Classification of Dural Arteriovenous Shunts (DAVS) based on the Craniospinal Epidural Venous Drainage of the Central Nervous System and Adjacent Bony Structures

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The cranio spinal epidural spaces were categorized into three different compartments — ventral, dorsal and lateral. Each compartment has its specific drainage role in relation to the embryologic development of the venous system of the central nervous system (CNS) and the surrounding bony structures. The ventral epidural space drains structures derived from the notochord and adjacent sclerotomes. The dorsal epidural group is related to the drainage of the spinal processes at the spinal level and to the vault and calvarium cranially. The lateral epidural group collects the emissary bridging veins of the pial venous system of the spinal cord and brain.

The dural arteriovenous shunts (DAVS) developing in these spaces predictably drain either in the subarachnoid veins or in the epidural-paraspinal collectors according to the epidural compartment involved. Additional comorbidity, like epidural venous thrombosis or high flow characteristics of the DAVS, will be responsible for changes in the draining pattern of otherwise anticipated spinofugal or craniofugal drainage. This embryologically based classification establishes homologies between spinal and cranial epidural spaces, thus allowing epidemiological and clinical comparison including spinal and cranial DAVSs.

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**Introduction**

Dural arteriovenous shunts or fistulas (DAVS or DAVF) are a broad group of diseases that share involvement of the epidural space and adjacent dura mater and bony structures.

Different classifications have been proposed for these lesions \(^{1-3} \) however it is generally accepted that the presence or absence of cortical venous reflux angiographic finding constitutes the major and only clinical consideration regarding the natural history and, therefore, the therapeutic strategies for these lesions. The purpose of this new classification is an attempt to ground the gender dominance or age at presentation seen in some localization and to link spinal and cranial lesions.

Three observations of the venous development of the brain and spinal cord and adjacent bony structures, contribute to the generation of the new classification:

- The venous system of the notochord and corresponding sclerotome, extends from the basisphenoid (cavern-
ous plexus) to the sacrum; it gives rise to the ventral epidural drainage group. It collects the blood from spongyous bony structures, and has no primary role in the drainage of the central nervous system.

- The dorsal epidural venous space is normally poorly developed at the spinal level. The major difference between the venous systems of the brain and spine formation is linked to the appearance, during evolution, of the dural falces, the tentorium, and associated to the development of the paleo and neo pallial structures of the brain and cerebellum. These sinuses result from the confluence in the epidural space of two different venous systems—the osseous system draining the cranial vault and the leptomeningeal system draining the brain.

- The veins draining the central nervous system (spinal cord and deep cerebral) use "emissary–bridging veins" to join the lateral epidural venous spaces as a connecting drainage system. This leptomeningeal venous drainage has no direct confluent communication with the ventral and dorsal epidural venousplexuses, which drain the skull and spine.

All three epidural venous spaces remain compartmented and converge secondarily to join the jugular, ayzygos, lumbar or sacral, paraspinal venous collectors. Reflux into the afferent veins of an adjacent epidural group is likely to signify a constraints placed upon the outlet (occlusive or hemodynamic).

Fig. 1 Schematic representation of the topographic distribution of the epidural venous subgroups according to bone structures (Basis for the new classification of DAVS).

A: Spinal level.
B: Cranial level.
Blue: Ventral epidural group, Green: Lateral epidural group, Orange: Dorsal epidural group.

Fig. 2 Lower lumbar arterial angiogram—AP view. Lower lumbar spinal dural arteriovenous fistula (Ventral epidural type). Note the shunt zone (arrowhead) at the level of the vertebral body and epidural space anteriorly draining to the ventral group of epidural venous spaces (arrows) and outward to the ascending lumbar veins.

Three venous subgroups according to the relationship of the epidural venous spaces with the afferent veins from the bone, and central nervous system (CNS) (Fig. 1) can therefore be distinguished:

- Ventral epidural (VE)
- Dorsal epidural (DE)
- Lateral epidural (LE)
**Fig. 3** Epidural arteriovenous shunt at the basi-occipital region level (VE type).

A: Selective angiogram of the ascending pharyngeal artery demonstrating the shunt zone at the left petrous-clival region level draining to the jugular bulb with reflux into the cavernous sinus through the inferior petrosal sinus and upper cervical ventral epidural venous space.

B: Note on the MRI the involvement of the bone (white arrow).

**Fig. 4** Right external carotid angiogram—Lateral view. Epidural arteriovenous shunt at the transverse and sigmoid sinus level (VE type). It is mainly fed by branches from the occipital (mastoid transosseous branches) and middle meningeal (petrosquamous branch) arteries. Usually it does not have cortical venous reflux except when it is associated with a distal venous thrombosis.

**Fig. 5** Selective right maxillary artery angiogram (A: AP view; B: Lateral view). Epidural arteriovenous shunt at level of the basi-sphenoid bone region (VE type). Cavernous sinus shunt with reflux to ophthalmic vein (★), inferior petrosal sinus (★★) and contralateral cavernous plexus (★★★).
New classification of DAVIS

1 Ventral epidural shunts (Fig. 2 - 5)

DAVS in these regions involve mainly the epidural space and are in direct contact with the adjacent osseous structures that they may invade and or recruit the blood supply. The venous afferents of these regions is closely related to the bony structures and they drain outside the bony limits, thus resulting in no direct subarachnoid (spinal or cortical) venous reflux (CVR). However some factors may precipitate the development of CVR in these regions such as; thrombosis within the epidural space either surrounding, remote or distal to the shunt. It will produce reflux in the lateral epidural space as seen in cases of ventral epidural spinal shunts with perimedullary venous reflux. CVR can also be encountered in high-flow...
Fig. 10  A: Right external carotid angiogram (Lateral view). Epidural arteriovenous shunts at tentorial base level draining into the latero mesencephallic venous system (curved arrows).
B: Different patient, right internal carotid artery (Lateral view). Note the dural contributions from the ICA to the fistula that can be used as a route for transarterial embolization. Typical aspects of a lateral epidural type intracranially.

Fig. 11 Internal carotid angiogram—lateral views (A : Right side, B : Left side). Epidural arteriovenous shunts at level of the anterior cranial fossa level (Lateral epidural type) fed by ethmoidal branches of the ophthalmic artery. Note the direct cortical venous reflux.

shunts forcing the emissary-bridging vein opening after reflux in the lateral epidural space. In this group, the following DAVS locations are encountered: “vertebral body” (Fig. 2), basi–occipital (Fig. 3), sigmoid sinus (Fig. 4), petrous pyramid, basi sphenoid (Fig. 5), adjacent sphenoid wings and related dural structures.

2 Dorsal epidural shunts (Fig. 6, 7)
At the spinal level, they are exceptional and clinically present with epidural hematoma (Fig. 6). The superior sagittal sinus (SSS) (Fig. 7), torcular, transverse sinus, medial occipital sinus and posterior marginal sinus at the foramen magnum lesions are included in this group. The venous pressure within the dural sinuses is usually low, thus antegrade, craniofugal flow of the shunts is normally observed. CVR may occur following associated venous outflow restriction, or with high flow shunts; variations of the venous opening into this system or distal restriction of the sinus opening will rapidly produce CVR. In this group, the following DAVS locations are encountered: “dorsal spinal epidural DAVS”, marginal sinus (dorsal portion), medial occipital sinus, torcular, transverse and accessory epidural sinuses, and superior sagittal sinus.

3 Lateral epidural shunts (Fig. 8–11)
The most typical ones correspond to the space where
spinal DAVFs are located. Intracranial locations include DAVS draining into emissary-bridging veins of the brainstem and their homologues draining deep cerebral structures, such as the condylar vein at the foramen magnum, the superior petrosal vein, the basilar vein, the vein of Galen, the veins of the anterior cranial fossa (lamina cribrosa/ethmoid) and the orbits. The drainage is always directed to the cortical or perimedullary veins, therefore the DAVS developing there are always considered to be aggressive. In this group the following DAVS locations are encountered: lateral "spinal dural AV shunts" (Fig. 8), marginal sinus (lateral portion, with the emissary-bridging vein to the condylar vein) (Fig. 9), falco-tentorial (vein of Galen), petrosal and basi-tentorial (Fig. 10), Breschet sinus, para cavernous region (embryonic tentorial sinus remnants), intra orbital shunts and lamina cribrosa (Fig. 11).

Conclusion

The roles of venous afferents of the three epidural spaces established during embryologic development of the central nervous system and cranio spinal structures are different. This reference to embryology allows analyzing both cranial and spinal homologues and, therefore, is the basis for a classification system that can be applied to all types of lesions developing in these spaces. DAVS in these different areas will drain according to the specific role of the venous system of each region, unless there is an associated constraint (co-morbidity) placed upon the venous outlet. These venous outlet modifications (i.e. occlusion or stenosis) can be either adjacent to the shunting area, most commonly from thrombosis rather than endothelial proliferation, and/or remote from the shunt, such as seen in jugular bulb dysmaturation in pediatric patients. Although they have been thought to be the cause of the shunt development, they represent an associated co-morbidity of the disease. Since thrombosis of the venous system is uncommon in the general population, it may reflect an underlying biological disorder in these patients with possible different geographic impact. Finally, the clear gender dominance of certain locations (spinal—male, cavernous plexus—female) further suggests a specific biological/hormonal vulnerability within the three groups.

References