Anatomy and Pathology of the Cranial Emissary Veins: A Review With Surgical Implications

Martin M. Mortazavi, MD*
R. Shane Tubbs, MS, PA-C, PhD*
Sheryl Riech, BS*
Ketan Verma, BS*
Mohammadali M. Shoja, MD‡
Anna Zurada, MD, PhD§
Brion Benninger, MD||
Marios Loukas, MD, PhD¶
Aaron A. Cohen Gadol, MD, MSc#

*Section of Pediatric Neurosurgery, Children's Hospital, Birmingham, Alabama; ‡Neuroscience Research Center, Tabriz University of Medical Sciences, Tabriz, Iran; §Department of Anatomy, Medical Faculty, University of Varmia and Masuria, Olsztyn, Poland; ||Departments of Surgery, Oral Maxillofacial Surgery, Integrated Biosciences, Oregon Health & Science University, Portland, Oregon; ¶Department of Anatomical Sciences, St. George's University, Grenada; #Goodman Campbell Brain and Spine, Indiana University Department of Neurological Surgery, Indianapolis, Indiana

Correspondence:
Aaron A. Cohen-Gadol, MD, MSc,
Goodman-Campbell Brain and Spine,
Department of Neurological Surgery,
Indiana University,
1801 North Senate Blvd., Suite 610,
Indianapolis, IN 46202.
E-mail: acohenmd@gmail.com

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Emissary veins connect the extracranial venous system with the intracranial venous sinuses. These include, but are not limited to, the posterior condyloid, mastoid, occipital, and parietal emissary veins. A review of the literature for the anatomy, embryology, pathology, and surgery of the intracranial emissary veins was performed. Detailed descriptions of these venous structures are lacking in the literature, and, to the authors', knowledge, this is the first detailed review to discuss the anatomy, pathology, anomalies, and clinical effects of the cranial emissary veins. Our hope is that such data will be useful to the neurosurgeon during surgery in the vicinity of the emissary veins.

KEY WORDS: Anatomy, Cranial, Neurosurgery, Venous system

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"If there were no emissary veins, injuries and diseases of the scalp would lose half their seriousness."—Sir Frederick Treves (1853-1923)[1]

Emissary veins connect the veins outside the cranium with the intracranial venous sinuses (Figure 1A).[2-6] These structures are more commonly found in children, and not all of the various emissary veins are identified in every individual.[7] These veins serve an important function of equalizing intracranial pressure and can act as safety valves during cerebral congestion or in patients with lesions of the neck or cranium such as obstruction of the internal jugular veins.[5-10] The foramina for these vessels tend to be larger during childhood[6] and may communicate with the diploic veins.[10]

Emissary veins are also considered an important component for selective brain cooling.[2,4] These veins are valveless,[7] so, technically, blood can flow bidirectionally, thereby allowing cooler blood from the evaporating surfaces of the head to cool the brain.[4] Louis et al[5] found that emissary veins act as the primary outflow route for venous drainage in the upright position and may serve to cool venous blood circulating through the head.

Emissary veins can often be seen on magnetic resonance imaging, computed tomography, and angiography, and the various types are named according to their position on the cranium.[5,8,11] Interestingly, an enlarged emissary foramen does not necessarily transmit a large emissary vein,[8] and fossil records indicate that there is an increasing frequency of some emissary veins, such as the mastoid and parietal vessels in humans.[3]

Because information regarding these specialized structures is scant, we reviewed the anatomy and clinical and surgical implications of the emissary veins. Standard search engines (eg, PubMed) and anatomy textbooks were reviewed for the term "emissary vein."

ANATOMY

Posterior Condyloid Emissary Vein

The posterior condyloid emissary vein connects the lower end of the sigmoid, marginal or occipital sinuses with the internal vertebral venous plexus (Figure 1A).[3,6,10,12] Irmak et al[4] noted that a posterior condylar emissary vein may connect the sigmoid sinus with the suboccipital plexus of veins.[10] Observations have shown that the posterior condylar foramen is the largest emissary foramen in the retromastoid region.[8]

Mastoid Emissary Vein

The mastoid emissary vein passes through the mastoid canal and connects the transverse or sigmoid sinus to the posterior auricular or occipital veins, which then join the vertebral plexus of veins (Figure 1A and B).[3,4,8,10,13,14] Lang and Samii[15] observed that the mastoid emissary foramen exists less frequently in females

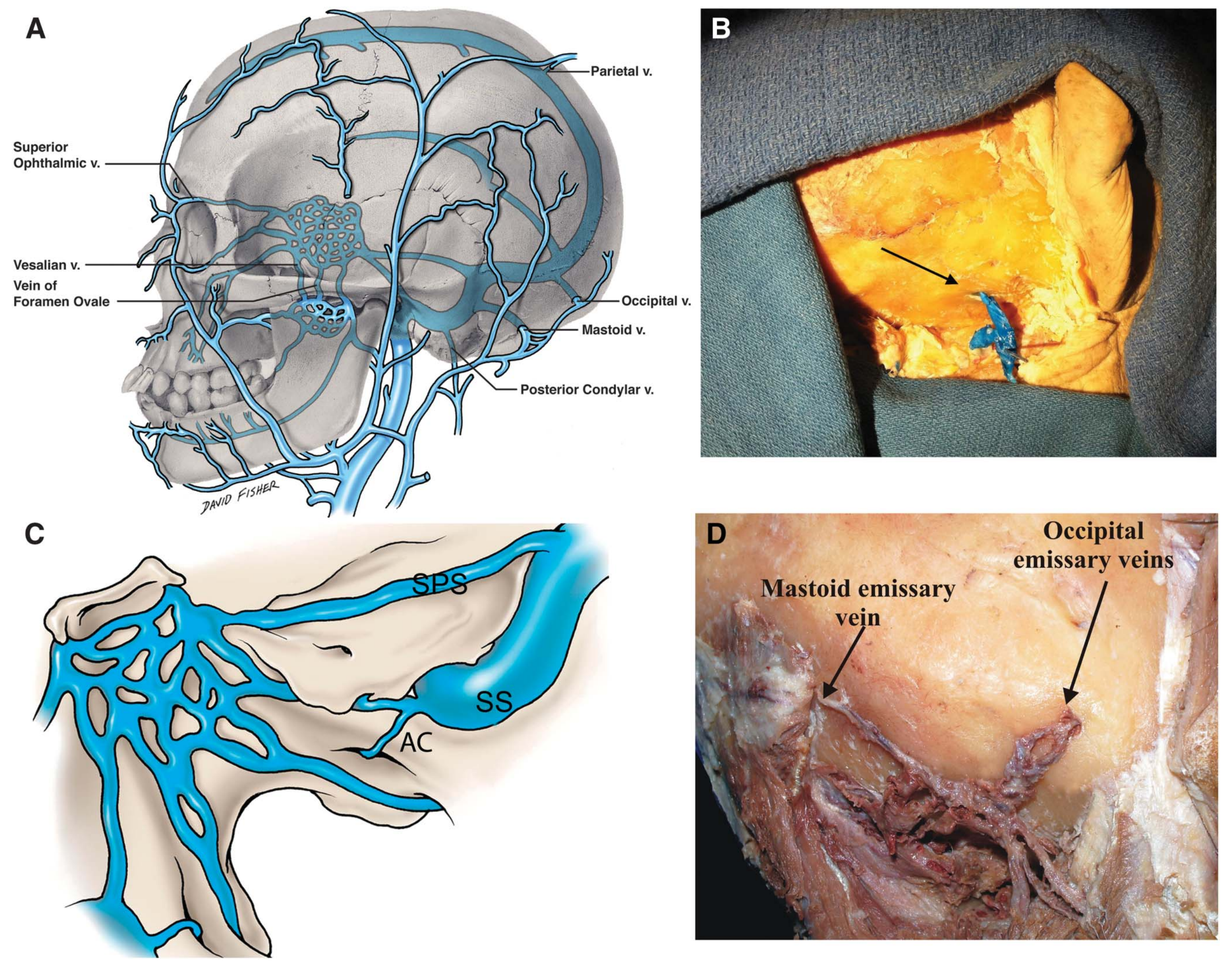

FIGURE 1. **A**, *schematic drawing of the major emissary veins and their internal connections.* **B**, *posterior view of a cadaver cranium noting a large injected (blue) right-sided mastoid emissary vein.* **C**, *schematic drawing illustrating the anterior condylar vein (AC) traveling through the hypoglossal canal. For reference, also note the right sigmoid sinus (SS) and superior petrosal sinus (SPS). Also note the basilar venous plexus applied to the dorsal surface of the clivus.* **D**, *cadaveric dissection revealing the left mastoid and occipital emissary veins.*

than males, although the reason for this is unclear. It is controversial whether mastoid foramina are more common on the right or left side.[5] Cheatle[13] noted an infrequent association between the mastoid emissary vein and the petrosquamosal sinus.

Occipital Emissary Vein

The occipital emissary vein connects the transverse sinus to the occipital vein, which then drains blood to the vertebral venous plexus (Figure 1A).[3,6] On occasion, the occipital emissary vein joins the transverse–sigmoid sinus complex.[16] Okudera et al[17] reported that the occipital vein may drain to the confluence of sinuses.

Parietal Emissary Vein

The parietal emissary vein connects the superior sagittal sinus with the occipital vein that then joins the vertebral venous plexus (Figure 1A).[3,6] Parietal emissary veins also interact with the diploic veins within the cranial bones, which as mentioned previously, may allow for the cooler blood to spread through the cranium to the meninges.[4] Both the parietal and mastoid emissary veins are found at high frequencies in *Homo sapiens* compared with other hominid species.[2]

Petrosquamosal Sinus

Although it serves as the primary cerebral drainage site in many lesser primates and quadrupeds, the petrosquamosal sinus is a rare emissary vein in humans that typically disappears before birth in humans. The petrosquamosal sinus ranges from 2 to 4 mm in diameter and originates at the junction between the transverse and sigmoid sinuses, coursing laterally above the superior border of the temporal bone.

Ophthalmic Veins

The ophthalmic veins are considered by some to be emissary veins (Figure 1A) because they may perform a similar function as the emissary veins by connecting the exterior with the interior cranium (angular vein to cavernous sinus) and are valveless. The ophthalmic veins travel through the orbit and traverse the superior orbital fissure to reach the most anterior portion of the cavernous sinus.[18]

Sphenoidal Emissary Vein (Vesalius)

Sphenoidal emissary veins (Vesalian veins) connect the cavernous sinus with the pterygoid or pharyngeal plexuses (Figure 1A).[18-20] These veins are not constant and are found in only approximately 1 in 3 cases.[18] The foramen for this vessel is found just medial to the foramen ovale.

Emissary Veins of the Foramen Ovale

Just like the sphenoidal emissary veins, the emissary veins of the foramen ovale connect the cavernous sinus to the pterygoid plexus (Figure 1A).[18,19]

Internal Carotid Venous Plexus

The internal carotid plexus of veins extends through the carotid canal and connects the cavernous sinus with the internal jugular vein.[19] This collection of veins is classified by some as emissary veins because it joins the intradural sinuses with extracranial veins.[21]

Emissary Vein of the Foramen Cecum

The single emissary vein of the foramen cecum joins the superior sagittal sinus with veins of the nasal cavity and is unpaired.[19] This vessel is larger at birth than in the adult.

Emissary Veins of the Foramen Lacerum

An inconsistent number of small veins may traverse the cartilage-filled foramen lacerum. Such emissary veins connect the cavernous sinus with the pterygoid venous plexus.[18]

Emissary Veins of the Clivus

Some have identified transclival emissary veins.[22] These structures connect the basilar venous plexus to veins on the inferior surface of the clivus adjacent to the pharynx.

Anterior Condylar Vein

The anterior condylar vein accompanies the hypoglossal nerve through the hypoglossal canal (Figure 1C) and joins the anterior condylar confluent.[23]

Temporal Emissary Vein

This venous structure may connect the remnant of the petrosquamosal sinus with the deep temporal vein and likely represents the dorsal cerebral vein seen in some mammals.

Superficial Petrosal Emissary Vein

This vein connects the vessel(s) traveling along the superficial petrosal vein in the middle cranial fossa to the vein traveling with the facial nerve within the stylomastoid foramen. Such vessels may be remnants of the primary head sinus.

Significance of Emissary Veins During Surgery

Open Procedures

The cranial emissary veins provide surgical advantages. For procedures such as the transcondylar and far lateral approaches, the emissary veins act as landmarks for the deeper lying venous sinuses.[24-28] In the retrosigmoid approach to the posterior cranial fossa, emissary veins should be freed from the bone to avoid avulsion of the vein or lacerations of the underlying sinuses to which they are connected; otherwise, hemorrhage or air embolism may occur (Figure 1D).[25] Bleeding from emissary veins may result in postoperative epidural hematoma formation.[29,30] Although the most appropriate amount of material, including fibrin glue used to put into a bleeding emissary foramen, is not known, care should be used when applying these because, for example, bone wax applied to bleeding emissary foramina has been known to enter the deeply placed venous sinuses and result in extensive thrombosis.[31,32] In cases in which the bleeding emissary vein is large, the use of a muscle plug has been recommended.[13]

In dealing with the surgical removal of some cranial base tumors, collateral emissary veins have been noted to take on the role of primary venous outflow. Sacrificing these veins may lead to sinus thrombosis; therefore, presurgical angiography has been recommended (Figure 2).[26] Preoperative endovascular procedures aimed at occluding such enlarged tumor-related veins might be considered. Hoshi et al[33] reported a case of removal of a hypoglossal neurinoma in which the condylar emissary veins were enlarged. Coagulation of these channels resulted in dural venous sinus thrombosis and cerebellar infarction leading to the patient's death. To avoid this problem, some have suggested enlarging the bony foramen carrying the emissary vein and lightly coagulating the vessel in lieu of packing the foramen with wax.[32] Acute thrombosis could be treated with open or closed thrombectomy procedures. Sphenoidal emissary veins and veins of the foramen ovale may hinder lateral extradural approaches to the cranial base. Hayashi et al[20] found that if the pterygoid venous plexus via its connections with the emissary veins of the foramina ovale and

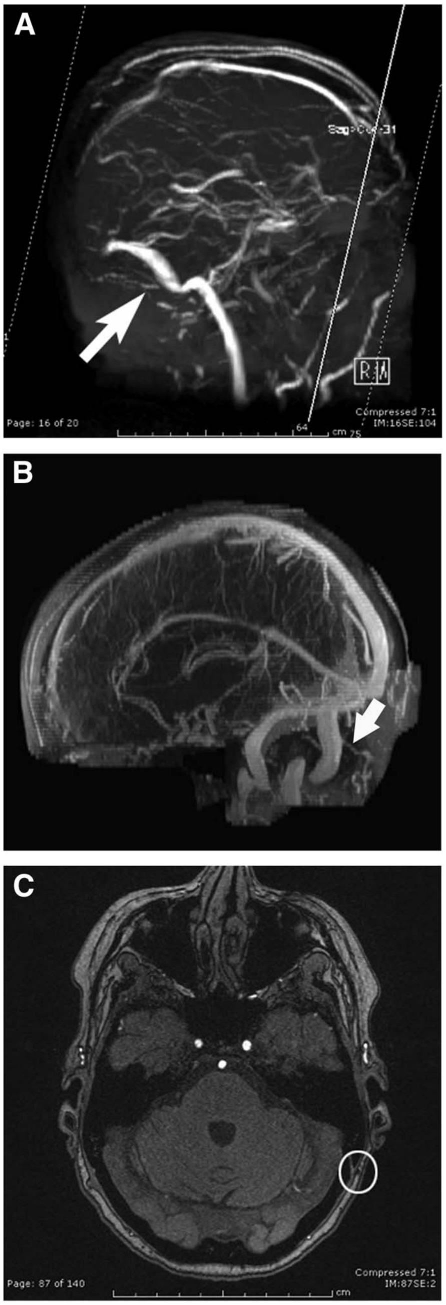

FIGURE 2. **A**, *angiography noting a probable mastoid emissary vein (arrow) entering the sigmoid sinus. This patient is an adult male being evaluated for pseudotumor cerebri.* **B**, *angiography noting a probable posterior condylar emissary vein (arrow) entering the sigmoid sinus in a patient followed for a small asymptomatic aneurysm of the anterior communicating artery.* **C**, *axial magnetic resonance imaging noting a small emissary vein, which probably represents the mastoid emissary vein (circle). This is a preoperative study performed on an adult male patient with medically recalcitrant trigeminal neuralgia.*

Vesalius are primarily responsible for cavernous sinus drainage, then epidural procedures in this area may result in more complications. The petrosquamosal emissary vein, when present, may be encountered with posterior petrosectomy procedures.

Closed Procedures

The cranial emissary veins may also be used to gain access to the intracranial dural venous sinuses via endovascular procedures.[17] For example, Rivet et al[28] described using the mastoid emissary vein to gain access to the transverse sigmoid sinus junction for treatment of Borden-Shucart type II dural arteriovenous fistulae. Cannulation of the supraorbital vein has been used for access to the superior ophthalmic vein and then the cavernous sinus for the treatment of carotid cavernous fistulae.[26]

Emissary Veins as Conduits for Infection

Along with their surgical advantages, the emissary veins may serve as pathways by which infections are carried into the cranial cavity.[1,10,13,34] Boyd[8] brought forth the popular belief that the subaponeurotic space, being traversed by the parietal emissary veins (Figure 3A), has been referred to as the "danger area of the scalp."[8] Samuel et al[34] shared a similar belief, stating that the dura is usually resistant to penetration of infection unless the transmission of the infection is through the thrombophlebitic process of an emissary vein. Cheatle[13] discussed surgery for extensive mastoiditis and how this can lead to the deeper lying venous sinuses becoming septically thrombosed after opening of emissary veins. Friedman and Greenfield[35] echoed this opinion. The mastoid emissary vein has also been suspected as a pathway for cavernous sinus thrombosis.[13] This was seen in a patient with infection of the posterior neck that presumably extended from the occipital veins through the mastoid emissary vein into the transverse sinus and then through the superior petrosal sinus and into the cavernous sinus.[13] The petrosquamosal sinus, considered by some as an emissary vein, has been found frequently in individuals with inner ear malformations or underdevelopment of the jugular vein and may promote the spread of infection or metastasis from the auditory canal.[36] The danger area of the face just lateral to the nose and inferior to the orbit is a well-known site of potential passage of superficial infection through emissary veins of the orbit that may join the ophthalmic veins and thus spread infection from the skin of the face to the cavernous sinus.[14,19]

Anomalies Related to Cranial Emissary Veins

In the event of vascular deformities in areas of high blood flow or compromise of the internal jugular veins due to cranial malformations such as craniosynostosis, emissary veins may increase in size and provide the primary venous outflow of the cranium.[36,37] O'Connor et al[38] discussed a case study involving a 5-month-old female infant presenting with a swelling that increased with crying in the right posterior occipitomastoid region. The patient was found to have a 5 × 3-cm mass stemming from an opening

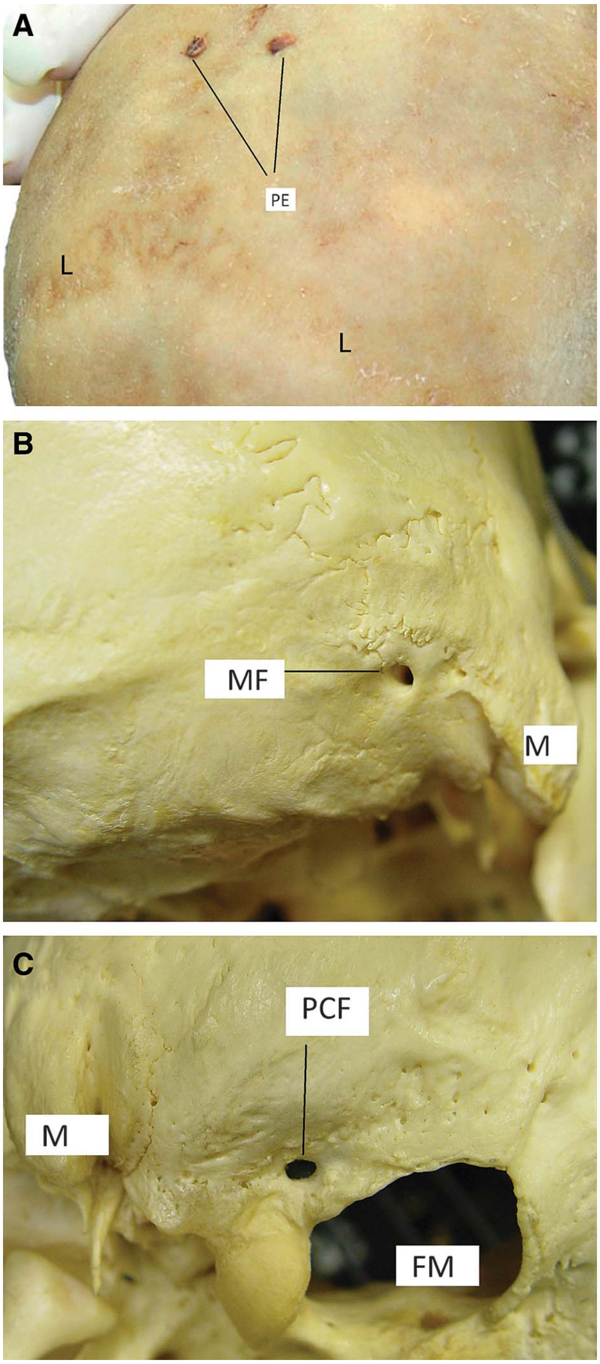

FIGURE 3. **A**, *cadaveric dissection of the posterior cranium. For reference, note the left and right lambdoid sutures (L). Anterior to the bregma and alongside the sagittal suture, note the left and right parietal emissary veins (PE) leaving their respective foramina in the parietal bone.* **B**, *posterior cranial specimen noting the mastoid foramen (MF) for the mastoid emissary vein on the right side. For reference, note the right mastoid process.* **C**, *posterior cranial view noting the posterior condylar foramen (PCF) for transmission of the posterior condylar emissary vein. For reference, note the medially placed foramen magnum (FM) and the laterally placed mastoid process (M).*

just posterior to the right mastoid process. The patient did not survive surgery and the postmortem examination showed that during surgery, air had entered the venous circulation in sufficient amounts to cause death,[38] and this air was proposed to have entered the dural sinus through an enlarged emissary vein. Lipow and Rickham[39] reported 2 patients with similar symptoms who had undergone surgical repair of extracranial varices near the sigmoid sinus. An avulsed emissary vein passing from the superior sagittal sinus through the foramen cecum and into the nasal cavity may lead to epistaxis.[7,40] The main venous outflow of the posterior fossa venous sinuses may be via the occipital and mastoid emissary veins (Figures 1D and 3B).[40] Because of increased intracranial pressure, in some patients with achondroplasia, blood flows away from the orbit via the ophthalmic veins.[41]

The mastoid emissary vein can serve as a primary drainage pathway in cases of venous sinus occlusion or vascular malformation.[5,32] An enlarged mastoid canal is sometimes noted in patients with high-flow states or vascular malformations.[37,38] The mastoid emissary vein has also been used for the endovascular treatment of dural arteriovenous fistulae[17] and serves as a surgical landmark for the underlying junction of the transverse and sigmoid sinuses.[24] During retrosigmoid and far lateral approaches, it is important to appreciate the anatomy of the mastoid emissary vein, considering there is a possibility of sigmoid sinus thrombosis as mentioned previously.[5,7,13,27,32]

Tinnitus has been reported as a consequence of large posterior condylar veins.[23,42,43] One case of tinnitus was alleviated after decreasing blood flow through the internal jugular vein via direct pressure on the neck, thus altering the flow within the posterior condylar emissary vein (Figure 3C).[43,44] Although rare, dural arteriovenous fistulae have been identified at the anterior condylar vein, and in these cases, it is important to evaluate the drainage of the fistula because, as often in these cases, the venous drainage pattern is irregular.[43,44] Ernst et al[21] reported 3 cases of dural arteriovenous fistulae involving this vein within the hypoglossal canal.

An enlarged anterior condylar emissary vein has also been linked to unilateral tongue atrophy.[45] Sinus pericranii are dilated extracranial veins found under the scalp[46] and are characterized by communication of pericranial varicosities with an underlying dural sinus.[47] Such vessels may be sizable and may represent ectopic diploic veins. Some have posited that such dilations share a common congenital origin with arteriovenous malformations.[48] Emissary veins such as the parietal veins may connect these structures to the diploic venous system.

Embryology

Although little is known regarding the detailed development of the emissary veins, some have made observations of their anatomy during early periods of formation. Padget[48,49] stated that the emergence of most emissary veins can be seen during embryonic stage 7. However, the emissary veins of the hypoglossal canal are first visualized at stage 4.[50] The parietal emissary veins are the last emissaries to form, and Padget drew our attention to the fact that these vessels are near vestigial structures and their vasculature is related to the vertebrate pineal eye.[49] Okudera et al[17] found that at approximately 3 fetal months of development, the mastoid and anterior and posterior condylar emissary veins are easily discernible. They found that the anterior condylar veins appear before the posterior condylar veins and that at 5 months' gestation, the veins significantly enlarge. Between the sixth and seventh fetal months, the condylar veins were found to connect to the intracranial sinuses. The emissary veins were found to begin most of their development after the ballooning of the transverse sinuses. The earliest emissary veins to develop drain extracranial structures medially into the primitive dural venous sinuses, and the chondrocranium develops around these vessels and will form the respective foramina.[51]

Blood Flow Through the Emissary Veins

In general, blood flow through the emissary veins is from external to internal. However, because these vessels lack valves, their flow can be altered by increased intracranial pressure (eg, Valsalva maneuver). Interestingly, Cabanac and Brinnel[2] found that during hyperthermia, blood flow through the mastoid and parietal emissary veins was from superficial to deep. However, during hypothermia, there was either no flow or the normal flow was reversed. As mentioned earlier, Louis et al[5] found that the emissary veins act as the primary outflow route for venous drainage in the upright position and may serve to cool venous blood circulating through the head. Because in the upright position most venous outflow from the head passes into the vertebral venous plexus, recent theories that also link a cooling effect for the spinal cord to these veins make the relationship between the emissary veins and this system more pertinent (Figure 4).[52]

Parenthetically, use of Doppler ultrasonography to localize the emissary veins has many practical applications. For example and as mentioned later, Mueller and Reinertson[41] used this modality to examine blood flow in achondroplastic dwarfs. Based on their study and that of Cabanac and Brinnel,[2] such an inexpensive tool may be useful in other pathologies in which the emissary veins may be involved.

Recently, Miyachi et al[53] proposed a mechanism for dural arteriovenous fistulae that involves flow through the emissary veins. These authors proposed that local inflammation near the emissary vein's penetration of the cranium results in dilation and local neovascularization that forms aberrant connections to nearby arteries.[53] Recruitment of feeders then ensues, resulting in the mature dural arteriovenous fistula.

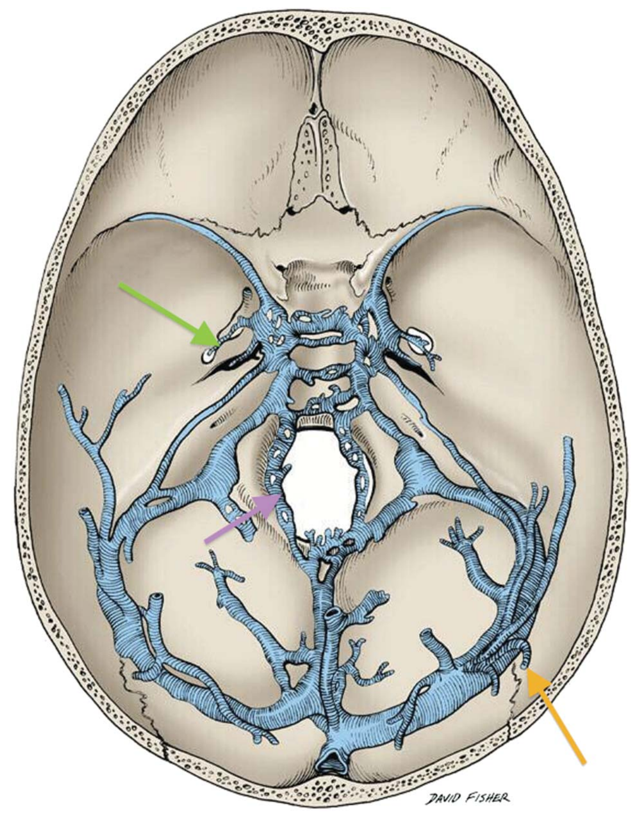

FIGURE 4. *Schematic drawing of the major venous structures of the cranial base. Regarding emissary veins and their relation to cranial venous outflow, note the veins of the foramen ovale (green arrow), mastoid emissary vein (orange arrow), and marginal sinus/vertebral venous plexus complex (purple arrow).*

CONCLUSION

Because the emissary veins of the cranium will be encountered by the neurosurgeon, knowledge of their anatomy, utility, and potential complications is important. Our hope is that our review will serve as a source of information for these often overlooked venous structures.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Treves F. *Surgical Applied Anatomy*. Philadelphia, PA: Lead Brothers & Co; 1885.
2. Cabanac M, Brinnel H. Blood flow in the emissary veins of the human head during hyperthermia. *Eur J Appl Physiol Occup Physiol*. 1985;54(2):172-176.
3. Falk D. Evolution of cranial blood drainage in hominids: enlarged occipital/marginal sinuses and emissary foramina. *Am J Phys Anthropol*. 1986;70(3):311-324.
4. Irmak MK, Korkmaz A, Erogul O. Selective brain cooling seems to be a mechanism leading to human craniofacial diversity observed in different geographical regions. *Med Hypotheses*. 2004;63(6):974-979.
5. Louis RG Jr, Loukas M, Wartmann CT, et al. Clinical anatomy of the mastoid and occipital emissary veins in a large series. *Surg Radiol Anat*. 2009;31(2):139-144.
6. Williams P, Warwick R, Dyson M, Bannister L. *Gray's Anatomy*. 37th ed. Edinburgh, United Kingdom: Churchill Livingstone; 1989.
7. Eckley W. Anatomic and physiological correspondences of child and the adult. *JAMA*. 1903;20:1337.

8. Boyd G. The emissary foramina of the cranium in man and the anthropoids. *J Anat*. 1930;65(pt 1):108-121.
9. Braun JP, Tournade A. Venous drainage in the craniocervical region. *Neuroradiology*. 1977;13(3):155-158.
10. Cure JK, Van Tassel P, Smith MT. Normal and variant anatomy of the dural venous sinuses. *Semin Ultrasound CT MR*. 1994;15(6):499-519.
11. Hacker H. Emissary veins related to the transverse sinus, sigmoid sinus, and torcular herophili. In: Newton TH, Potts DG, eds. *Radiology of the Skull and Brain*. Vol. 2. St. Louis, MO: C.V. Mosby Company; 1974:1852-1858.
12. Pearson BW. Microsurgical anatomy of the approach to the base of the skull. *Clin Neurosurg*. 1979;26:379-390.
13. Cheatle A. The mastoid emissary vein and its surgical importance. *Proc R Soc Med*. 1925;18:29-34.
14. Standring S. *Gray's Anatomy: the Anatomical Basis of Clinical Practice*. 39th ed. New York, NY: Elsevier Churchill Livingstone; 2005.
15. Lang J Jr, Samii A. Retrosigmoidal approach to the posterior cranial fossa. An anatomical study. *Acta Neurochir (Wien)*. 1991;111(3-4):147-153.
16. Neuroangio. *Venous Anatomy of the Brain. (n.d.)*. Available at: http://neuroangio.org/VenousAnatomyoftheBrain.aspx. Accessed October 28, 2011.
17. Okudera T, Huang YP, Ohta T, et al. Development of posterior fossa dural sinuses, emissary veins, and jugular bulb: morphological and radiologic study. *AJNR Am J Neuroradiol*. 1994;15(10):1871-1883.
18. Dwight T, Hamann C, McMurrich J, Piersol G, Piersol G, ed. *Human Anatomy: Including Structure and Development and Practical Considerations*. 1st ed. Philadelphia, PA: Human Anatomy; 1913:879.
19. Gray H. *Anatomy of the Human Body*. Philadelphia, PA: Lea & Febiger; 1918.
20. Hayashi N, Sato H, Tsuboi Y, Nagai S, Kuwayama N, Endo S. Consequences of preoperative evaluation of patterns of drainage of the cavernous sinus in patients treated using the anterior transpetrosal approach. *Neurol Med Chir (Tokyo)*. 2010;50(5):373-377.
21. Ernst R, Bulas R, Tomsick T, van Loveren H, Aziz KA. Three cases of dural arteriovenous fistula of the anterior condylar vein within the hypoglossal canal. *AJNR Am J Neuroradiol*. 1999;20(10):2016-2020.
22. Tubbs RS, Kelly DR, Humphrey ER, et al. The tectorial membrane: anatomical, biomechanical, and histological analysis. *Clin Anat*. 2007;20(4):382-386.
23. Chen Z, Feng H, Zhu G, Wu N, Lin J. Anomalous intracranial venous drainage associated with basal ganglia calcification. *AJNR Am J Neuroradiol*. 2007;28(1):22-24.
24. McLaughlin MR, Jannetta PJ, Clyde BL, Subach BR, Comey CH, Resnick DK. Microvascular decompression of cranial nerves: lessons learned after 4400 operations. *J Neurosurg*. 1999;90(1):1-8.
25. Matsushima T, Matsukado K, Natori Y, Inamura T, Hitotsumatsu T, Fukui M. Surgery on a saccular vertebral artery-posterior inferior cerebellar artery aneurysm via the transcondylar fossa (supracondylar transjugular tubercle) approach or the transcondylar approach: surgical results and indications for using two different lateral skull base approaches. *J Neurosurg*. 2001;95(2):268-274.
26. Schipper J, Hoffmann T, Wagenmann M, et al. Significance of emissary veins in surgical treatment of temporal paragangliomas [in German]. *HNO*. 2009;57(2):146-152.
27. Tedeschi H, Rhoton AL Jr. Lateral approaches to the petroclival region. *Surg Neurol*. 1994;41(3):180-216.
28. Rivet DJ, Goddard JK III, Rich KM, Derdeyn CP. Percutaneous transvenous embolization of a dural arteriovenous fistula through a mastoid emissary vein. Technical note. *J Neurosurg*. 2006;105(4):636-639.
29. Garza-Mercado R. Extradural hematoma of the posterior cranial fossa. Report of seven cases with survival. *J Neurosurg*. 1983;59(4):664-672.
30. Reis CV, Deshmukh V, Zabramski JM, et al. Anatomy of the mastoid emissary vein and venous system of the posterior neck region: neurosurgical implications. *Neurosurgery*. 2007;61(5 suppl 2):193-200; discussion 200-201.
31. Crocker M, Nesbitt A, Rich P, Bell B. Symptomatic venous sinus thrombosis following bone wax application to emissary veins. *Br J Neurosurg*. 2008;22(6):798-800.
32. Hadeishi H, Yasui N, Suzuki A. Mastoid canal and migrated bone wax in the sigmoid sinus: technical report. *Neurosurgery*. 1995;36(6):1220-1223; discussion 1223-1224.
33. Hoshi M, Yoshida K, Ogawa K, Kawase T. Hypoglossal neurinoma–two case reports. *Neurol Med Chir (Tokyo)*. 2000;40(9):489-493.
34. Samuel J, Fernandes CM, Steinberg JL. Intracranial otogenic complications: a persisting problem. *Laryngoscope*. 1986;96(3):272-278.
35. Friedman J, Greenfield S. Primary thrombosis of the mastoid emissary vein with secondary involvement of the lateral sinus. *Laryngoscope*. 1923;33:347-352.
36. Marsot-Dupuch K, Gayet-Delacroix M, Elmaleh-Berges M, Bonneville F, Lasjaunias P. The petrosquamosal sinus: CT and MR findings of a rare emissary vein. *AJNR Am J Neuroradiol*. 2001;22(6):1186-1193.
37. Ginsberg LE. The posterior condylar canal. *AJNR Am J Neuroradiol*. 1994;15(5):969-972.
38. O'Connor W, Cook A, Bedo A. Varix of the sigmoid sinus; persistent emissary veins. *Pediatrics*. 1955;15:768-770.
39. Lipow HW, Rickham PP. An extracranial varix of the sigmoid sinus. *J Pediatr*. 1956;49(4):465-469.
40. Jeevan DS, Anlsow P, Jayamohan J. Abnormal venous drainage in syndromic craniosynostosis and the role of CT venography. *Childs Nerv Syst*. 2008;24(12):1413-1420.
41. Mueller SM, Reinertson JE. Reversal of emissary vein blood flow in achondroplastic dwarfs. *Neurology*. 1980;30(7 pt 1):769-772.
42. Forte V, Turner A, Liu P. Objective tinnitus associated with abnormal mastoid emissary vein. *J Otolaryngol*. 1989;18(5):232-235.
43. Lambert PR, Cantrell RW. Objective tinnitus in association with an abnormal posterior condylar emissary vein. *Am J Otol*. 1986;7(3):204-207.
44. Harrigan M, Deveikis J. *Cerebrovascular Disease and Neurointerventional Technique*. Heidelberg, London, New York, NY: Humana Press; 2009.
45. Shiozawa Z, Koike G, Seguchi K, Shindo K, Sugita K. Unilateral tongue atrophy due to an enlarged emissary vein in the hypoglossal canal. *Surg Neurol*. 1996;45(5):477-479.
46. Ohta T, Waga S, Handa H, Nishimura S, Mitani T. Sinus pericranii. *J Neurosurg*. 1975;42(6):704-712.
47. Carpenter JS, Rosen CL, Bailes JE, Gailloud P. Sinus pericranii: clinical and imaging findings in two cases of spontaneous partial thrombosis. *AJNR Am J Neuroradiol*. 2004;25(1):121-125.
48. Padget DH. The cranial venous system in man in reference to development, adult configuration, and relation to the arteries. *Am J Anat*. 1956;98(3):307-355.
49. Padget D. The development of cranial venous system in man: from the viewpoint of comparative anatomy. *Contrib Embryol*. 1957;18:145-191.
50. Streeter G. Development of venous sinus of dura mater in human embryo. *Am J Anat*. 1915;18:145-191.
51. Streeter G. The development of alterations in the vascular system of the embryo. *Am J Anat*. 1918;24:7-38.
52. Hoogland PV, Vorster W, Groen RJ, Kotze SH. Possible thermoregulatory functions of the internal vertebral venous plexus in man and various other mammals: evidence from comparative anatomical studies. *Clin Anat*. 2011 Sep 12 [Epub ahead of print].
53. S Miyachi E, Izumi T, Matsubara N, Naito T, Haraguchi K, Wakabayashi T. Mechanism of the formation of dural arteriovenous fistula: the role of the emissary vein. *Interv Neuroradiol*. 2011;17(2):195-202.

COMMENTS

The authors are to be commended on this very interesting review that is pertinent to all neurosurgeons performing cranial procedures. The illustrations are excellent, and the topic, which can be very dry, was written with the appropriate length, detail, and, most importantly, relevant to practice. The appeal is to both residents and experienced surgeons alike.

Erol Veznedaroglu
Hamilton, New Jersey

In this article, Mortazavi et al review the anatomy of cranial emissary veins and discuss their clinical importance. Awareness of this anatomy is useful for avoidance of complications, especially during cranial base approaches. Emissary veins are also helpful because of their potential for providing endovascular access to lesions such as carotid cavernous fistulae and dural arteriovenous fistulae. As the authors mention, there is limited literature on this topic, and this review article will serve as a helpful resource for neurosurgeons in training and provide impetus for anatomic studies.

Ananth K. Vellimana
St. Louis, Missouri

This nice review describes the anatomy, embryology, and significance of emissary veins, often neglected in literature and clinical practice as well. As stated, in microsurgical procedures, they have significance as landmarks and in endovascular procedures increasingly as routes to deeper structures and lesions. Notably, they may act as potential sources of several intra- and postoperative complications such as hemorrhage, air embolism, and thrombosis or act as conduits for infections with high morbidity and even mortality. With modern imaging, these veins may be better visualized and thereafter taken into account when planning and executing the surgical approach.

Mika Niemelä
Juha Hernesniemi
Helsinki, Finland

The authors have correctly identified that although emissary veins do exist, an overall knowledge of their function and clinical import is wanting. Their detailed review on the emissary veins addresses this by describing the connection with the extracranial venous system with the intracranial venous sinuses and focusing on the posterior condyloid, mastoid, occipital, and parietal emissary veins. The authors' discussion of the anatomy, embryology, pathology, and surgery of the intracranial emissary veins addresses the previous lack of information relevant to pathologies, anomalies, and clinical effects affecting these vascular territories. Finally, the well-documented (bibliographically) review will therefore serve as a reference for those desiring to learn more about this system.

Jeffrey T. Keller
Cincinnati, Ohio

Considered together, the emissary veins of the head form a pathway to an alternative venous draining system that can be recruited in several pathological situations. Residual embryological connections between superficial and middle layers of vessels at the venous side,[1] the emissary veins further develop between 4 ½ and 6 months of fetal life, at a time when there is relative hypoplasia of the sigmoid-jugular venous outlet, and their formation is coincident with ballooning and pressure increase in the transverse sinus.[2] The studies of Padget[1] (1956), Okudera et al (1994),[2] Epstein et al (1970),[3] and Falk (1986)[4] support the statement that the development of the emissary veins in the human fetus parallels the ontogenetic development of the venous system in human species and as such seems to be strongly influenced by bipedalism. In neurosurgery, this alternative venous system seems to play important roles in situations that span from hydrocephalus to venous drainage according to surgical positioning and therefore need to be better understood. Detailed literature reviews as the one presented by Mortazavi et al are welcome and doubtless help foster future research on the topic.

Carolina Martins
Recife, Brazil

1. Padget DH. The cranial venous system in man in reference to development, adult configuration, and relation to the arteries. *Am J Anat*. 1956;98:307-355.
2. Okudera T, Huang YP, Ohta T, et al. Development of posterior fossa dural sinuses, emissary veins, and jugular bulb: morphological and radiologic study. *AJNR Am J Neuroradiol*. 1994;15:1871-1883.
3. Epstein HM, Linde HW, Crampton AR, Ciric IS, Eckenhoff JE. The vertebral venous plexus as a major cerebral venous outflow tract. *Anesthesiology*. 1970;32: 332-337.
4. Falk D. Evolution of cranial blood drainage in hominids: enlarged occipital/ marginal sinuses and emissary foramina. *Am J Phys Anthropol*. 1986;70:311-324.

This review brings together diverse information regarding emissary veins in 1 review article with an extensive bibliography. Dealing with emissary veins is usually not a major issue during surgery; however, there are a few situations in which these have major implications. For example, overzealous and injudicious packing of bleeding emissary veins may result in thrombosis of the adjacent major sinus with its consequences. One should also be aware of and recognize sinus pericranii.

Emissary veins may serve as supplementary landmarks during operative approaches, such as the condylar emissary veins during the transcondylar far lateral and the mastoid emissary vein in retrosigmoid approaches. With advances in neuroimaging, these veins can be identified as shown in the MRV images provided by the authors.

The authors have touched on the implications regarding spread of infections, dural arteriovenous fistulae, and other pathologies, as well as mention the relevance of emissary veins in endovascular diagnostics and treatment.

This article may serve as an inspiration for further future anatomic studies.

Ramez Kirollos
Thomas Santarius
Cambridge, United Kingdom