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INTERVENTIONAL NEURORADIOLOGY

Spinal cord arteriovenous shunts of the ventral (anterior) sulcus: anatomical, clinical, and therapeutic considerations

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Abstract
Introduction Ventral sulcus spinal cord arteriovenous shunts (SCAVS) are rare vascular lesions that are located outside the spinal cord, are exclusively vascularized by the anterior spinal axis, and drain exclusively through the anterior spinal vein. We report the anatomical, clinical, and neuro-radiological features of SCAVS managed by our team.
Methods We conducted a retrospective study of patients with SCAVSs evaluated by the senior author of this report (GR) between 1981 and 2014. Data were collected by reviewing clinical notes and by a systematic analysis of spinal angiograms and MRI.
Results Among 358 patients, we identified 8 patients (3 women) with ventral sulcus spinal cord arteriovenous shunts. Mean age was 30.5 years. Six patients presented with progressive neurological symptoms, and two with acute neurological symptoms related to hematomyelia. Three shunts were located in the cervical cord, four in the thoracic cord, and one at the conus medullaris; there were two nidus type A-V shunts (AVMs) and six fistula type A-V shunts (AVFs). Seven patients were treated by endovascular therapy with glue embolization. Embolization led to anatomical cure in 5 cases, and a significant reduction of shunt volume and flow of more than 75% in 2 cases. In none of the cases we observed permanent morbidity.
Conclusions AVS of the ventral sulcus of the spinal cord are rare. Recognition of these lesions and precise localization of the anatomical space in which they are located, may allow a better understanding of their pathophysiology and clinical manifestations and guide proper therapeutic decisions.

Keywords Spinal cord arteriovenous shunts · Interventional neuroradiology · Anterior spinal artery · Ventral sulcus · Embolization

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Introduction

Spinal cord arteriovenous shunts (SCAVS) are rare lesions; despite the scarcity of large studies on natural history, they are considered to be devastating vascular malformations because of their aggressiveness with poor neurological outcome if left untreated [1–4].

SCAVS have been submitted to several, often conflicting, different classifications. We identified artero-venous shunts of the ventral sulcus as lesions located in the ventral sulcus of the cord and vascularized exclusively by the anterior spinal artery (ASA) through one or more sulco-commisural arteries. Endovascular or surgical treatment of SCAVSs is challenging, especially when they are

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vascularized by the anterior spinal cord artery (ASA), given the eloquence of the spinal cord tissue that it takes in charge. Detailed anatomical works [5, 6] show that the ASA is a continuous axis extending from the vertebro-basilar junction to the conus terminalis, with 4–8 radiculo-medullary arteries (RMA) participating to its constitution. When these RMA reach the midline of the cord, they divide into a cranial and a caudal branch. The anastomosis between these adjacent cranial and caudal branches on the midline, and over the ventral sulcus, makes the continuity of the ASA. From the ASA arise secondary branches that are pial (remaining at the surface of the cord, participating to its anterior superficial extrinsic network and vascularizing the anterior funiculi) and sulcal (or sulco-commissural). These latter penetrate into the ventral sulcus, and have an intrasulcal trajectory before penetrating into the cord and vascularizing mainly the grey matter in a centrifugal way.

We prefer using the term *sulcal* or *sulco-commissural artery* instead of *central artery.* In fact, the definition sulcal artery points to the extramedullary location of the lesion while the definition central artery could also apply to an intrinsic artery localized within the cord parenchyma and thus be more appropriate to the description of lesions embedded inside the cord. Endovascular treatment of a ventral sulcus artero-venous shunt is thus safe if the continuity of the ASA is respected, and if perforating arteries vascularizing the adjacent funiculi are not damaged.

We report the anatomical, clinical, and neuro-radiological features of A-V shunts located in the ventral sulcus of the cord without invasion of the nervous tissue and detail the angio-anatomic data that allow their recognition.

Materials and methods

Patient population

We retrospectively evaluated the clinical and imaging data of AVS of the ventral sulcus identified from a total of 358 intradural spinal cord AV shunts managed by our group between 1981 and 2014. Among this population, 8 patients matched the criteria of ventral sulcus AVSs, in particular:

1) A nidus (AVM) or fistula (AVF) type of shunt
2) Lesions vascularized exclusively by the ASA via sulco-commissural arteries (SCAs) and draining exclusively into the anterior spinal vein (ASV) via sulco commissural veins (SCVs).

The patients' clinical statuses at baseline and at follow up were evaluated according to Aminoff-Logue scale (ALS) [7]. ALS clinical scale grades motor function (1: leg weakness but no restriction in gait, 2: reduced tolerance to exercise, 3: need for a cane to walk, 4: need for two canes or crutches to walk, 5: wheelchair bound) and bladder function (0: normal, 1: hesitancy, urgency, frequency, altered sensation, but continent, 2: occasional urinary incontinence or retention, 3: total incontinence or persistent retention).

Imaging

All patients underwent angiography at our institution in order to analyze the lesion. Attention was drawn to these features of the SCAVS:

1) Location (cervical, thoracic, lumbar).
2) Type (i.e., nidus type AVM or arteriovenous fistula (microAVF or macroAVF).
3) Number (single or multiple).
4) Angio-architecture.

In all patients, MRI was performed before angiography; magnetic resonance imaging was of variable protocol because some patients were referred to our institution already having undergone MRI of diagnostic quality. In all cases, T2-weighted and T1-weighted images obtained in sagittal and axial planes were available; in seven cases gadolinium-enhanced T1-weighted images were obtained. Four patients were studied with contrast-enhanced magnetic resonance angiography (MRA). MRI pictures were examined to identify the following features:

1) Presence and location of T2 hyper-signal within the cord (distribution on cross sectional axial images and longitudinal extension).
2) Presence of mass effect on the cord related to dilated vascular structures.
3) Presence of signal modifications compatible with hemoglobin degradation products confirming previous haemorrhage.
4) Presence and location of peri-medullary flow-voids on T2 weighted images and/or serpiginous vascular enhancement of post-contrast images.

Rating of these features was done by consensus of two independent neuroradiologists.

Treatment

Endovascular treatment was considered in first intention in all our patients. In all patients, endovascular treatment was conducted under general anesthesia without provocative tests. Acrylic glue was utilized for embolization in all cases.