[1] Intracranial DAVF exhibit various angiographic features according to the location of fistulas, disposition of arteriovenous shunt flows, and venous drainage patterns. Of these, the clinical course of DAVF is determined primarily by the venous drainage patterns; specifically, retrograde venous drainage into the leptomeningeal vein is associated with aggressive clinical behaviors, such as intracranial hemorrhage (ICH) and nonhemorrhagic neurologic deficits.[2,3] The location of fistula is useful to explain clinical symptoms, and the amount of shunt flows determines severity of the symptoms.[4] In addition, the existence of accessible venous sinus or arterial pedicles influences the establishment of treatment modality and approach route. From a practical point of

Key words
- Central nervous system
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Abbreviations and Acronyms
AphA: Ascending pharyngeal artery
CI: Confidence interval
DAVF: Dural arteriovenous fistula
DSA: Digital subtraction angiography
ECA: External carotid artery
ICA: Internal carotid artery
ICH: Intracranial hemorrhage
LMVD: Leptomeningeal venous drainage
MMA: Middle meningeal artery
MR: Magnetic resonance
MRA: Magnetic resonance angiography
ROC: Receiver-operating characteristic

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view, intracranial DAVFs can be classified into two main types according to the relationship between the fistulas and the dural venous sinus—namely as sinus or non-sinus fistulas.[5] The non-sinus DAVFs are defined as fistulas with no direct communication between the fistulous point and the dural venous sinus. Instead, there is a direct communication between the feeder and arterialized leptomeningeal veins.[4] They include DAVFs with sole retrograde leptomeningeal venous drainage (LMVD) and extra-sinusal type DAVFs. DAVFs with sole retrograde LMVD are defined as fistulas confined to the wall of the dural venous sinus that do not pass into the sinus.[5,6] This condition has no communication between the arterialized leptomeningeal veins and dural venous sinus.[7] The extra-sinusal type DAVFs are defined as fistulas at a distance from the dural venous sinus, and they include DAVFs in the anterior cranial fossa, tentorium cerebelli, craniocervical junction, and parasagittal cerebral convexity.

There is a growing body of literature demonstrating that the ethylene-vinyl alcohol copolymer liquid embolic system (Onyx; Covidien, Irvine, California, USA) is an effective single embolic agent in the treatment of intracranial DAVFs. Accordingly, transarterial Onyx embolization has become the preferred treatment strategy in many institutes.[8-15] Recently published series have reported high initial angiographic cure rates with long-term durability with Onyx treatment.[8-10,12,14,16] However, treatment responses to Onyx embolization vary per series, and recanalizations, of DAVFs after Onyx treatment, although uncommon, have been noted in several studies.[8,10,12,14,16,17] We hypothesized that diverse angiographic features of intracranial DAVFs might influence the treatment outcomes of transarterial Onyx embolization. To our knowledge, thus far there have been no data published on the predictive factors associated with favorable treatment response to transarterial Onyx embolization. The purpose of the present study was to find significant predictive factors, including specific angiographic subtypes, for transarterial Onyx embolization of intracranial noncavernous DAVFs.

MATERIALS AND METHODS

Patients

Written informed consent for the procedure was obtained after providing information regarding the advantages and complications of the procedure. From August 2008 to August 2014, 95 consecutive patients with intracranial DAVFs were treated at our institute. We excluded patients with cavernous DAVFs ($n = 30$) or patients who were treated via surgical excision ($n = 1$) or endovascular embolization using embolic materials other than Onyx ($n = 9$). A retrospective review of 55 patients with intracranial noncavernous DAVF treated by transarterial Onyx embolization was performed. There were 37 men and 18 women, ranging from 15 to 85 years of age (mean, 58 ± 13.1 years). The most common clinical presentation was headache ($n = 22$), followed by tinnitus ($n = 17$), intracranial hemorrhages ($n = 11$), dizziness and ocular symptoms ($n = 7$), seizure ($n = 5$), intracranial hypertensions ($n = 3$), and venous infarctions ($n = 2$). Intracranial hemorrhage and nonhemorrhagic neurologic deficits, such as seizures and venous infarction, were categorized as aggressive symptoms. The other symptoms were categorized as nonaggressive. Six patients had been embolized previously: 3 patients with intraarterial Onyx, 2 patients with intraarterial contour PVA (polyvinyl alcohol) particles, and 1 patient with intraarterial glue and intravenous coils.

Angiographic Analysis

All patients underwent preoperative transfemoral angiography of the bilateral internal carotid artery (ICA) and external carotid artery (ECA) and the vertebrobasilar complex to assess the detailed angioarchitecture of DAVFs. DAVFs were classified, on the basis of the presence of leptomeningeal venous reflux, according to the Cognard classification as follows[18]: type I lesions were found in 4 patients, type IIa lesions in 7 patients, type IIb lesions in 8 patients, type IIa and IIb lesions in 11 patients, type III lesions in 3 patients, and type IV lesions in 22 patients. In total, 44 patients had retrograde LMVD. Eleven patients without leptomeningeal venous reflux were indicated for treatment because of intolerance of symptoms, such as pulsatile tinnitus or headache associated with intracranial hypertension.

Kawaguchi et al.[6] designated non-sinus DAVFs to describe fistulas that do not flow into the dural venous sinus, and we expanded this concept to describe various angioarchitectures of DAVFs.[6] In the present study, we classified intracranial noncavernous DAVFs into two groups according to the relationship between the fistulas and the dural venous sinus as follows: sinus and non-sinus DAVFs. The entire conceptual classification is depicted in **Figure 1**. Among the sinus DAVFs, fistulas with retrograde LMVD resulting from thrombosis on either side of the arterialized sinus segment are defined as DAVFs with an isolated sinus.[5] This condition is thought to develop because of dural venous sinus thrombosis.[19,20]

The location and multiplicity of fistulas were evaluated. Multiplicity was defined as the involvement of ≥ 2 fistulas in separate anatomic sites in the same patient, and the torcular region was considered a separate site.[21] Identification, number, and bilaterality of pial or dural feeding arteries were also assessed. Patients were divided into two groups according to the cutoff number of feeding arteries obtaining from receiver-operating curve, and 11 patients had a cutoff at 7 or more arterial feeders, whereas the remaining 44 patients had fewer than 7 feeding arteries. In addition, 24 patients had DAVFs fed by bilateral ECA branches, and 31 patients had feeding arteries from unilateral ECA.

Embolization Procedure and Treatment Outcomes

The specific aspects recorded for each embolization were as follows: the identification and number of embolized pedicles, use of adjunctive embolic materials, total number of embolization sessions, technical and clinical complications, and immediate posttreatment angiographic results. Patients were generally scheduled for immediate postoperative (within 48 hours after the treatment) and follow-up magnetic resonance angiography (MRA) to assess any alterations in completely occluded or residual lesions. Further digital subtraction angiography (DSA) was reserved for patients with clinical or magnetic resonance (MR) angiographic aggravation.

Immediate posttreatment angiographic results were classified into three groups based on the final control angiogram after embolization as follows: complete occlusion (angiographic cure), small residual fistulas (fine residual feeding arteries with an absence of early venous drainage and a dense Onyx cast formation in the fistulous sites), and incomplete occlusion (evident contrast