Neurology

Blood Supply and Venous Drainage of the Brain

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The arterial blood supply of the brain occurs primarily via three large arteries (anterior, middle and posterior cerebral arteries). The arterial supply of the brain stem occurs via the basilar and vertebral arteries and their branches. The cerebellum is also supplied by three arteries. (PICA-posterior inferior cerebellar artery, AICA-anterior inferior cerebellar artery and SCA-superior cerebellar artery). The venous drainage of the brain occurs via the dural venous sinuses, which are located between the periosteum of the calvaria and the dura mater.

Arterial Blood Supply of the Brain

The arterial blood supply of the brain is derived from the vertebral artery and internal carotid artery (ICA). The vertebral arteries supply blood to the ‘posterior circulation’ and the carotid arteries supply blood to the ‘anterior circulation’. However, these 2 important sources of blood are directly connected (think of this as nature’s ‘back up system’, should one of the systems fail). The connection of the vertebral and carotid circulations is via the Circle of Willis.
Anatomy of the internal carotid artery (anterior circulation)

The **common carotid artery** divides at the level of the 4th cervical vertebra (C4) to form the **ICA** and **external carotid artery**. This site is referred to as the **carotid bifurcation** and contains the **carotid body**, which contains chemoreceptors that detect changes in the oxygen concentration and the pH-value of blood circulating through the carotid arteries.

The **external carotid artery** divides into 8 major branches.

The **internal carotid artery (ICA)**, on the other hand, has no branches in the cervical region. The **ICA** is divided into several **segments** including pars cervicalis (cervical segment), pars petrosa (petrous segment), pars cavernosa (cavernous segment), and pars cerebralis (cerebral segment). Each of these segments, with the exception of the pars cerebralis, has numerous **branches**. The intracranial portion of the ICA is further divided into 5 segments (C1–C5), terms that are used in clinical practice.
The direct continuations of the ICA are the middle cerebral artery (MCA) and anterior cerebral artery (ACA). The ACA is the smaller of the 2 and supplies the medial portion of the hemispheres to the parietal lobe.

The ICA supplies the frontal, parietal and the temporal lobes, as well as the diencephalon. The ophthalmic artery is a branch of the ICA and supplies the eyes and parts of the paranasal sinus.

Vertebrobasilar circulation (posterior circulation)

The vertebral arteries arise from the subclavian arteries and proceed through the transverse foramina of the cervical vertebrae at the levels of C1 through C6. Subsequently, at the level of the foramen magnum, the vertebral arteries pierce the posterior atlantooccipital ligament, dura mater, and arachnoid membrane, reaching the subarachnoidal space. The vertebral artery then gives rise to the posterior inferior cerebellar artery, the largest branch of the vertebral artery and 1 of 3 arteries that supply the cerebellum.

Another branch of the vertebral artery is the single anterior spinal artery, which is supplied by both vertebral arteries.

In the region of the pons, both vertebral arteries merge to form the single basilar artery. Unlike the vertebral arteries, the basilar artery is an unpaired artery, which means that occlusion of the basilar artery can lead to devastating clinical consequences. For example, occlusion of the distal part of the basilar artery can result in infarction of the pons and the clinical picture of a ‘locked-in syndrome’.

The basilar artery proceeds along the ventral surface of the pons. Along its course, the basilar artery gives rise to the anterior inferior cerebellar artery (AICA), the pontine perforators, as well as the superior cerebellar artery (SCA). Another possible branch of the basilar artery is the labyrinthine artery, which supplies the inner ear. However, the labyrinthine artery may also arise from the AICA.

Posterior cerebral artery

At the transition of the pons to the mesencephalon, the basilar artery bifurcates into the paired posterior cerebral arteries (PCAs), 1 of the 3 major arteries that supply the brain. There are several branches of the PCA. The posterior communicating artery connects the PCA (and therefore the posterior circulation) to the ICA (and the anterior circulation). Other important branches of the PCA include the following: anterior and posterior temporal arteries (supply the temporal lobe), medial and lateral occipital arteries (supply the occipital lobe), calcarine artery (supplies the visual cortex), and medial and lateral posterior choroidal arteries (supply the choroid plexus).

The PCA can also be divided into 4 segments P1-P4, which are useful for describing the precise localization of a vascular lesion.

Anatomy of the circle of Willis

The circle of Willis is a circulatory anastomosis between the vascular territory of the carotid arteries, known as the ‘anterior circulation’ and the vascular territory of the vertebrobasilar circulation, also known as the ‘posterior circulation’. The anterior and posterior circulations are connected at the base of the skull via the paired anterior
communicating arteries and posterior communicating arteries. Therefore, if one part of the cerebral circulation is occluded, the circle of Willis allows collateral supply via an alternate vascular route.

The anterior and posterior communicating arteries are also clinically important because they are a frequent site for intracranial aneurysms (pathologic vascular dilatations), which can result in a subarachnoid hemorrhage if the aneurysm ruptures.

It is important to note that there are many normal anatomical variations to the circle of Willis.
Vascular anatomy of the brain

The MCA supplies a large part of the lateral aspect of the hemispheres, including Broca’s area and Wernicke’s areas—the primary motor and sensory language centers respectively. The occipital lobe is supplied by the PCA and includes the visual cortex. The frontal lobes, the medial portion of the hemispheres, and the superior portion of the parietal lobes are supplied primarily by the ACA. For a detailed view of the vascular supply and corresponding anatomy, please review the image.

Note: The arterial vessels run inside the sulci.

Stroke syndromes

Stroke occurs when there is a disruption of cerebral blood flow and is associated with ischemia in the associated brain tissue. This can occur due to occlusion of a cerebral vessel (ischemic stroke) or due to the rupture of a cerebral blood vessel (hemorrhagic stroke). The clinical symptoms and signs of a stroke depend on which blood vessel and corresponding brain tissue are affected.

The classical clinical presentation of stroke in the ACA vascular territory includes hemiparesis (i.e. weakness), which involves the legs more than the arms and is always contralateral to the vascular lesion. This is because the anterior cerebral artery supplies the frontal, prefrontal, and supplementary motor cortices as well as part of the primary motor and sensory cortex. Additionally, occlusion of the ACA can lead to bladder dysfunction. Review of the homunculus may help clarify these details (please see image).

When the MCA territory is affected by a stroke, the classical clinical presentation includes contralateral hemiparesis (weakness), as well as sensory deficits. Aphasia (the inability to speak), may also occur when the dominant hemisphere for language is affected (which is the left hemisphere for most right-handed people and many left-handed people).

Since the PCA supplies the visual cortex, strokes in this vascular territory will typically
result in visual disorders, e.g. in the form of hemianopsia. If the vascular supply to the thalamus is also affected, clinical findings can include sensory deficits (numbness) in the contralateral face, arm, and leg.

**Arterial supply of the brain stem and cerebellum**

The brain stem and cerebellum are supplied by the **basilar artery** and **cerebellar arteries** or branches of these vessels. The branches are differentiated into medial, mediolateral, and lateral portions, based on their localization and which anatomical territory they supply. The medulla, which follows the brain stem, is supplied, among others, by the **anterior spinal artery**, a branch of the **vertebral artery**.

The cerebellum is supplied by the **AICA (anterior inferior cerebellar artery)**, **posterior inferior cerebellar artery (PICA)**, and **superior cerebellar artery (SCA)**. The AICA is the first branch of the basilar artery. The PICA is a branch of the vertebral artery. The SCA is the final and largest branch of the basilar artery before it splits into the paired **PCAs**.

Remember: Veins and arteries in the brain proceed **independently** of each other.

**Table: Aortic Arch, Bifurcation, and Cerebral Circulation**

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subclavian Artery</td>
<td>The right subclavian artery arises from the brachiocephalic artery and the left subclavian artery from the aortic arch; they proceed to the chest wall, vertebrae and thyrocervical parts; supply blood to the arms, chest, shoulders, back and the central nervous system.</td>
</tr>
<tr>
<td>Vertebral Artery</td>
<td>Branch of the subclavian artery, which proceeds through the vertebral foramen and the foramen magnum into the brain; connects to the internal carotid artery to form the Circle of Willis; supplies blood to the brain and the medulla.</td>
</tr>
<tr>
<td>Common Carotid Artery</td>
<td>The right common carotid originates from the brachiocephalic artery, the left common carotid artery from the aortic arch; each artery divides into the external and internal carotid arteries; supplies the respective sides of head and neck.</td>
</tr>
<tr>
<td>External carotid Artery</td>
<td>Branch of the common carotid artery; supplies blood to numerous facial structures, mandibula, neck, esophagus, and larynx.</td>
</tr>
<tr>
<td>Internal carotid artery</td>
<td>Branch of the common carotid artery; starts with the carotid sinus nerve; passes through the carotid canal of the temporal bone at the cranial base; connects to the branches of the vertebral artery to form the Circle of Willis. Supplies blood to the brain.</td>
</tr>
<tr>
<td>Circle of Willis</td>
<td>An anastomosis at the cranial base, which ensures a continuous blood supply; formed by the branches of the internal carotid and vertebral arteries; supplies blood to the brain.</td>
</tr>
<tr>
<td>Anterior Cerebral Artery</td>
<td>Branch of the internal carotid artery; supplies blood to the frontal lobe of the cerebrum.</td>
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</table>
### Venous Drainage of the Brain

The venous drainage of the brain occurs via the superficial and deep venous systems, both of which drain via the dural venous sinuses. Both systems are connected via anastomoses. At the transition of both drainage areas, a reversal of the venous flow is possible. Unlike all other veins of the body, cerebral veins do not have valves.

#### Superficial venous system

The superficial venous system includes the **cortical veins** and the **sagittal sinus** and drains the cerebral cortex. The major cortical veins are named based on their location and include a superior, middle, and inferior group. The **superior cerebral veins** drain primarily into the **superior sagittal sinus** and the **superficial middle cerebral veins** into the **cavernous sinus**. Based on the direction of the drainage, superficial veins that are located laterally can be further divided into ascending and descending veins.

Ascending veins primarily drain into the **superior sagittal sinus**, while descending veins prefer to drain into the **transverse sinus**. Veins that are located between the arachnoid membrane and the dura mater connect the superficial veins with the sinus system, and are also referred to as bridging veins. If these bridging veins rupture, a **subdural hemorrhage** may occur. The major cause of the rupture of bridging veins is trauma.

#### Deep venous system

The deep venous system includes the **deep cerebral veins, straight sinus, sigmoid sinuses**, and **lateral sinuses**. The paired **deep cerebral veins** and the paired **basal veins** are part of the deep venous system.

The **basal vein** is formed by the fusion of **anterior cerebral vein** and **deep middle cerebral vein**. Similar to the arterial circulation of the Circle of Willis, there is a venous anastomosis at the cranial base formed by a connection of both **basal veins (basal vein of Rosenthal)**. The anterior **communicating vein** connects both anterior cerebral veins, which leads to the formation of a closed circulation.

Further venous drainage takes place via the paired **deep cerebral veins**, as well as the
paired basal veins into the vein of Galen (great cerebral vein). The site where both veins fuse together is also referred to as the confluence of sinuses (Torcula). The great cerebral vein originates at this site.

The great cerebral vein (vein of Galen) is an unpaired vein and discharges into the straight sinus. The drainage area of the internal cerebral vein includes the thalamus, striatum, choroid plexus, and septum pellucidum. The basal vein drains blood from the medial and basal parts of the frontal and temporal lobes, insular cortex, and hypothalamus, as well as from the mesencephalon.

Dural venous sinuses

The dural venous sinuses are small venous structures that drain blood from the cerebral veins, orbits, and skull into the internal jugular veins.

Structure of the dural venous sinuses

The dural venous sinuses are located between the periosteal and meningeal layers of the dura mater, which consists of firm collagenous connective tissue. Besides the connective tissue of the dura mater, the wall of the dural venous sinuses is also made of the endothelium. Like all other cerebral veins, the dural venous sinuses do not have valves. The dural venous sinuses show extensions at some sites, also referred to as lateral venous lacunes. CSF reabsorption, via the arachnoid villi, takes place in the area of the lateral venous lacunes.

The superficial cerebral veins, diploic veins of the surrounding periosteum, and the emissary veins discharge into the dural venous sinuses via the bridging veins. The emissary veins connect the dural venous sinuses to the extracranial veins, which drain
the scalp into the diploic veins.

**Classification of the dural venous sinuses**

Within the system of dural venous sinuses, there is an upper and a lower group. Both groups are connected to the veins of the vertebral canal, via the marginal sinus and the basilar plexus.

The upper group includes the superior and inferior sagittal sinuses, occipital sinus, transverse sinus, straight sinus, sigmoid sinus, and the confluence of sinuses.

The lower group includes the cavernous sinus, together with anterior and posterior intercavernous sinus, the sphenoparietal sinus, as well as the superior and inferior petrosal sinuses.

**Inlets and outlets of the dural venous sinuses**

The inlets of the dural venous sinuses are the superficial and deep cerebral veins. There are numerous anastomoses, which make it possible for larger occlusions in the area of the dural venous sinuses to remain clinically asymptomatic.

The main drainage pathway for the dural venous sinuses is the internal jugular veins. There are also accessory drainage pathways, which include the emissary veins, superior ophthalmic vein, marginal sinus, and basilar plexus, as well as the venous plexus of foramen ovale.

Since the cerebral veins and the dural venous sinuses have no valves, the blood flow of the venous system can occur in either direction. This can lead to the spread of extracranial infections into the sinus system. Infection can further result in an occlusion of a segment of the dural venous sinuses, also referred to as venous sinus thrombosis.

Clinical symptoms of a venous sinus thrombosis include headache, nausea, vomiting, and even altered consciousness. These symptoms occur due to increased intracranial pressure resulting from reduced venous drainage.

Additionally, infections can spread via the emissary veins, which form the connection between dural venous sinuses and the extracranial veins, from the scalp to the dura mater, and could lead to meningitis.

**Venous drainage of the brain stem**

The veins in the region of the medulla and brain stem are connected to the basal cerebral veins. The veins of the brain stem are connected to each other via a longitudinal and a transverse network. Furthermore, there is an infratentorial and a supratentorial venous system. Veins arising from the medulla oblongata, pons, and cerebellum belong to the infratentorial system. The supratentorial system starts at the transition to the mesencephalon. There are numerous anastomoses between the 2 systems.

**Venous drainage of the cerebellum**

The venous drainage of the cerebellum is differentiated roughly into a medial and a lateral part, with numerous anastomoses between the 2 parts. The drainage of the cerebellar vermis, cerebellar hemispheres, and medial part of the superior and inferior cerebellar veins takes place via the medial system. The remaining parts of the cerebellar hemispheres are drained via the lateral system.
References


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