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

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)

Emissary veins connect the veins outside the cranium with the intracranial venous sinuses (Figure 1A). These structures are more commonly found in children, and not all of the various emissary veins are identified in every individual. 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. The foramina for these vessels tend to be larger during childhood and may communicate with the diploic veins.

Emissary veins are also considered an important component for selective brain cooling. These veins are valveless, so, technically, blood can flow bidirectionally, thereby allowing cooler blood from the evaporating surfaces of the head to cool the brain. Louis et al 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. Interestingly, an enlarged emissary foramen does not necessarily transmit a large emissary vein, and fossil records indicate that there is an increasing frequency of some emissary veins, such as the mastoid and parietal vessels in humans.

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). Irmak et al noted that a posterior condylar emissary vein may connect the sigmoid sinus with the suboccipital plexus of veins. Observations have shown that the posterior condylar foramen is the largest emissary foramen in the retromastoid region.

**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). Lang and Samii observed that the mastoid emissary foramen exists less frequently in females.
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.\(^6\) 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.\(^7\)
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.

Sphenoidal Emissary Vein (Vesalius)

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

Emigrant 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). This collection of veins is classified by some as emissary veins because it joins the intradural sinuses with extracranial veins.

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. This collection of veins is classified by some as emissary veins because it joins the intradural sinuses with extracranial veins.

Emigrant Vein of the Foramen Cecum

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

Emigrant 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.

Emigrant Veins of the Clivus

Some have identified transcervical emissary veins. 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 confluence.

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. 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 embolism may occur (Figure 1D). Bleeding from emissary veins may result in postoperative epidural hematoma formation. 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. In cases in which the bleeding emissary vein is large, the use of a muscle plug has been recommended.

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). Preoperative endovascular procedures aimed at occluding such enlarged tumor-related veins might be considered. Hoshi et al 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. 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 found that if the pterygoid venous plexus via its connections with the emissary veins of the foramina ovale and...
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. For example, Rivet et al 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.

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. Boyd 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.” Samuel et al 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 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 echoed this opinion. The mastoid emissary vein has also been suspected as a pathway for cavernous sinus thrombosis.

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 craniostenosis, emissary veins may increase in size and provide the primary venous outflow of the cranium. O’Connor et al 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 2](image-url)
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. This air was proposed to have entered the dural sinus through an enlarged emissary vein. Lipow and Rickham 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. The main venous outflow of the posterior fossa venous sinuses may be via the occipital and mastoid emissary veins (Figures 1D and 3B). Because of increased intracranial pressure, in some patients with achondroplasia, blood flows away from the orbit via the ophthalmalic veins.

The mastoid emissary vein can serve as a primary drainage pathway in cases of venous sinus occlusion or vascular malformation. An enlarged mastoid canal is sometimes noted in patients with high-flow states or vascular malformations. The mastoid emissary vein has also been used for the endovascular treatment of dural arteriovenous fistulae and serves as a surgical landmark for the underlying junction of the transverse and sigmoid sinuses. 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.

Tinnitus has been reported as a consequence of large posterior condylar veins. 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). 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. Ernst et al 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. Sinus pericranii are dilated extracranial veins found under the scalp and are characterized by communication of pericranial varicosities with an underlying dural sinus. 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. 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 stated that the emergence of most emissary veins can be seen during embryonic stage 7. However, the emissary veins of the hypoglossal canal are

![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).]
first visualized at stage 4. 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. Okudera et al 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.  

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 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 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). Parenthetically, use of Doppler ultrasonography to localize the emissary veins has many practical applications. For example and as mentioned later, Mueller and Reinertson used this modality to examine blood flow in achondroplastic dwarfs. Based on their study and that of Cabanac and Brinnel, such an inexpensive tool may be useful in other pathologies in which the emissary veins may be involved. Recently, Miyachi et al 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. Recruitment of feeders then ensues, resulting in the mature dural arteriovenous fistula.

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

19. Neukam FW, Hasiewicz S, Kossack M, et al. Association of cerebrovascular disease and neurointerventional techniques with the appropriate length, detail, and, most importantly, relevant to this topic, and this review article will serve as a helpful resource for 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.
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.

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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 condylar, 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.

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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 Padget¹ (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.

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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.

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