Learning objectives

Cerebral venous drainage occurs primarily by the internal jugular veins (IJV) and the vertebral venous plexuses (VVP). External jugular veins (EJV) contribute to a lesser degree to venous outflow. Numerous interconnections exist between these venous systems at the skull base.

By this educational exhibit we aim to:

- illustrate part of the anatomy of the complex venous network at the craniocervical region by means of CT and MRI,
- present anatomic variations that may have clinical implications and
- outline what the radiologist needs to report.

Background

Venous anatomy at the craniocervical junction has been investigated mainly by anatomical and angiographic methods. Doppler ultrasonography has been used to assess venous haemodynamics associated with anomalous venous outflow. Recent published data suggest that MDCT and MRI could be valuable tools in describing the detailed anatomy and anomalies of skull base venous structures.

Intracranial veins and sinuses converge to form the major dural venous sinuses of the posterior fossa, the transverse sinus (TS) and the sigmoid sinus (SS), draining in the IJV. At this level in particular, multiple venous anastomoses form a complex network, directing cerebral venous drainage extracranially to the three venous outflow pathways (TS-SS-IJV, VVP, EJV). Communication between these venous systems is taking place by smaller dural venous sinuses and emissary venules, coursing through osseous canals of the skull base [1].

Emissary veins (EV) connect the intracranial venous sinuses with the extracranial venous systems through osseous cranial foramina and canals. They are valveless veins allowing blood to flow bidirectionally, providing thus a significant function in controlling the intracranial pressure [2]. They represent important connections between posterior fossa venous sinuses and VVP, regulating the cerebral venous drainage relative to the body position. It has been found that in the supine position this occurs primarily through the IJV. In the erect position vertebral venous systems represent the major outflow pathway, receiving the cerebral venous drainage through the EV [1, 2]. These venous networks are
also known to have an important role as collateral pathways in cases of veno-occlusive
disease (Fig. 1 on page 3).

Only recently, radiologic recognition of these venous channels has been described,
indicating their increasingly appreciated significance.

**Images for this section:**
**Fig. 1:** MIP-MR venography image in a patient with history of recurrent central venous catheter-related IJV thrombosis. There is extensive collateral venous network at the skull base redirecting cerebral venous drainage to the VVP.
We encountered MDCT and MRI examinations performed in our department in the last three years. Using axial and reconstructed images we evaluated the anatomy and variations of the venous structures around the craniocervical region including the following: sigmoid sinus, jugular bulb, condylar emissary veins (anterior and posterior), mastoid emissary vein, occipital emissary vein, inferior petrosal sinus, suboccipital cavernous sinus, occipital sinus and petrosquamosal sinus.

Due to anatomic complexity of the skull base, side to side comparison is a method that many radiologists use for detection of abnormalities. However, asymmetry does not always indicate abnormality as there is high frequency of anatomical variations in this area. Profound knowledge of the anatomy and variations is critical to avoid misinterpretation of a normal finding [3].

**Posterior Condylar Vein (PCV)**

The PCV connects the medial aspect of the SS with the posterior portion of the **Suboccipital Cavernous Sinus (SCS)**-the venous plexus that surrounds the horizontal portion of the vertebral artery), traveling through the condylar canal [2, 4] (Fig. 2 on page 9).

PCV courses the osseous condylar canal within the occipital condyle. Posterior condylar foramen is referred to be the largest emissary foramen in the retromastoid region [2, 4] (Fig. 3 on page 9).

**Suboccipital Cavernous Sinus (SCS)** is the venous plexus that surrounds the horizontal portion of the vertebral artery [1]. In the medial part SCS is connected with the internal VVP. Therefore, the PCV connects the two major venous outflow pathways, the SS with the VVP, allowing thus redirection of the cerebral venous drainage (Fig. 4 on page 10).

Turbulent flow within emissary veins may cause signal intensity alterations in MRI. Special attention should be paid in order to avoid unnecessary confusion [3] (Fig. 5 on page 11).

**Anterior Condylar Vein (ACV)**

The ACV is the venous plexus of the hypoglossal canal accompanying the hypoglossal nerve. As the ACV has numerous anastomoses, the venous drainage may have various
patterns [2, 4, 6]. Using thin section, contrast-enhanced 3D T1W MR Images, this venous plexus offers a great opportunity to illustrate the hypoglossal nerve as a low signal intensity linear structure within high signal background (Fig. 6 on page 11).

Dural AVF of the hypoglossal canal have been described as a cause of pulsatile tinnitus [9]. Dilated ACV has been linked to unilateral tongue atrophy due to compression of the hypoglossal nerve within the hypoglossal canal [2] (Fig. 7 on page 12).

**Mastoid Emissary Vein (MEV)**

The MEV, passing through the mastoid foramen, connects the transverse or sigmoid sinus to the posterior auricular or occipital veins, which then join the VVP [2, 10] (Fig. 8 on page 13).

The MEV may cause significant bleeding during middle ear and skull base operations, particularly during a retrosigmoid approach. Thus, substantial anatomical knowledge contributes to prevent these complications [2]. A dilated MEV might sometimes be a cause of tinnitus [5]. In cases of acute otomastoiditis, thrombosis of the MEV may occur, presenting with edema of the postauricular soft tissues (Griesinger's sign). This can be complicated with dural sinus occlusive disease.

**Petrosquamosal Sinus (PSS)**

PSS is a rare emissary vein in humans which regresses in the mature skeleton. It originates at the junction TS-SS, courses anteriorly along the petrosquamosal fissure of the temporal bone, through a groove or a complete bony canal, and terminates at the postglenoid foramen at the posterosuperior aspect of the mandibular joint. In this level, PSS drains into the retromandibular vein and in that way connects the dural venous sinuses with the EJV [7, 10].

Radiologic recognition of PSS has been recently reported. The radiologic report should include the description of PSS in order that ENT surgeons avoid life threatening hemorrhage during operations. Persistent PSS is usually associated dorsally with large TS-SS and MEV making more difficult to drill the mastoid. PSS might be a source of tumor and infection spread and has been associated with skull base deformities and inner ear malformations (Fig. 9 on page 13).

**Emissary Vein of the Foramen Ovale (EVFO)**
Another communication of cerebral venous system with EJV is the middle cranial fossa venous network which, through skull base foramen, drains extracranially to the pterygoid plexus.

EVFO travels through the bony foramen ovale, along with the third division of the trigeminal nerve, and connects the cavernous sinus with the pterygoid plexus [2]. These emissary venules may serve as pathways for tumor and infection to extend intracranially. It is reported that the EVFO could be used as venous access to the cavernous sinus in interventional neuroradiologic procedures (Fig. 10 on page 14).

**Inferior Petrosal Sinus (IPS)**

IPS originates from the posterior part of the cavernous sinus, descends along the petroclival fissure and terminates into the pars nervosa of the jugular foramen [4] (Fig. 11 on page 15).

IPS consists an important venous structure for the navigation of catheters during interventional neuroradiologic procedures. It represents the major route to reach the cavernous sinus for endovascular treatments and the pituitary gland for venous sampling in cases of pituitary pathology.

**Occipital sinus (OS)**

OS is infrequently present and in most cases originates from the torcular herophili, runs along the internal occipital crest and drains in the marginal sinus, the circular venous sinus of the foramen magnum [4]. Occasionally, instead of running in the midline, the occipital sinus deviates towards one side to join the sigmoid sinus at the level of the jugular foramen. In such cases the OS is termed Oblique OS, may be prominent and is associated with anomalies of the transverse sinus (Fig. 12 on page 15).

OS may serve as important collateral pathway in veno-occlusive disease. Particular attention should be paid by neurosurgeons in occipital craniotomy, especially if the persistent OS is of the prominent type [4].

**Occipital Emissary Vein (OEV)**

The occipital emissary foramen at the squamous part of the occipital bone transmits the OEV which drains extracranially in the suboccipital venous plexus. The OEV is only present in a small percentage of cases and may emerge from transverse sinus, torcular herophili or occipital sinus when present. Its location is variable as to left, right or midline. Not infrequently a confluence of OEV may be seen crossing the occipital emissary
foramen. Knowledge of its existence may help the neurosurgeon to avoid unnecessary blood loss during suboccipital craniotomy [2] (Fig. 13 on page 16).

MAJOR VENOUS SYSTEM

Even the major venous structures (TS, SS, IJV) may show anatomical variations that may have clinical effects, such as tinnitus [5].

Transverse - Sigmoid Sinus

Variations of the TS-SS include abnormal course, dehiscence of the bony wall and diverticulum. Venous pulsatile tinnitus may be associated with variations or anomalies of the TS-SS [5].

Aberrant SS bulging further laterally or anteriorly than normal, protruding into the mastoid, should be mentioned in the radiologic report in order to prevent laceration during mastoidectomy. CT images with bone algorithm reconstruction, are mandatory in detecting dehiscence of its wall (Fig. 14 on page 17).

Jugular bulb (JB)

JB is defined as the dilated superior portion of the IJV at the junction SS-IJV, in the pars vascularis of the jugular fossa, and may exhibit remarkable variations.

High-riding JB (HRJB)

Although many reports mention a HRJB, this is often not clearly defined. The most common location used for definition is that between the position of the JB and the internal auditory canal (IAC). JB is considered high-riding when reaches or extends over the floor of the IAC. HRJB can pose difficulty for the surgical removal of vestibular schwannomas [8] (Fig. 15 on page 18).

Dehiscent JB

JB lacking complete cortical covering and bulging into the middle ear cavity is defined as dehiscent and may present as a vascular mass on otoscopy [8,10]. CT images with bone algorithm reconstruction, are substantial to confirm the discontinuity of the cortex of the jugular fossa. It should not be mistaken for retrotympanic vascular tumor and, therefore, should not be biopsied (Fig. 16 on page 18).
JB Diverticulum

Occasionally an outpouching of the JB may be seen, dehiscent or not, and is called JB diverticulum (Fig. 17 on page 19).

Asymmetrically large JB

The size of the jugular bulbs is variable, with the right side being significantly larger than the left in two thirds of people. Minor differences can be easily appreciated as anatomical variants, however significant differences may lead to diagnosing confusion [10]. In such cases the evaluation of the bony margins of the jugular fossa for erosions is critical to exclude an aggressive lesion such as paraganglioma [3] (Fig. 18 on page 19).

Images for this section:

Fig. 2: Right prominent PCV, transverse contrast-enhanced 3D-T1W Gradient Echo MR images. (a) PCV originating from the medial SS (arrow). (b) PCV at the outer border of the condylar canal before entering the SCS (arrow).
Fig. 3: Contrast-enhanced CT, bone algorithm. Right prominent PCV exiting the SS and traveling though the condylar canal (arrows b to d). Note the extremely different size of the two PCV and condylar canals - very small on the left side.
**Fig. 4:** Right Suboccipital Cavernous Sinus (SCS). (a) CT arteriography phase. The arrow indicates the vertebral artery. (b) CT venography phase. The arrows indicate the SCS, venous plexus surrounding the vertebral artery. Arrowhead points to terminal branch of the PCV entering the SCS.

**Fig. 5:** Prominent right PCV, initially described as a skull base lesion. (a) Transverse T2W MR image shows no flow void within the PCV (arrow), leading to misinterpretation of a pseudolesion. (b), (c) Fat-suppressed contrast-enhanced 3D T1W MR images. Venous contrast enhancement of the PCV along its course in the condylar canal (arrows) is shown.
Fig. 6: Contrast-enhanced 3D-T1W MR image. Hypoglossal nerves in the hypoglossal canals surrounded by the ACV (arrows).

Fig. 7: Dilated right ACV. (a) The contrast enhanced CT image shows enlargement of the right hypoglossal canal with an associated enlarged ACV, mimicking an osteolytic-like lesion. (b) Contrast-enhanced 3D-T1W MR image. The enhancing structure that the arrow indicates represents the ACV. Notice the extensive asymmetry with the
contralateral side. (c) Contrast-enhanced 3D-T1W MR image, coronal reconstruction, shows the dilated right ACV (ellipse).

Fig. 8: Contrast enhanced CT, bone algorithm (a-d). Left prominent MEV exits the SS through dehiscence of the bony wall, to reach extracranial veins in the postauricular region (arrows). Notice the enlarged mastoid emissary canal, containing the dilated left MEV.
Fig. 9: Left persistent PSS, CT scan (bone algorithm). (a) Left PSS originating from the junction TS-SS (arrow). (b) PSS travels anteriorly within bony canal at the superior part of the temporal bone (ellipse). (c) PSS ends at the postglenoid foramen (arrow) draining into the retromandibular vein and, through it, to the EJV. (d) Usual coexistence of persistent PSS, large SS (asterisk) and MEV (arrow).
**Fig. 10:** Emissary vein of the foramen ovale on the left side. Contrast enhanced CT scan. (a) Transverse image at the level of the intracranial part of the emissary vein (arrow). (b) Coronal reformatted image illustrates the EVFO connecting the cavernous sinus with the pterygoid plexus through the foramen ovale (ellipse).

**Fig. 11:** Contrast-enhanced 3D-T1W MR images. Left IPS originating from the cavernous sinus, coursing posteroinferiorly to drain in the jugular foramen (arrows a to d). Notice the right IPS being much smaller.
Fig. 12: Persistent, prominent Oblique OS. (a) MIP-MR venography image. OS connecting the confluence of sinuses with the junction SS-JB on the left side (arrow). Notice the small caliber of the medial part of the left TS (arrowhead). OS more commonly drains on the right side. (b), (c), (d) TOF MR Venography, source images. OS originates from the torcular herophili, descends along the inner surface of the occipital bone, ending at the jugular foramen (arrows).
Fig. 13: Right occipital emissary foramen and OEV emerging from the right TS. (a), (b) Transverse CT images, bone algorithm. Right occipital emissary foramen at the occipital bone (arrows). (c) Transverse contrast-enhanced 3D-T1W MR image depicts the enhancing right OEV within the foramen (arrow). (d) Coronal reformatted, contrast-enhanced 3D-T1W MR image shows the OEV emerging from the right TS (arrow).
**Fig. 14:** (a), (b) Right SS bulging anteriorly and laterally. Transverse CT scan, bone window. Note the extremely thin, but not dehiscent, wall of the SS (arrow in a).

**Fig. 15:** Left high-riding JB. CT (bone algorithm), axial (a) and coronal reformatted (b) images, show JB at the level of the internal auditory canal (arrows). (c) Notice the difference between the left HRJB and the contralateral JB (arrows). (d) Axial image. In some publications, HRJB is defined when seen at the level of the basal turn of the cochlea (arrow).
Fig. 16: Dehiscent JB on the right. CT scan (bone algorithm). (a) Axial image. (b) Sagittal reformation. Notice the absent cortical covering of the right JB (arrows). (c) Sagittal reformation. Left JB with intact bony wall (arrow). (d) Coronal reformation image of both JB (arrows).

Fig. 17: Right JB diverticulum. (a) Axial CT scan (bone algorithm). Outpouching of the JB, posterior to the internal auditory canal (arrow). Coronal (b) and sagittal (c) reformations, show the diverticulum of the JB (arrows).
**Fig. 18:** The contrast enhanced axial CT image shows the asymmetrically large left JB (arrows).
Conclusion

With the application of modern CT and MRI techniques the skull base structures are demonstrated with high spatial and contrast resolution in the clinical set up. MDCT volume imaging and 3D MR sequences allow for multiplanar reconstructions that may highlight the anatomy of craniocervical region. High resolution imaging assists to identify such tiny venous structures, slice by slice, continuously along their course. MR Venography has been proved an appreciable technique to depict the cerebral venous system. CT imaging with bone algorithm is excellent to illustrate the osseous canals and foramina at the skull base in detail.

EV provide valuable anatomic landmarks to the surgeon for the underlying venous sinuses. In addition to iatrogenic bleeding, they could be associated with many other, intraoperative and postoperative, important complications, such as air embolism or dural sinus thrombosis. Due to their connections with the dural venous sinuses, they may serve as pathways for intracranial spread of infections.

Pulsatile tinnitus is a devastating symptom which may be caused by vibrations from turbulent blood flow through abnormal vessels that reach the cochlea. Venous causes of pulsatile tinnitus include variations and abnormalities of TS-SS, abnormal condylar and mastoid emissary veins, high-riding or dehiscent JB, or turbulent flow through a dominant jugular vein.

Dural arteriovenous fistulas (dAVFs) are common in the posterior fossa and may present with pulsatile tinnitus, depending on the pattern of drainage. TS-SS is a usual location and many of the emissary veins, could not only be involved, but can also be used as access routes in endovascular treatment of posterior fossa dAVFs. Although detection of dAVFs is possible by CT and MRI techniques, conventional angiography is the method of choice in delineating the direct arterio-venous communication. However, recent published data suggest that newer CT angiographic algorithms may be promising tools for the diagnosis and treatment planning of dAVFs.

Familiarity with the anatomy and the basic variations of the venous network at the craniocervical junction is essential for accurate radiologic diagnosis and can prevent misinterpretation of the normal findings. The radiologist has to report those variants that may correlate with the patient's symptoms. Reporting specific variations might be of major clinical importance for the neurosurgeon, ENT surgeon and interventional neuroradiologist, when treating skull base disorders.
References


Personal Information