Endovascular Treatment of Noncavernous Dural Arteriovenous Fistulas: Analysis of Outcomes with and without Ethylene Vinyl Alcohol

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Objective: Noncavernous dural arteriovenous fistulas (DAVFs) are uncommon lesions that can be treated from an endovascular approach using various embolic materials. The purpose of this study was to evaluate our outcomes for endovascular treatment of DAVFs with and without the use of ethylene vinyl alcohol (EVOH). *Methods:* We performed a retrospective analysis of 65 patients treated for DAVF at our institution from January 1995 to May 2015. Lesions were classified as aggressive or benign, based on angiography according to Cognard classification. Demographic data, medical comorbidities, presenting symptoms, treatment modality, treatment outcomes, and complications were evaluated for each group. Primary outcome was defined as angiographic occlusion for an aggressive DAVF, and resolution of clinical symptoms for a benign DAVF. *Results:* The primary outcome was met in 47 (82.5%) of 57 cases with endovascular therapy alone; 23 (69.7%) of 33 aggressive fistulas; and 24 (100.0%) of 24 benign fistulas. There was a 5% overall complication rate. The primary outcome was achieved via endovascular approach in 80.0% (24 of 30) of cases with EVOH, and 85.2% (23 of 27) of cases without EVOH ($P = .73$). There was a 6% complication rate for procedures using EVOH versus 3% for cases without EVOH ($P = 1.00$), a 13% clinical recurrence rate for cases using EVOH compared to .0% when EVOH was not used ($P = .24$), and no angiographic recurrences in either group ($P = 1$). There were no procedure-related mortalities. *Conclusions:* Endovascular treatment of DAVFs has a high success rate and low complication rate. Our experience demonstrated no difference in outcomes between lesions treated with EVOH and those treated without EVOH.
Key Words: Arterial embolization—arteriovenous fistula—endovascular treatment—ethylene vinyl alcohol.

Introduction

Noncavernous dural arteriovenous fistulas (DAVFs) are uncommon lesions with an abnormal direct connection (fistula) between a meningeal artery and a cortical vein, perimedullary vein, or dural venous sinus. Lesion grade is determined by the venous drainage pattern of the DAVF. Cortical venous reflux (CVR) and direct cortical venous drainage (CVD) are ominous findings, as they portend a more aggressive natural history.[1-4] Aggressive lesions (those with CVR or CVD) are estimated to have a yearly morbid event rate of 15% and a yearly mortality rate of

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10%.[2,5-8] Treatment for aggressive lesions is complete occlusion of all CVR and CVD.[2,6,9,10] Benign DAVFs typically have an uneventful clinical course and are often treated expectantly[11,12]; however, in cases of benign DAVFs with disabling symptoms, treatment can be offered. DAVFs can be treated using an endovascular approach via an intra-arterial and/or transvenous route. Multiple embolic materials have been employed in the endovascular treatment of DAVFs, including n-butyl cyanoacrylate (NBCA) (TRUFILL; Codman Neurovascular, Raynham, MA), polyvinyl alcohol particles, coils, and ethylene vinyl alcohol (EVOH) (Onyx; ev3, Irvine, CA). EVOH is a liquid embolic agent that has been touted to have superior properties when compared to traditional embolic materials in the therapy of DAVFs, particularly in complex lesions, which were previously thought to be poor candidates for endovascular treatment.[13,14] Although there are several series in the literature that discuss EVOH or other embolic materials in the therapy of DAVFs, there is only one series that directly compares outcomes between EVOH and other embolic materials.[13] The purpose of this study was to evaluate the outcomes of our endovascular treatment of DAVFs with and without the use of EVOH.

Materials and Methods

Our local institutional review board approved this study. We conducted a retrospective analysis of patients with DAVF presenting at our institution between January 1, 1995 and May 1, 2015. Cases were identified using operative logs and a search of the electronic medical record system. Pertinent medical records, including clinical and operative notes, were reviewed and correlated with imaging. Radiology imaging includes computed tomography (CT), magnetic resonance imaging (MRI), and digital subtraction angiography. DAVFs were defined as an abnormal direct connection (fistula) between a meningeal artery and a cortical vein, perimedullary vein, or dural venous sinus. DAVFs of the cavernous sinus and spinal dural fistulas were excluded from our analysis. Cerebral angiograms were reviewed by 2 interventional neuroradiologists with 10 and 16 years of experience. Lesion location was assigned based on the predominant draining venous sinus (transverse sigmoid, tentorium, or superior sagittal). Lesions were assigned to 2 groups—aggressive or benign—based on their Cognard classification, which was determined by angiography. Aggressive lesions were defined as those with CVR or CVD (Cognard class IIa+b, IIb, III, and IV). Benign lesions were those without CVR or CVD (Cognard class I and IIa). Preprocedural data, including patient demographics, medical comorbidities, and presenting symptoms, were collected. Intraprocedural data were also collected, including treatment modality, endovascular approach (arterial, venous, or both), embolic material, number of treatment stages, and complications. Complication rate was calculated per procedure and included complications resulting in permanent neurologic deficits and severe transient iatrogenic complications (i.e., occipital scalp necrosis, radiation injury). Severe technical complications (vessel perforation, catheter retention, nontarget embolization, catheter rupture) were also included, even if there were no clinical sequelae. Postprocedural data, including immediate and midterm clinical and angiographic outcomes, were also reviewed.

Treatment Approach

In patients with aggressive lesions, the primary outcome was obliteration of the DAVF based on angiography. For benign lesions, the primary outcome was resolution of the patient's clinical symptoms. In general, both aggressive and benign DAVFs were treated via an endovascular approach until the primary outcome was reached, unless the patient elected against therapy or was lost to follow-up.

Endovascular Procedure

Cerebral angiography of the bilateral external carotid, internal carotid, and vertebral arteries was performed to fully evaluate the lesions prior to therapy. Endovascular procedures were performed under general anesthesia. Percutaneous femoral artery access was obtained utilizing ultrasound guidance and a modified Seldinger technique with a 4F micropuncture kit (Cook Medical, Bloomington, IN). In some cases, femoral vein access was also obtained. Patients were heparinized based on body weight (60-100 IU/kg) to maintain an activated clotting time between 250 and 300 seconds.

Arterial Embolization

Following arterial access and sheath placement, a 6F guide catheter was placed into the origin of the internal or external carotid artery on the ipsilateral side of the DAVF. A microcatheter was then advanced under roadmap guidance into the major feeding artery. Angiography was performed to determine the portion of the fistula supplied by the artery and to identify potential dangerous anastomoses. The microcatheter was advanced as closely as possible to the site of the arteriovenous fistula. Embolization proceeded, using various embolic materials including NBCA, particles, and/or coils (Fig 1).

In cases using EVOH, the dead space of the microcatheter was primed with dimethyl sulfoxide (Fig 2). An EVOH plug was formed around the tip of the microcatheter over approximately 20 minutes. In later cases, EVOH was injected through a detachable tip microcatheter (Apollo; ev3) or using a double-lumen balloon catheter (Sceptor XC; Microvention, Tustin, CA). EVOH was then slowly injected under negative roadmap into the fistula. Progress during the procedure was monitored periodically via catheter angiography. Embolization was repeated in as many feeding arteries as necessary or possible. In