AJNR

Cerebral Veins: A New "New Frontier"

L. Hacein-Bey

AJNR Am J Neuroradiol 2022, 43 (1) 78-79
doi: https://doi.org/10.3174/ajnr.A7359
http://www.ajnr.org/content/43/1/78

Cerebral Veins: A New "New Frontier"

The article by Ide et al[1] in this issue of the *American Journal of Neuroradiology* has significant relevancy from both theoretic and practical perspectives.

The cerebral venous system develops through a series of complex stages, some that remain incompletely understood.[2] In the early embryo (5–8 mm), a continuous primitive venous plexus drains the brain through 3 stems (anterior, middle, and posterior). Around the 11- to 14-mm stage, lateral dural sinuses develop, which drain the brain through primitive pia-arachnoid vessels. By the 17- to 20-mm stage, posterior (sigmoid, tentorial, and marginal) sinuses are formed, while the 2 anterior components of the primitive venous plexus start to involute and form the prootic sinus (a stem of the middle dural plexus that connects to the posterior plexus via the sigmoid sinus). At the 40-mm stage, the cavernous sinuses form as medial extensions of the prootic sinus, which is continuous with the inferior petrosal sinus; laterally, the prootic sinus anastomoses with a primitive temporal emissary vein to form the petrosquamous sinus. By the 60- to 80-mm embryonic stage, while the posterior (sigmoid, transverse, tentorial) sinuses move backward to their permanent configuration, the otic capsule promotes the development of the superior petrosal sinus, while the prootic sinus remains continuous with the petrosquamous sinus. Laterally, the petrosquamous sinus and prootic sinus remnants are later destined to involute as diploic veins, which drain meningeal structures via the foramen ovale. Medially, the primitive tentorial sinus also involutes after the superior petrosal sinus has formed and is connected to the cavernous sinus. Variations may occur as a result of incomplete involution of those venous structures, lateral and medial.

Comparative anatomy among species reveals that major evolutionary variations exist in the cranial venous anatomy, especially in primates.[3] In primitive primates, cerebral venous drainage is mainly through the postglenoid emissary vein, which receives the cranio-orbital and petrosquamous sinuses in a configuration that is recognized as the orbitotemporal venous sinuses. In higher primates and humans, while the orbitotemporal sinuses persist as the middle meningeal venous network, the petrosquamous sinus generally involutes or becomes intradiploic. Remnants of the orbitotemporal sinuses are occasionally encountered in the form of a persistent petrosquamous sinus,[4] a venous sinus of Kelch,[5] which runs through the superior orbital fissure and connects the superior ophthalmic and middle meningeal veins to the transverse sinus, or a sinus of Hyrtl,[6] which connects the sphenoparietal sinus to middle meningeal veins in the foramen spinosum.

Therefore, the article by Ide et al[1] sheds new light on the embryology of the human cerebral venous system with the description of what likely represents a previously unrecognized remnant of orbitotemporal connections of the primitive prootic sinus.

Indeed, an important contribution to our understanding of human cerebrovascular embryology, this work has also considerable practical implications. Proper knowledge of venous anatomic variations may minimize misdiagnoses of vascular lesions and, more important, may help prevent surgical complications of hemorrhage, thrombosis, or venous infarction.

Similarly, the spread of infections from the middle ear to the intracranial venous system has been reported to only occur with the presence of an abnormal petrosquamous sinus.[4] The same would be expected with periorbital infections and the rare persistent sinuses of Kelch of Hyrtl. Recognition of such predisposing pathways of intracranial spread of disease may prompt earlier, more aggressive treatment.

It has been suggested by Miyachi et al[7] that emissary veins contribute to the pathophysiology of dural arteriovenous fistulas (DAVFs). Emissary veins, along with their companion emissary arteries within skull base or transdiploic foramina, may be exposed to inflammation (from adjacent infection or trauma), which may lead to angiogenic stimuli and the opening of physiologic postcapillary arteriovenous shunting, all resulting in dural sinus or cortical vein DAVFs. The emissary vein of the foramen ovale may, therefore, have a role in triggering cavernous sinus fistulas, and the petrobasal vein described in the article may further promote the extension of arteriovenous shunting to the superior petrosal sinus and possibly the tentorium (which does not receive emissary veins).

Endovascular therapy has become the preferred treatment option for DAVFs, having virtually replaced surgery or radiosurgery in most specialized centers. The transvenous approach to embolization is becoming increasingly favored over the transarterial approach, which is associated with a higher incidence of complications of cerebral ischemia or cranial neuropathy. Increasingly, more precise knowledge of the cerebral venous anatomy allows treating more complex lesions, including with the use of open surgical access when needed.[8]

Similarly, transvenous endovascular therapy of brain AVMs is increasingly used and is increasingly successful as definitive therapy in skilled hands, with expected improvements in technique and extension in indications.[9]

Another practical area to benefit from sound anatomic understanding of cerebral venous anatomy is the field of neuromodulation, which is expected to take off in major ways. Decades of experience with implantable cardiac electronic devices (cardiac defibrillators and permanent pacemakers) have definitely established the safety of intravenous wiring. More recently, technologic advances in signal transmission through increasingly miniaturized transvenous devices have opened the path to intracranial neuromodulation, considering the immediate proximity of eloquent brain regions to various venous structures. Applications of neuromodulation that are currently well underway include epilepsy monitoring, neurostimulation in various indications (including epilepsy), motor control of exoskeletons and robotic limbs in paralyzed patients, and the enabling of speech paradigms on the basis of text or even thought in patients after a stroke.[10] In the same "vein," transvenous catheter-based ablation for epilepsy is predicted to allow treating epilepsy in "the same way as cardiac disturbances."[11]

A novel treatment for communicating hydrocephalus currently under prospective multicenter evaluation involves the transvenous implantation of a miniaturized 1-way valve allowing CSF to drain directly from the cerebellopontine angle cistern into the jugular vein. This device (eShunt System; CereVasc), or some improved version of it, is expected to obviate the need for extensive surgical placement of ventriculoperitoneal shunts in many patients.[12,13]

The cerebral venous system may be currently considered the "new frontier" in neuroscience therapeutics with the convergence of major advances in technology, vascular access, and our increased understanding of the anatomy. In that regard, the article by Ide et al[1] is also a useful contribution.

REFERENCES

1. Ide S, Kiyosue H, Shamada R, et al. **Petrobasal vein: a previously unrecognized vein directly connecting the superior petrosal sinus to the emissary vein of the foramen ovale.** *AJNR Am J Neuroradiol* 2022;43:70–77 CrossRef
2. Padget DH. **The cranial venous system in man in reference to development, adult configuration, and relation to the arteries.** *Am J Anat* 1956;98:307–55 CrossRef Medline
3. Diamond MK. **Homology and evolution of the orbitotemporal venous sinuses of humans.** *Am J Phys Anthropol* 1992;88:211–44 CrossRef Medline
4. An YH, Wee JH, Han KH, et al. **Two cases of petrosquamosal sinus in the temporal bone presented as perioperative finding.** *Laryngoscope* 2011;121:381–84 CrossRef Medline
5. Couldwell M, Aysenne A, Iwanaga J, et al. **Bilateral venous sinuses of Kelch.** *Anat Cell Biol* 2021;54:395–98 CrossRef Medline
6. Tubbs RS, Loukas M, Shoja MM, et al. **Accessory venous sinus of Hyrtl.** *Folia Morphol (Warsz)* 2007;66:198–99 Medline
7. Miyachi S, Izumi T, Matsubara N, et al. **Mechanism of the formation of dural arteriovenous fistula: the role of the emissary vein.** *Interv Neuroradiol* 2011;17:195–202 CrossRef Medline
8. Bhatia KD, Lee H, Kortman H, et al. **Endovascular management of intracranial dural AVFs: transvenous approach.** *AJNR Am J Neuroradiol* 2021 Oct 14. [Epub ahead of print] CrossRef Medline
9. Mosimann PJ, Chapot R. **Contemporary endovascular techniques for the curative treatment of cerebral arteriovenous malformations and review of neurointerventional outcomes.** *J Neurosurg Sci* 2018;62:505–13 CrossRef Medline
10. Raza SA, Opie NL, Morokoff A, et al. **Endovascular neuromodulation: safety profile and future directions.** *Front Neurol* 2020;11:351 CrossRef Medline
11. Thoma C. **Epilepsy: novel transvenous catheter mapping and ablation could supersede invasive antiepileptic surgery.** *Nat Rev Neurol* 2014;10:306 CrossRef Medline
12. Heilman CB, Basil GW, Beneduce BM, et al. **Anatomical characterization of the inferior petrosal sinus and adjacent cerebellopontine angle cistern for development of an endovascular transdural cerebrospinal fluid shunt.** *J Neurointerv Surg* 2019;11:598–602 CrossRef Medline
13. **First patient treated in eShunt clinical trial.** In: *Proceedings of the Barts Research and Advanced Interventional Neuroradiology Brain Conference,* London, UK. December 13–16, 2021

L. Hacein-Bey
University of California Davis Medical School
Sacramento, California

http://dx.doi.org/10.3174/ajnr.A7359