Neuroanatomy 12: Blood Supply of the Brain

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The CNS needs, and has, a rich blood supply due to its continuous activity relative to other tissues. The CNS tissue is very sensitive to ischemia, it cannot survive interruption of blood supply more than few minutes. Arteries penetrating brain tissue are "end arteries", meaning that they do not anastomose significantly with each other, & a block in one artery results in tissue death of the area it supplies.

Arterial Supply

The brain is supplied by 2 main arteries on each side: the internal carotid artery (anteriorly) & the vertebral artery (posteriorly). The four arteries lie within the subarachnoid space, and their branches anastomose on the inferior surface of the brain to form the circle of Willis, & give off the main branches supplying the brain.

Internal Carotid Artery

The internal carotid artery ascends the neck and perforates the base of the skull by passing through the carotid canal of the temporal bone. The artery then runs horizontally forward through the cavernous sinus and emerges by perforating the dura mater to enter the subarachnoid space and turn posteriorly to the region of the medial end of the lateral cerebral fissure. Here, it divides into the anterior and middle cerebral arteries.

Branches of the Cerebral Portion

- The ophthalmic artery arises as the internal carotid artery emerges from the cavernous sinus. It enters the orbit through the optic canal below and lateral to the optic nerve. It supplies the eye and other orbital structures, and its terminal branches supply the frontal area of the scalp, the ethmoid and frontal sinuses, and the dorsum of the nose.
- The posterior communicating artery is a small vessel that originates from the internal carotid artery close to its terminal bifurcation. It runs posteriorly above the oculomotor nerve to join the posterior cerebral artery, thus forming part of the circle of Willis.
- The anterior choroidal artery, a small branch, also originates from the internal carotid artery close to its terminal bifurcation. The choroidal artery passes posteriorly close to the optic tract, enters the inferior horn of the lateral ventricle, and ends in the choroid plexus. It gives off numerous small branches to surrounding structures, including the crus cerebri, the lateral geniculate body, the optic tract, and the internal capsule.
- The hypophyseal arteries are small branches that pass inferomedially to supply the hypophysis (pituitary gland).
- The anterior cerebral artery a terminal branch of the internal carotid artery. It runs forward and medially superior to the optic nerve and enters the longitudinal cerebral fissure. Here, it is joined to the anterior cerebral artery of the opposite side by the anterior communicating artery. It curves backward over the corpus callosum and, finally, anastomoses with the posterior cerebral artery. The cortical branches supply all the medial surface of the cerebral cortex (as far back as the parieto-occipital sulcus), plus about 1 inch strip of the lateral cerebral surface. The anterior cerebral artery thus supplies the “leg area” of the precentral gyrus. A group of central branches pierces the anterior perforated substance and helps to supply parts of the lentiform and caudate nuclei and the internal capsule.
- The middle cerebral artery, the largest branch of the internal carotid, runs laterally in the lateral cerebral fissure to emerge & branch on the lateral cerebral surface. Cortical branches supply the entire lateral surface of the hemisphere, except for the narrow strip supplied by the anterior & posterior cerebral arteries. This artery thus supplies all the motor area except the “leg area.” Central branches enter the anterior perforated substance and supply the lentiform and caudate nuclei and the internal capsule.

Vertebral Artery

The vertebral artery, a branch of the first part of the subclavian artery, ascends the neck by passing through the foramina in the transverse processes of the upper six cervical vertebrae. It enters the skull through the foramen magnum and pierces the dura mater and arachnoid to enter the subarachnoid space. It then passes upward, forward, and medially on the medulla oblongata. At the lower border of the pons, it joins the vertebral artery of the opposite side to form the basilar artery.

Branches of the Cranial Portion

- The meningeal branches are small and supply the bone and dura in the posterior cranial fossa.
- The posterior spinal artery may arise from the vertebral artery or the posterior inferior cerebellar artery. It descends on the posterior surface of the spinal cord close to the posterior roots of the spinal nerves.
- The anterior spinal artery is formed from a contributory branch from each vertebral artery near its termination. The single artery descends on the anterior surface of the medulla oblongata and spinal cord and is embedded in the pia mater along the anterior median fissure.
- The posterior inferior cerebellar artery, the largest branch of the vertebral artery, passes on an irregular course between the medulla and the cerebellum. It supplies the inferior surface of the vermis, the central nuclei of the cerebellum, and the undersurface of the cerebellar hemisphere; it also supplies the medulla oblongata and the choroid plexus of the fourth ventricle.
- The medullary arteries are very small branches that are distributed to the medulla oblongata.

Basilar Artery

The basilar artery, formed by the union of the two vertebral arteries, ascends in a groove on the anterior surface of the pons. At the upper border of the pons, it divides into the two posterior cerebral arteries.

Branches:

- The pontine arteries are numerous small vessels that enter the substance of the pons.
- The labyrinthine artery is a long, narrow artery that accompanies the facial and the vestibulocochlear nerves into the internal acoustic meatus and supplies the internal ear. It often arises as a branch of the anterior inferior cerebellar artery.
- The anterior inferior cerebellar artery passes posteriorly and laterally and supplies the anterior and inferior parts of the cerebellum. A few branches pass to the pons and the upper part of the medulla oblongata.
- The superior cerebellar artery arises close to the termination of the basilar artery. It winds around the cerebral peduncle and supplies the superior surface of the cerebellum. It also supplies the pons, the pineal gland, and the superior medullary velum.
- The posterior cerebral artery curves laterally and backward around the midbrain and is joined by the posterior communicating branch of the internal carotid artery. Cortical branches supply the whole inferior cerebral surface, medial surface of the occipital lobe, & the adjacent 1 inch of the lateral cerebral surface. Thus, the posterior cerebral artery supplies the visual cortex. Central branches pierce the brain substance and supply parts of the thalamus and the lentiform nucleus as well as the midbrain, the pineal, and the medial geniculate bodies. A choroidal branch enters the inferior horn of the lateral ventricle and supplies the choroid plexus; it also supplies the choroid plexus of the third ventricle.

Circle of Willis

The circle of Willis lies in the interpeduncular fossa at the base of the brain. It is formed by the anastomosis between the two internal carotid arteries and the two posterior cerebral arteries (terminal branches of the basilar artery). The anterior communicating, anterior cerebral, internal carotid, posterior communicating, posterior cerebral, and basilar arteries all contribute to the circle. The circle of Willis allows blood that enters by either internal carotid or vertebral arteries to be distributed to any part of both cerebral hemispheres. Cortical and central branches arise from the circle and supply the brain substance.
Variations in the sizes of the arteries forming the circle are common, and the absence of one or both posterior communicating arteries has been reported.

Central arteries:
A large number of small branches that arise from the circle of Willis & its major branches. These branches penetrate the brain substance, supplying its internal structures (thalamus, basal ganglia, internal capsule, etc). Central arteries include the following groups:

Group	Origin	Supplied territory
Anteromedial central	Anterior cerebral, anterior communicating arteries	Head of caudate nucleus
Anterolateral central (lenticulostriate)	Middle cerebral artery	Internal capsule, lentiform nucleus
Posteromedial central (thalamoperforating)	Posterior cerebral, basilar, & posterior communicating arteries	Anterior half of thalamus
Posterolateral central (thalamogeniculate)	Posterior cerebral artery	Posterior half of thalamus

Arteries to Specific Brain Areas

- The corpus striatum and the internal capsule are supplied mainly by the medial and lateral striate central branches of the middle cerebral artery.
- The thalamus is supplied by central branches of the posterior communicating, basilar, and posterior cerebral aa.
- The midbrain is supplied by the posterior cerebral, superior cerebellar, and basilar arteries.
- The pons is supplied by the basilar, anterior inferior and superior cerebellar arteries.
- The medulla oblongata is supplied by the vertebral, anterior and posterior spinal, posterior inferior cerebellar, and basilar arteries.
- The cerebellum is supplied by the superior cerebellar, anterior inferior cerebellar, and posterior inferior cerebellar arteries.

Nerve Supply of Cerebral Arteries

The cerebral arteries receive a rich supply of sympathetic postganglionic nerve fibers. These fibers are derived from the superior cervical sympathetic ganglion. Stimulation of these nerves causes vasoconstriction of the cerebral arteries. However, the local blood flow is mainly controlled by the concentrations of CO_2, hydrogen ions, and O_2 present in the nervous tissue; a rise in the CO_2 and hydrogen ion concentrations and a lowering of O_2 tension causes vasodilatation.

Veins of the Brain

The veins of the brain have no muscular tissue in their very thin walls, and they possess no valves. They emerge from the brain and lie in the subarachnoid space. They pierce the arachnoid mater and the meningeal layer of the dura and drain into the cranial venous sinuses.

External Cerebral Veins

The superior cerebral veins pass upward over the lateral surface of the cerebral hemisphere and empty into the superior sagittal sinus.

The superficial middle cerebral vein drains the lateral surface of the cerebral hemisphere. It runs inferiorly in the lateral fissure and empties into the cavernous sinus.

The deep middle cerebral vein drains the insula and is joined by the anterior cerebral and striate veins to form the basal vein. The basal vein ultimately joins the great cerebral vein, which in turn drains into the straight sinus.

Internal Cerebral Veins

There are two internal cerebral veins, and they are formed by the union of the thalamostriate vein and the choroid vein at the interventricular foramen. The two veins run posteriorly in the tela choroidea of the third ventricle and unite beneath the splenium of the corpus callosum to form the great cerebral vein, which empties into the straight sinus.

Veins of Specific Brain Areas

- The midbrain is drained by veins that open into the basal or great cerebral veins.
- The pons is drained by veins that open into the basal vein, cerebellar veins, or neighboring venous sinuses.
- The medulla oblongata is drained by veins that open into the spinal veins and neighboring venous sinuses.
- The cerebellum is drained by veins that empty into the great cerebral vein or adjacent venous sinuses.

Clinical Considerations

The brain receives about 15% of the resting cardiac output. The distributing arteries—the anterior, middle, and posterior cerebral arteries—that arise from the circle of Willis pass over the outer surface of the brain and anastomose with one another. They give rise to branches that penetrate the brain at right angles. In the brain substance, further branching occurs, but no further anastomoses take place. It is the anastomoses on the brain surface that provide the vital collateral circulation should one of the arteries be occluded by disease.

Cerebral Ischemia

Unconsciousness occurs in 5 to 10 seconds if the blood flow to the brain is completely cut off. Irreversible brain damage with death of nervous tissue rapidly follows complete arrest of cerebral blood flow. Neuronal function ceases after about 1 minute and irreversible changes start to occur after about 4 minutes, although this time may be longer if the patient's body has been cooled.

Anterior Cerebral Artery Occlusion

If the occlusion of the anterior cerebral artery is proximal to the anterior communicating artery, the collateral circulation is usually adequate to preserve the circulation. Occlusion distal to the communicating artery may produce the following signs and symptoms:

- *Contralateral hemiparesis and hemisensory loss involving mainly the leg and foot (paracentral lobule of cortex)*
- *Inability to identify objects correctly, apathy, and personality changes (frontal and parietal lobes)*

Middle Cerebral Artery Occlusion
Occlusion of the middle cerebral artery may produce the following signs and symptoms, but the clinical picture will vary according to the site of occlusion and the degree of collateral anastomoses:

- *Contralateral hemiparesis & hemisensory loss involving mainly the face and arm (precentral & postcentral gyri)*
- *Aphasia if the left (dominant) hemisphere is affected (rarely if the right hemisphere is affected)*
- *Contralateral homonymous hemianopia (damage to the optic radiation)*

Posterior Cerebral Artery Occlusion
Occlusion of the posterior cerebral artery may produce the following signs and symptoms, but the clinical picture will vary according to the site of the occlusion and the availability of collateral anastomoses:

- *Contralateral homonymous hemianopia with some degree of macular sparing (damage to the calcarine cortex, macular sparing due to the occipital pole receiving collateral blood supply from the middle cerebral artery)*
- *Visual agnosia (ischemia of the left occipital lobe)*
- *Impairment of memory (possible damage to the medial aspect of the temporal lobe)*

Internal Carotid Artery Occlusion
Occlusion of the internal carotid artery can occur without causing symptoms or signs or can cause massive cerebral ischemia depending on the degree of collateral anastomoses.

- *The symptoms and signs are those of middle cerebral artery occlusion, including contralateral hemiparesis and hemianesthesia.*
- *There is partial or complete loss of sight on the same side, but permanent loss is rare (emboli dislodged from the internal carotid artery reach the retina through the ophthalmic artery).*

Vertebrobasilar Artery Occlusion
The vertebral and basilar arteries supply all the parts of the central nervous system in the posterior cranial fossa, and through the posterior cerebral arteries, they supply the visual cortex on both sides. The clinical signs and symptoms are extremely varied and may include the following:

- *Ipsilateral pain and temperature sensory loss of the face and contralateral pain and temperature sensory loss of the body*
- *Attacks of hemianopia or complete cortical blindness*
- *Ipsilateral loss of the gag reflex, dysphagia, and hoarseness as the result of lesions of the nuclei of the glossopharyngeal and vagus nerves*
- *Vertigo, nystagmus, nausea, and vomiting*
- *Ipsilateral Horner syndrome*
- *Ipsilateral ataxia and other cerebellar signs*
- *Unilateral or bilateral hemiparesis*
- *Coma*

END