E-027

FLUID FLOW AND PRESSURE MEASUREMENTS FROM A 3D PRINTED ARTERIOVENOUS MALFORMATION PHANTOM FOR FLUID STRUCTURE INTERACTION MODELING OF A SIMPLE ARTERIOVENOUS MALFORMATION

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Introduction Cerebral arteriovenous malformation (AVM) rupture risk is thought to be approximately 3% per year, but varies with high risk anatomic features. Recent studies have raised the question about whether treatment is indicated for unruptured AVMs. The important decisions about treatment versus conservative management is largely based on a collection of outcome studies that may not match a patient's particular AVM. The ultimate purpose of this research is to create a predictive computational model for a patient's specific AVM anatomy to give them a lifetime risk of rupture profile. Our hypothesis is that the flow and pressure patterns within the nidus of the AVM can be determined by creating a 3D printed model of a simple AVM with internal imbedded pressure and flow sensors. This information can then be incorporated into a fluid structure interaction model of a simple arteriovenous malformation.

Methods In an IRB approved study, unruptured Spetzler Martin Grade I and II AVMS were evaluated to select an AVM that demonstrated a relatively de-compact nidus and simple inflow and outflow vessels with cerebral angiography imaging with at least 4 frames/second anterior-posterior and lateral runs. This AVM was then processed in Matlab as well as manually segmented to create a 3D printing stereolithography file. The AVM was then printed in the Cleveland Clinic 3D printing laboratory with hollow lumens within the vessels and was fitted with inline flow probes within the inflow, outflow and nidus vessels and pressure transducers. This AVM was then inserted into a flow circuit connected to a cardiac cycle pump. The pump was then run with fluid that mirrors the viscosity of blood and cycled for 10 repetitions to verify stability of the pressure and flow readings at each 10 mmHg increment of output pressure between 100 mmHg to 260 mmHg. The model was then imaged in a cerebral angiography machine and connected to a pressure injector to compare transit time between the flow model and the previously obtained cerebral angiogram data from the patient.

Results We successfully built and measured flow and pressure from a 3D printed replica of a simple brain AVM incorporated into a cardiac cycle fluid circuit. This data is currently

being compared to cerebral angiography transit rates to validate the data and fit the projected flow and pressure measurements to clinically obtained data. The data additionally is being incorporated into inflow and outflow parameters in the ANSYS fluid structure interaction model of the same simple AVM to compare predicted pressure and flow through the simulation compared to the 3D printed AVM measurements.

Conclusions We have made progress in the multistep task of building a fluid structure interaction model of a simple AVM by measuring flow rate and pressure measurements in an anatomically correct 3D printed model of a simple AVM. This data allows for more accurate simulation and for further evaluation of whether flow and pressure characteristics can be simplified for a compact AVM nidus with the goal of developing a predictive model of the natural history of AVM rupture.

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E-028

DELAYED CRANIAL NERVE PALSY AFTER TRANSVENOUS EMBOLIZATION OF INDIRECT CAROTID CAVERNOUS FISTULAE

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Introduction Carotid cavernous fistulae (CCF) can present with diplopia secondary to cranial nerve palsy (CNP). Immediate development of post operative CNP has been described in the literature. This study discusses delayed presentation of CNP after complete obliteration of the CCF and resolution of initial CNP.

Methods A retrospective analysis was carried out on patients with indirect CCF between 1987 and 2006 at 4 centers. Details of the endovascular procedures, embolic agents used, and complications were studied. Partial and complete obliteration was noted. Immediate and delayed cranial nerve palsies were assessed.

Results 267 patients with symptomatic indirect CCF underwent endovascular treatment. 4 patients (1.5%) developed delayed abducens nerve (VI) palsy after complete resolution of presenting symptoms after embolization. Delayed presentation ranged between 3 months -13 months after complete resolution of initial double vision and cranial nerve palsies. Transvenous coil embolization through the inferior petrosal sinus was performed in all four affected patients. All had follow up angiography demonstrating durable closure of their CCF. In all four patients, their abducens nerve (VI) palsy remained.

Abstract E-028 Table 1 Summary of four patients with delayed abducens nerve palsy after TVE of CCF

Case	Age	Sex	Presentation	TVE	Time until delayed CNP	CNP on follow up	Follow up angiogram
1	63	F	Right abducens nerve palsy	Complete obliteration	6 months	Persistent	Complete obliteration
2	60	F	Right abducens nerve palsy	Complete obliteration	7 months	Persistent	Complete obliteration
3	64	F	Right abducens nerve palsy	Complete obliteration	13 months	Persistent	Complete obliteration
4	58	F	Right abducens nerve palsy	Complete obliteration	3 months	Persistent	Complete obliteration

Abstract E-028 Figure 1

Abstract E-028 Figure 2

Conclusion Delayed CNP can develop despite complete endovascular obliteration of the CCF. Long term follow-up is needed even after complete neurological and radiological recovery is attained in the immediate perioperative period.

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E-029 CLINICAL, ANGIOARCHITECTURAL AND TREATMENT CHARACTERISTICS OF SPINAL DURAL ARTERIOVENOUS FISTULAS VERSUS SPINAL EPIDURAL ARTERIOVENOUS FISTULAS

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Background and Purpose Spinal epidural arteriovenous fistulas (SEDAVs) are an increasingly recognized form of spinal vascular malformation. The aim of this study was to analyze the clinical presentation, imaging findings and treatment outcomes of spinal epidural arteriovenous fistulas in a contemporary single-center series.

Materials and Methods Consecutive patients diagnosed and/or treated for SEAVFs at our institution between January 2000 and November 2018 were included. Data were collected on demographics, clinical presentation, imaging findings and treatment outcomes. All cross-sectional and angiographic imaging were reviewed by a diagnostic and interventional neuroradiologist and endovascular neurosurgeon. All patients underwent at least 3 months of clinical follow-up.

Results Forty-nine patients were included. Median follow-up was 21 months. 29 patients (59.2%) were males and mean age was 63.5 ± 14.8 years. The median time from symptomatic presentation to diagnosis was 12 months. The most common finding on lumbar spine MRI were T2 hyperintense signal in the conus (42 patients, 85.7%), perimedullary flow voids (34 fistulas, 69.4%) and cord enhancement (30 patients, 61.2%). Thirty-eight patients had a spinal MRA and 35 (92.1%) had a pouch of contrast/venous varix in the epidural space. All patients on DSA had a pouch of contrast in the ventral or lateral epidural space at the site of the abnormal fistulous connection (49 lesions, 100.0%). 40 SEAVFs (81.6%) were located in the lumbosacral spine. A total of 40 patients underwent endovascular embolization for treatment of their fistula. One patient suffered a treatment related complication (2.5%). Of the treated patients, 4 patients (10.0%) had residual fistula requiring additional embolization or surgery.

Conclusions SEDAVFs have similar findings to spinal dural arteriovenous fistulas on conventional MRI with high T2 cord signal, cord enhancement and perimedullary flow voids. However, they have a characteristic appearance on spinal MRA and DSA with a large pouch of epidural contrast. Endovascular embolization is safe and effective for treatment of these lesions.

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E-030 ANTIPLATELET THERAPY IS ASSOCIATED WITH BETTER OUTCOMES IN PATIENTS WITH MOYAMOYA DISEASE. A META-ANALYSIS

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Introduction Moyamoya disease causes progressive stenosis of the supraclinoid internal carotid arteries with subsequent development of moyamoya collaterals. The mainstay treatment is surgical revascularization using direct or indirect bypass techniques. The use of antiplatelet agents is advocated to facilitate blood flow, maintain bypass patency, and reduce thrombotic events. We searched published literature to determine the benefits of antiplatelet therapy in this patient population.

Methods We performed a literature search of published papers in the English language using EMBASE, PUBMED, and Web