Treatment of dural arteriovenous fistula using ethylene vinyl alcohol (Onyx) arterial embolization as the primary modality: short-term results

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Object. A dural arteriovenous fistula (DAVF) typically involves meningeal feeding arteries and can cause clinical symptoms ranging from tinnitus to rupture of draining cortical or parenchymal veins. Surgical treatment may be technically demanding. Ethylene vinyl alcohol (Onyx, ev3 Neurovascular) has several properties that make it potentially useful as a primary treatment agent for DAVF. Onyx is expected to be a permanent embolic agent. It should have a decreased risk of catheter retention when compared with other permanent embolic materials.

Methods. The authors report a series of six patients with symptomatic DAVF who were treated initially with transarterial Onyx embolization and other endovascular techniques.

Results. Five patients had complete occlusion of their DAVF noted on the follow-up angiogram obtained between 2 and 4 months. One patient had residual filling via a small arterial branch that was stable on follow-up angiography. None of the patients had worsening of neurological function. One case was complicated by a retained catheter fragment.

Conclusions. Transarterial Onyx embolization and other endovascular methods can angiographically obliterate DAVF. In some cases, embolization allowed occlusion of multiple arterial feeding arteries from a single arterial injection. Technically, the embolization was optimized when a microcatheter position immediately adjacent to the point(s) of fistulization was achieved. (DOI: 10.3171/JNS-07/12/1120)

KEY WORDS • arteriovenous fistula • cerebrovascular location • dura mater • embolization • endovascular treatment • Onyx

Abbreviations used in this paper: CT = computed tomography; DAVF = dural arteriovenous fistula; ECA = external carotid artery; GKS = Gamma Knife surgery; ICA = internal carotid artery; MHT = meningohypophyseal trunk; MMA = middle meningeal artery; MR = magnetic resonance; NBCA = N-butyl cyanoacrylate; SSS = superior sagittal sinus.
Arterial embolization for DAVF

Clinical Material and Methods

Records of six patients consecutively treated at our facility over the period between December 2005 and October 2006 were retrospectively reviewed after obtaining approval from the University of New Mexico Human Research Review Committee (Table 1). Each patient was treated in a biplane angiography suite after induction of general endotracheal anesthesia. Vascular access was obtained via the right common femoral artery, and a standard coaxial catheter technique was used. For arterial embolization, Onyx was delivered via a Marathon or an UltraFlow microcatheter (both ev3 Neurovascular). The Marathon catheter was used preferentially because of the durability of its nitinol-braded tip; however, this catheter proved too inflexible to maneuver in several vessels prompting use of the UltraFlow. When the fistula involved more than one major feeding artery, the artery with the largest caliber and least amount of tortuosity was chosen as the initial target vessel. Prior to Onyx injection, effort was made to position the microcatheter tip immediately adjacent to the fistula, or as close to that position as possible. In one case an Excelsior or SL-10 microcatheter (Boston Scientific Neurovascular) was used to deliver detachable coils into a venous sinus. In one case a Rebar microcatheter (ev3 Neurovascular) was used to deliver detachable coils followed by Onyx into a venous sinus. Onyx was injected according to the method described in the product literature. Between 0.4 and 4.8 ml of Onyx was injected. The microcatheter was removed without difficulty after Onyx injection in all cases.

Results

Summary of Cases

Case 1. This 50-year-old man presented with a seizure. Head CT scanning revealed acute hemorrhage in the left occipital lobe. Angiography showed a DAVF fed by a posterior branch of the left MMA and from the posterior meningeal artery. The fistula was in the occipital dura mater, and it drained into the cortical veins and subsequently into the left transverse sinus (Fig. 1 left). Arterial catheterization of the posterior branch of the MMA was achieved. High flow through the fistula prompted consideration of simultaneous venous embolization. Venous catheterization of the left transverse sinus was performed, and four detachable coils were deployed medial to the junction with the vein of Labbé. Onyx (1.8 ml) was injected into the MMA filling the fistula and cortical veins. The posterior meningeal artery was filled retrogradely through the fistula. A follow-up angiogram showed no residual filling of the fistula. The left transverse sinus was occluded; the vein of Labbé and the sigmoid sinus remained patent. The patient recovered neurologically without deficit. An angiogram obtained 4 months after embolization showed no filling of the fistula and no change in the configuration of the Onyx cast (Fig. 1 right).

Case 2. This 71-year-old man experienced acute onset of nausea, vomiting, numbness, tingling, and ataxia 8 months prior to his first neurosurgical evaluation. Initial head CT scanning and brain MR imaging performed in June 2005 revealed findings consistent with brainstem ischemia, but no other vascular abnormality was noted. His neurological status deteriorated prior to neurosurgical evaluation to the point that he required a feeding tube due to poor swallowing, and he was wheelchair dependent due to ataxia and weakness. Magnetic resonance imaging and MR angiography performed immediately prior to neurovascular evaluation in December 2005 revealed a new varix in the medulla that was not present on the previous study. Angiography demonstrated a DAVF fed by the marginal tentorial artery of the left MHT. The MHT was selectively catheterized and injected with 0.2 ml of Onyx. Follow-up angiography showed no filling through the MHT; however, the fistula continued to fill via a posterior branch of the MMA. Immediate attempts at catheterization of the MMA were unsuccessful. Six weeks later the patient underwent angiography again, and the MMA was successfully catheterized and embolized. Onyx (0.7 ml) was injected immediately proximal to the fistula. The ICA and ECA angiograms at that time and 3 months later showed no residual filling of the DAVF. The patient’s condition improved at a rehabilitation facility to the point where he was able to ambulate with a four-post cane and was able to swallow and commence oral intake.

Case 3. This 71-year-old man presented with new onset headaches and syncope. He was neurologically intact. An MR imaging study revealed a DAVF involving the SSS. Angiography showed arterial feeding from two branches of the right MMA and two branches of the left MMA. The malformation was adjacent to the SSS at the vertex. There was retrograde filling of cortical veins with eventual drainage to the SSS (Fig. 2A). Arterial catheterization of each MMA was achieved; however, due to tortuosity and small caliber of the vessel, the catheter could not be advanced to the level of the DAVF. Onyx was injected into the proximal right MMA in the hope of pushing the material through the fistula, but this was unsuccessful as the fistula continued to fill through the left MMA. The following day, a combined transvenous and transarterial approach was used for further embolization. Transvenous catheterization of the anterior third of the SSS was achieved, followed by repeated arterial catheterization of the left MMA. Multiple coils were placed into the SSS just proximal to the DAVF where there was evidence of previous occlusion and recanalization. Onyx was then injected into the fistula and found to fill the fistula and cortical veins. At this point, further detachable coils were placed into the SSS distal to the fistula (Fig. 2B). The fistula continued to fill via a falcine branch of the ophthalmic artery, although there was no reflux into cortical veins (Fig. 2C). Attempts were made to selectively catheterize this vessel via the left ophthalmic artery; however, during manipulation of the catheter in this very tortuous vessel, the tip of the catheter was broken. The remainder of the catheter was withdrawn, and angiography showed continued adequate filling of the ophthalmic artery. No new clinical deficits were noted, and the patient remained seizure free. The ICA and ECA angiograms at 3 months showed weak residual filling of the DAVF, presumably via the falcine branch of the left ICA; however, the fistula itself was too small to be visualized. The patient was treated with GKS for the residual DAVF. Of note, the Onyx was not thought to interfere with GKS planning. Clinically, the patient did not have any further headaches, but complained of intermittent diplopia.
Case 4. This 72-year-old man presented with sudden onset of a severe headache and left side dysmetria. Head CT scanning revealed a left cerebellar hematoma and subarachnoid hemorrhage. An MR imaging study revealed dilated cerebellar veins consistent with DAVF. Angiography confirmed DAVF with a single feeding artery from a posterior branch of the MMA. Arterial catheterization of this vessel was performed, and 0.4 ml of Onyx was injected into the artery just proximal to the DAVF. The fistula was completely filled, and injection was stopped at the point of reflux into the feeding artery. Follow-up angiography at 9 weeks showed complete occlusion of the DAVF. The patient’s headache resolved and his dysmetria improved significantly, leaving him with only a small amount of residual intention tremor.

Case 5. This 55-year-old man presented with sudden loss of consciousness followed by headache, nausea, and blurred vision. The patient had fallen and sustained an L-4 burst fracture. Initial CT scanning of the head showed a large right-sided dilated cortical vein. Computed tomography angiography and time-of-flight MR angiography confirmed multiple dilated cortical veins associated with stenos of the SSS and dilation of the right MMA. Angiography showed DAVF adjacent to the SSS that was fed by two right MMA vessels, the left falcine artery, and two left MMA vessels. Filling from left ECA scalp vessels and posterior circulation meningeal artery branches was identified. Extensive retrograde filling of the cortical vessels was also noted. A microcatheter was inserted into the left MMA just proximal to the DAVF. Approximately 5 ml of Onyx was injected into the DAVF, and extensive filling was seen of multiple left and right meningeal and scalp arteries (Fig. 3). Follow-up angiography at 3 months showed no filling of the DAVF. The patient subsequently underwent lumbar fusion for his fracture and did not complain of any further headaches or syncopal episodes at the 6-month clinical follow-up.

Case 6. This 38-year-old man presented with an acute onset of headache and a focal seizure activity of the right arm. The patient was neurologically intact by the time of neurosurgical evaluation, and CT scanning of the head showed left parietal convexity subarachnoid hemorrhage. Magnetic resonance angiography and CT angiography did not show any vascular abnormality; however, angiography revealed a late filling DAVF fed by several distal branches of the right MMA, emptying into the SSS (Fig. 4 left). A microcatheter was successfully advanced into a small, somewhat tortuous branch of the MMA to the point of the fistula. Onyx (1.4 ml) was injected into the fistula, and filling was noted along a segment of abnormal SSS encompassing the location of the additional filling arteries. The injection was stopped when a small amount of Onyx was found to flow smoothly into the superior portion of the normal SSS. Immediate follow-up angiography of the left ICA and ECA showed no residual filling of the fistula (Fig. 4 right). The patient awoke from anesthesia neurologically intact with no headache. Follow-up angiography at 4 months revealed no residual filling of the DAVF, and the patient remained asymptomatic.

### TABLE 1

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Symptom</th>
<th>Feeding Vessel</th>
<th>Draining Vein</th>
<th>Additional Treatment Modality</th>
<th>Angiography Outcome</th>
<th>Clinical Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50, M</td>
<td>seizure, hemorrhage</td>
<td>lt MMA, pst branch</td>
<td>lt transverse sinus via cortical veins</td>
<td>transvenous placement of detachable coils</td>
<td>no filling, 4 mos</td>
<td>no residual deficit</td>
<td></td>
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<tr>
<td>2</td>
<td>71, M</td>
<td>brainstem ischemia from dilated varix</td>
<td>MHT, marginal tentorial artery</td>
<td>bilat MMA</td>
<td>delayed washout from varix</td>
<td>none</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>72, M</td>
<td>HA, syncope</td>
<td>lt MMA, pst branch</td>
<td>SSS via cortical veins</td>
<td>transvenous placement of detachable coils, GKS</td>
<td>weak residual filling, immediate &amp; 3 mos</td>
<td>no HA, mild diplopia mild tremor, no HA</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>55, M</td>
<td>HA, loss of consciousness</td>
<td>bilat MMA, falcine artery</td>
<td>SSS via cortical veins</td>
<td>none</td>
<td>no filling, 3 mos</td>
<td>no HA, no deficit</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>38, M</td>
<td>HA, SAH, seizure</td>
<td>rt MMA</td>
<td>SSS direct</td>
<td>none</td>
<td>no filling, 4 mos</td>
<td>no HA</td>
<td></td>
</tr>
</tbody>
</table>

* HA = headache; pst = posterior; SAH = subarachnoid hemorrhage.

[A. P. Carlson, C. L. Taylor, and H. Yonas](https://doi.org/10.1227/01.neu.0000327384.16517.81)

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**Discussion**

Endovascular embolization is currently accepted as an adjunct to definitive surgical treatment for arteriovenous malformations. Onyx in conjunction with other endovascu-
lar techniques may offer a permanent therapeutic alternative. This assertion is based on both our knowledge of the pathophysiology and nature of DA VF, and the unique properties of Onyx as an embolic agent. In the current series we have presented several cases in which embolization was successful in short-term angiographic obliteration of even complex DAVFs.

Defining features of DA VF include an artery-to-vein shunt located within the dura mater. Blood supply typically comes solely from meningeal arteries, with the exception of a carotid–cavernous fistula in which the ICA provides inflow. Outflow from a dural fistula may be directly to a venous sinus or indirectly to a sinus through parenchymal veins. Angiographically, a DA VF is characterized by the location of the shunt and by the appearance of abnormal venous drainage in the arterial or capillary phase of the study.

In the absence of cortical venous drainage, DAVF has a benign course. Observation is warranted, however, due to a 2% incidence of development of cortical venous drainage.7

Invasive treatment of DAVF may be recommended for a variety of reasons. Diverse symptoms including disabling tinnitus, focal neurological deficits, or elevated intracranial pressure can occur. Intracerebral hemorrhage may occur due to rupture of a parenchymal vein.8 In patients who present with symptoms unrelated to ICH or with an incidental finding, a significant risk of ICH may be inferred from the pattern of venous drainage, associated venous stenosis, or the presence of variceal dilation.9

There are several anatomical features of DAVF that suggest the usefulness of endovascular treatment. There is often a dilated feeding vessel that can be accessed using a microcatheter with low risk of a catheter-related embolic event. The fistulas themselves communicate with other feeding vessels, allowing for multiple vessels to be embolized with a single injection. The technique used in these cases involves very slow injection of the material until it is seen to occlude venous outflow. The injection is then stopped for 1 to 2 minutes allowing the plug to settle in the outflow tract. When injection is restarted, the material usually begins to fill a separate artery or vein. By stopping injection when venous outflow fills and speeding up injection slightly when arterial channels are filling, the feeding vessels are ideally preferentially filled. It should be noted, however, that embolic material that is pushed through the fistula may extend into the normal venous system. Care must be taken not to occlude any functioning venous drainage.

Several properties of Onyx suggest its usefulness as a permanent embolic agent for DAVF. It is a liquid when dissolved in dimethyl sulfoxide that polymerizes on contact with the bloodstream. This allows for casting of complex vascular networks. The polymer is expected to be permanent in vivo based on the molecular polymerization and
empirc evidence has shown a low rate of recanalization of Onyx-embolized aneurysns even at the 5-year follow-up. Onyx does not have the adhesive properties of NBCA thereby decreasing the risk of microcatheter retention after embolization.

The potential to backfill multiple feeding arteries from a single arterial injection is critical to the hypothesis that DAVF may be cured by arterial embolization alone with the use of Onyx. As demonstrated by several of the cases presented here, many arterial vessels contributing to a DAVF may be too small or tortuous to be individually catheterized for embolization. Preferential backfilling of feeding vessels with Onyx may be related to the hemodynamics of the fistula and the properties of Onyx. Treatment of the patient in Case 5 (Fig. 3) demonstrated unexpected backfilling of extensive feeding vessels with one injection and no occlusion of large venous channels. This may be partially explained by the presumed pathophysiology of DAVF, that is, capillary recruitment into thrombosed vessels. This may lead to a situation of high resistance at the venous outflow of the fistula and, when this connection is occluded, may allow for backfilling of all communicating feeding arteries. This may be most noticeable when the DAVF is located along the length of a cortical vein, although this distinction can be difficult to visualize when cortical veins are closely adjacent to a major sinus.

These observations suggest that the single-most important factor with regard to complete obliteration of the fistula is the microcatheter position at the time of injection. When the tip is at, or immediately adjacent to, the fistula, complete obliteration should be anticipated. In retrospect, combined venous embolization with detachable coils did not seem to increase the efficacy of the procedure, although it did increase cost, angiography time, and dye load.

Conclusions

Transarterial Onyx embolization can angiographically obliterate DAVF. Over very short-term follow-up these results appear to be angiographically stable. These observations are consistent with our understanding of the nature of DAVF and the properties of Onyx. The complications we observed included residual fistula and a retained portion of a microcatheter; however, no patient exhibited neurological worsening. Achieving a microcatheter tip position immediately adjacent to the point of fistulization is the most important technical factor in predicting obliteration of the DAVF. In our series, venous embolization was not thought to be of significant use.

Disclaimer

The authors have no financial investment in the products used in this study.

References

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