CME

The Cerebrospinal Venous System: Anatomy, Physiology, and Clinical Implications: Anatomy of the CSVS

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Anatomy of the CSVS

> *"In brief, the vertebral veins are a valveless plexiform network with a longitudinal pattern. They parallel and communicate with the superior and inferior venae cavae. The plexus extends the entire length of the vertebral column and finds a cranial terminus in the dural sinuses."* Batson[2]

The intracranial venous system, including the dural sinuses, has long been known, but it was Breschet[3] who most clearly and accurately depicted the rich, direct interconnections between the cranial venous sinuses and the vertebral venous plexus (Figure 1).[16] The thin-walled veins of the vertebral venous plexus require special methods to preserve their architecture for postmortem examination. First demonstrated by dissection, newer methods of injection[5,17,18] and imaging with x-ray,[6-8,19-23] CT, and MR[24-27] techniques have established and confirmed both the anatomy and anastomoses of this unique venous system. Moreover, the epidural veins have been referred to as the meningorachidian veins.[2,6]

The Vertebral Venous Plexuses: Internal, External, and Basivertebral Veins

Breschet's detailed description of the anatomy of the VVS was confirmed by Bock,[4] via the dissections, corrosion studies, and injection studies of Batson[2,9,10,12-14] in human cadavers and living monkeys, and by angiographic studies in humans carried out by Anderson.[28] These studies have shown that the vertebral venous plexus comprises an interconnected and richly anastomosed system of veins that run along the entire length of the vertebral canal. For descriptive purposes, Groen and colleagues[29] separated the vertebral venous plexus into three intercommunicating divisions: the internal vertebral venous plexuses (anterior and posterior) lying within the spinal canal but external to the dura; the external vertebral venous plexuses (anterior and posterior), which surround the vertebral column; and the basivertebral veins, which run horizontally within the vertebrae. Both the internal vertebral venous plexus and the external vertebral venous plexus course longitudinally along the entire length of the spine, from the sacrum to the cranial vault. Clemens[5] used corrosion casting and injections of *Araldite* to demonstrate that the internal and external vertebral venous plexuses freely intercommunicate, which was also demonstrated by Vogelsang[7] with intraosseous spinal venography. Groen and colleagues[17] used an improved *Araldite* injection technique and confirmed the fact that all 3 divisions of the VVS (internal and external plexuses and the basivertebral veins) freely intercommunicate, and that all divisions of this system lack valves. The internal vertebral venous plexus communicates with the intraspinal and radicular veins and freely communicates with the external vertebral venous plexus via the intervertebral veins (Figure 2).[10,23,29,30]

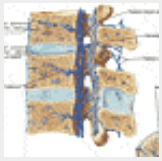

Figure 2. (click image to zoom) The veins of the spinal cord and the vertebral column, as depicted by Netter,[30] used with permission. Note the drainage of the interspinous space by the posterior external vertebral venous plexus.

The Interconnection of the Venous Systems of the Spine and the Brain

> *"When the amount of the injection mass was increased to a total of 200cc, the material attained the base of the skull and entered the cranial cavity."* Batson[2]

The anatomic anastomoses between the vertebral venous plexuses and the intracranial venous system, first depicted by Breschet,[3] have been confirmed by multiple investigators. In particular, Batson's[2,9,10,12-14] injection studies and Anderson's[28] angiographic studies in living humans demonstrated that injection into the VVS leads to visualization of the cranial venous sinuses. More recent investigations have detailed identical findings, and have established the direct functional connection of the vertebral venous plexus with the intracranial venous system, including the suboccipital cavernous sinus, the condylar veins, and the hypoglossal plexus.[17,18,25,31,32] Free communication between the VVS and the intracranial venous system was confirmed by Groen and colleagues,[17] who found *Araldite* distributed in the cranial sinuses (superior sagittal sinus, confluens sinuum, sigmoid sinus, cavernous sinus, and plexus basilaris) and the major cerebral and cerebellar cortical veins after injecting the dye into the VVS.

Communication of the Intracranial Venous System and the Veins of the Scalp, Skull, and Face

> *"Throughout the cranium the veins of the brain, the veins of the meninges (the venous sinuses), and the veins of the skull bones themselves (the diploic veins), and the veins of the various extracranial plexuses anastomose richly."* Batson[2]

> *"The facial veins and their important anastomoses with the intracranial venous system are less well appreciated."* Osborn[33]

Angiography has demonstrated communication between the facial veins, ophthalmic and orbital veins, and internal cerebral veins,[33] confirming Batson's[10,11] studies, which used both injection techniques and corrosion casting. Of note, the veins in the cavernous sinuses (lateral sellar compartments) are part of the CSVS.[2,18,28,29] Parkinson[34,35] described the vertebral venous plexus as part of the extradural neural axis compartment, which extends from the spine to the lateral sellar compartment (cavernous sinus) and the orbital veins. Anastomoses of the CSVS with veins of the skull, the scalp, and the face, and the possibility of bidirectional flow have led Zenker and Kubik[36] to speculate that one of the normal physiologic functions of these anastomoses is to enable cooling of the brain and spinal cord. Because this entire interconnected system is valveless, blood can flow in any direction, either to or from the brain, the ophthalmic veins, the cavernous sinuses, the spinal cord, or the vertebrae.

Communication of the Vertebral Venous Plexuses and the Veins of the Back and Thoracoabdominal Wall

> *"These vertebral veins have many and rich communications with the veins in the spinal canal, the veins around the spinal column, and those within the bones of the column. This system communicates with the segmental (intercostal) veins of the thoracico-abdominal wall (including those of the breast) and with the azygous system of veins."* Batson[2]

> *"Structures posterior to the transverse processes of the vertebrae drain their blood into the valveless postvertebral veins."* Batson[12]

In the same way that the intracranial venous system communicates with the superficial veins of the scalp, head, and face, the VVS freely communicates with other superficial valveless veins in the back and thoracoabdominal wall.[12,17] Batson[2,10,12] injected radioopaque dye into the subcutaneous breast veins of human cadavers and demonstrated flow into the VVS and the cranial dural sinuses, including the transverse sinus and the superior longitudinal sinus. The external vertebral venous plexus connects directly with veins overlying the posterior spinous processes, veins draining the interspinous space, and veins draining the deep back muscles (Figure 2).[5,7,14,29,30]

Anastomoses of the VVS With the Azygous, Pulmonary, and Caval Venous Systems

In addition, via anastomosis, the vertebral venous plexus communicates with the systemic venous system, including the azygous system of veins (and thereby the posterior bronchial vein and the parietal pleural veins), the left renal and suprarenal veins, the portal venous system, and both the inferior and superior vena cava, thereby providing a venous system that both bypasses and communicates with the valve-bearing systemic venous system.[12,17,29]

Communication of the Vertebral Venous Plexuses and the Pelvic, Prostatic, and Sacral Veins

> *"After a total of 200cc. of the diodrast had been injected into the deep dorsal penile vein, skull films were obtained... there is an accumulation of the opaque media in the superior sagittal sinus and in addition the confluens sinuum... and many of the superior cerebral veins are filled... the straight sinus is well filled... the great cerebral vein, the petrosal sinuses and a portion of the basilar plexus of veins are outlined."* Anderson[28]

At the caudal end, the vertebral venous plexus freely communicates with the pelvic and prostatic veins and the sacral venous plexus.[2,17,29]

In summary, multiple anatomic investigations have confirmed that the CSVS is an interconnected valveless venous system that runs from the pelvis to the cranium, and within which the venous drainage of the brain, the spinal cord, the spine, and the vertebral bodies

intermix. As Batson[14] stated, "the cranial dural veins are the uppermost terminus of the vertebral veins." The CSVS has connections to both the deep systemic, valved venous system (including the inferior and superior vena cava) and to valveless superficial veins in the face, head, back, and thoracoabdominal wall. The rich anastomoses and important functional connections between the cranial venous system and the VVS support naming this venous network the CSVS.

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