

Vasculature of the Central Nervous System

Objective

- To learn the arteries that supply blood to the major divisions of the CNS
- To reinforce the general understanding you (hopefully) achieved during the first two labs by relating the function of a given brain region and the deficits that could occur after that area is deprived of normal arterial perfusion
NTA Ch 4, pgs. 93-119
Key Figs. 4-1; 4-3; 4-5; 4-7; 4-8; 4-9
Clinical Cases
#3 WHOL; CC14-1,2
#4 Right arm weakness and aphasia; CC14-7
#5 Left side weakness and alien hand; CC14-8
Note: For most of the labs we will discuss a clinical case at the end of the lab. The text of each case is in Appendix III

Self evaluation

1. Know the regions supplied by all arteries listed under Key terms
2. Use neuroanatomy on the web to test your understanding

Note

The clinical relevance of this topic cannot be overstated. The better you learn brain vasculature from this lab, the better equipped you will be to diagnose the site of brain damage following stroke.

In this and all subsequent labs, the media list includes material that you will see during the laboratory session, either the same image that is on the web or a comparable static view. When you are reviewing the material after lab, as well as before the exams, you should use this listing in conjunction with material on the web.

List of media

H-1 Arteries supplying the brain stem and cerebral hemispheres – ventral view

The arterial blood supply to the brain is provided by two arterial systems – the anterior (carotid) system and the posterior (vertebro-basilar) system – which are interconnected by communicating arteries. The arterial supply of the spinal cord is provided by the vertebral arteries and various radicular arteries.

The internal carotid arteries and the vertebral arteries together provide the blood supply to the brain stem and cerebral hemispheres (NTA Fig. 4.1; Fig. 1). The paired vertebral arteries ascend along the anterolateral margin of the medulla and at the level of the pons join the midline to form the basilar artery which, in turn, gives off branches to supply the pons, midbrain, and cerebellum. The internal carotid arteries are part of the anterior system and the vertebral-basilar arteries, the posterior system. The internal carotid artery gives rise to the three cerebral arteries which supply blood to the cerebral hemispheres, basal ganglia, and thalamus. Two of the cerebral arteries, the anterior cerebral artery and the middle cerebral artery, are part of the anterior (internal carotid) system. The third cerebral artery, the posterior cerebral artery, derives embryologically from the anterior system but in the mature brain is connected to the posterior system. Branches of the internal carotid and vertebro-basilar systems form the circle of Willis, an anastomotic network of arteries which lie beneath the hypothalamus. Branches that originate directly from the circle of Willis, the internal carotid artery and the proximal portions of the cerebral arteries supply deep structures, such as the diencephalon and the internal capsule. Branches that originate from the more distal portions of the cerebral arteries supply the gray matter of the cerebral cortex and underlying white matter.

Identify the internal carotid, middle cerebral, and anterior cerebral arteries, and the anterior communicating artery. The middle cerebral artery lies within the lateral fissure and curves laterally to lie upon the surface of the insular cortex. What area of the brain does it supply? Next locate the paired vertebral arteries posteriorly; the vertebral arteries fuse on the midline at the pontomedullary sulcus to form the single basilar artery. Identify the two major intracranial branches of the vertebral arteries: (1) the lateral, rather sinuous posterior inferior cerebellar artery, and (2) the medial, at first paired, anterior spinal arteries. Review the courses of these two vessels and the territories that they irrigate. Follow the basilar artery anteriorly as it passes over the ventral surface of the pons. The anterior inferior cerebellar artery is usually the largest lateral branch of the basilar artery. The basilar artery ends anteriorly by dividing into the posterior cerebral arteries, which curve acutely dorsally and posteriorly around the brain stem to enter the occipital lobes. The next major arteries to branch off the basilar artery are the paired superior cerebellar arteries.

circle Circle of Willis (movie)

On this animation, note the components of the anterior and posterior circulations. Note the following spatial relations:

- 1) anterior cerebral artery and corpus callosum
- 2) middle cerebral artery and the insular cortex and lateral sulcus (fissure)

H-2 Arteries of the brain stem and cerebellum – ventro-lateral view

The blood supply of most of the brain stem is provided by the vertebro-basilar system (Fig. 1; NTA Figs. 4-1, 4-3). In general, three sets of arterial branches supply a given level of the brain stem. Paramedian branches (1) supply a medial wedge-shaped portion of tissue. Short circumferential branches (2) supply ventrolateral portions. Long circumferential branches (3) supply dorsolateral portions. In addition to the vertebral and spinal arteries, which we considered earlier, we will now focus on four additional arteries that arise as branches from this system: posterior inferior cerebellar artery, anterior inferior cerebellar artery, superior cerebellar artery, and the posterior cerebral artery.

The arterial supply to the caudal medulla derives from the anterior and posterior spinal arteries and the vertebral arteries. Farther rostrally, the posterior inferior cerebellar artery (PICA for short) supplies most of the dorsolateral medulla. Occlusion of PICA produces a complex set of neurological signs, that can be explained by knowledge of the functions served by the damaged structures. This condition is known as the lateral medullary or Wallenberg syndrome. In the general scheme outlined above, the anterior spinal artery supplies the paramedian portion of the caudal medulla, the vertebral artery supplies the ventrolateral medulla (ie., short circumferential), and the posterior spinal artery supplies the dorsolateral medulla (ie., long circumferential) (NTA Fig. 4-3).

The blood supply to much of the ventral part (base) of the pons and its central region is provided by branches of the basilar artery. Blood supply to more dorsal and lateral portions is from the anterior inferior cerebellar and superior cerebellar arteries (NTA Fig. 4-3). As their names imply, PICA, anterior inferior cerebellar artery, and the superior cerebellar artery also supply the cerebellum. The midbrain is primarily supplied by branches of the basilar artery, including the superior cerebellar artery and the posterior cerebral artery.

Identify the paired vertebral arteries and posterior inferior cerebellar artery (PICA). Note that the vertebral arteries join at the ponto-medullary junction to form the basilar artery. The superior cerebellar artery branches off the basilar artery at the junction between the pons and the midbrain. The oculomotor nerves exit from the mesencephalon and pass between the posterior cerebral and superior cerebellar arteries. Describe in general terms the major brain stem divisions and internal portions that are supplied to each artery.

H-3 Cerebral arteries

The blood supply of the cerebral hemispheres is provided by the internal carotid artery, which gives rise to the anterior and middle cerebral arteries, in addition to other smaller branches, and the posterior cerebral artery (Fig. 2 and NTA figs. 4-4, 4-9). Early in development, all three cerebral arteries derive blood from the internal carotid artery and these are part of the anterior circulation. Later in development, the posterior cerebral artery receives its blood from the basilar artery and is therefore part of the posterior circulation. The internal carotid artery has four

principal portions, most of which can be seen clearly during radiologic examination of the cerebral circulation. The cervical portion extends from the bifurcation of the carotid artery to where it enters the carotid canal. The intrapetrousal portion is not well visualized because it is surrounded by the petrous bone, which is very dense. The intracavernous portion courses nearly horizontally through the region of the cavernous sinus. From here, the cerebral portion extends to the point at which the internal carotid artery bifurcates to become the anterior and middle cerebral arteries (see below). The intracavernous and cerebral portions are collectively termed the carotid siphon.

The major branches of the internal carotid artery are, in order of emergence: 1) ophthalmic artery, 2) posterior communicating artery, and 3) anterior choroidal artery (NTA Figs. 4-4, 4-9). The internal carotid artery divides into two arteries at a point approximately lateral to the optic chiasm: the anterior cerebral artery and middle cerebral artery. While the precise boundaries may vary, it is important to be familiar with the general regions supplied by the different cerebral vessels (NTA Fig. 4-4, 4-9). This knowledge aids the clinician in localizing the source of a vascular obstruction or other pathology. The posterior cerebral artery supplies the occipital lobe and portions of the inferior and medial surfaces of the temporal lobe. The middle cerebral artery supplies most of the lateral convexity of the cerebral hemisphere, including the insular cortex.

Among the various branches of the cerebral arteries, the lenticulo-striate arteries are particularly important because they provide the principal blood supply for the rostral portions of the caudate nucleus, putamen, and parts of the internal capsule (Fig. 3). These arteries are particularly susceptible to occlusion and rupture. This stems from the fact that vesicular branches that are oriented at right angles from the source vessels are common sites of atherosclerotic deposits. Local turbulent blood flow seems to be an important factor in this pathological process.

Secondary branches from the cerebral arteries distribute on the brain surface and within the sulci of the cerebral cortex; tertiary branches distribute over adjacent gyri. Penetrating arterioles arise from both secondary and tertiary branches and run perpendicularly toward ventricles through the brain parenchyma. Once an artery has penetrated the brain there is little potential for effective collateral circulation. The secondary surface branches of the major arteries often form anastomoses with each other. For example, anastomoses occur between the branches of middle and anterior cerebral arteries, and also between the main branches of the middle and posterior cerebral arteries. These areas of contact between the territory of distribution of major arteries are important in limiting the extent of damage following the occlusion of major arteries. Subcortical areas of white matter with poor collateral circulation are particularly vulnerable when there is a general reduction in systemic blood pressure. An infarction occurring at the peripheral borders of the territory supplied by major vessels is often called a "border zone" infarct.

Review the areas of the cerebral cortex that are supplied by three cerebral arteries. Briefly describe the general functions of the areas supplied by each of the cerebral arteries. Consider why occlusion of the anterior cerebral artery can interrupt somatic sensory and motor functions of the lower limb but not the upper limb.

H-4 Deep cerebral arteries

This diagram shows the distribution of the lenticulostriate arteries (on right). Note their S-shaped course. Also follow the middle cerebral artery within the Sylvian fissure and its emergence from the fissure on the lateral surface of the cerebral hemisphere.

H-4a Collateral circulation

The circle of Willis is the most important intracerebral channel for providing collateral circulation following occlusion of the posterior system (NTA Fig. 4-1A; Fig. 1). The anatomy of the circle of Willis is often variable, however, and a functional "circle" is often not achieved. As a consequence, an acute occlusion may not permit the development of an effective collateral circulation. The most common location of major arterial occlusion is in the internal carotid in the cervical region just distal to the carotid bifurcation. Under these circumstances, even with marked variation in the circle of Willis, the collateral flow is possible from the opposite carotid system by way of the anterior communicating artery or from the posterior circulation by way of the posterior communicating artery. In association with the normal aging process, narrowing of the vessels by atherosclerosis usually occurs slowly and thus affords an opportunity for compensatory flow through available channels.

This slide shows the arrangement of the major arteries carrying blood to the brain as well as important anastomotic channels between the middle and anterior cerebral arteries. Where on this illustration would the medulla and pons be located?

H-5 Dural sinuses

Veins draining the caudal medulla empty into the spinal veins and those draining the rostral medulla and pons empty into the dural sinuses. Recall from the first laboratory that the dural sinuses are a collection of large channels located between layers in the dura (see also below). The midbrain is drained by deep cerebral veins (see below) and the cerebellum, by veins that ultimately empty into dural sinuses and the great cerebral vein.

As we saw in an earlier lab, venous drainage of the cerebral hemispheres is provided by the superficial and deep cerebral veins. The superficial cerebral veins arise from the cerebral cortex and underlying white matter and the veins anastomose in the pia and drain into the dural sinuses (see below). The superficial cerebral veins are quite variable in their course, however, two veins are sometimes

distinguishable, the superior and inferior anastomotic veins. The deep cerebral veins drain the deeper portions of the white matter, the basal ganglia and parts of the diencephalon. The great cerebral vein (of Galen) collects venous blood from many deep cerebral veins, and, in turn, drains into a dural sinus.

As mentioned above, the cerebral veins drain into the dural sinuses (NTA Fig. 4-12). The dural sinuses are located between the meningeal and periosteal layers of the dura and have an endothelial lining. Dural sinuses function as low-pressure channels for the flow of venous blood back to the systemic circulation. The superior sagittal sinus runs along the superior midline of the cranial cavity, at the superior margin of the falx cerebri. Within the superior sagittal sinus, roughly in the midline of its course, are the arachnoid villi. The arachnoid villi are small unidirectional valves that serve as sites for reabsorption of cerebrospinal fluid (CSF) into the blood (NTA Figs. 4-15, 4-18). The arachnoid villi are evaginations of arachnoid into the lateral walls of the dural sinuses. These evaginations are especially prominent over the dorsal (superior) convexity of the cerebral hemispheres near the midline, where they often become calcified and are known as arachnoid granulations. The inferior sagittal sinus runs along the inferior margin of the falx cerebri, joins the great cerebral vein, and together join the straight sinus (sometimes called rectus sinus). At the occipital pole the superior sagittal sinus and the straight sinus join, and the blood, together with reabsorbed CSF from the arachnoid villi, flow into the two transverse sinuses. The confluence of the sinuses is located here, although rarely is the confluence formed from the union of all four dural sinuses. The occipital sinus also joins the confluence of sinuses. The transverse sinuses drain into the internal jugular vein.

In the lower figure, identify the superior sagittal sinus, falx cerebri, inferior sagittal sinus, great cerebral vein, and straight (rectus) sinus. In the upper figure, identify the petrosal sinus, straight sinus, confluence of sinuses, and transverse sinus. Trace the flow of venous blood from the cerebral hemispheres to the internal jugular vein. Where are the arachnoid villi located? Trace the flow of CSF to the blood.

CC14-2 Anterior circulation

Cerebral angiography allows visualization of the intracranial vessels by injection of radiopaque contrast material into the vessels. Angiograms serve as useful diagnostic aids in situations that involve the cerebral vessels directly, e.g., atherosclerosis, thrombosis or intracranial tumors (which may cause a shift of vessel location, an increase in vascularity, or extravasation of contrast media into surrounding tissue). Angiograms are two-dimensional representations of an extraordinarily complex 3-D structure. As you view these slides imagine the shape of the brain and how the arteries course over and within the brain. The principal purpose for viewing angiograms in neuroanatomy lab is to help you to better understanding brain topography. Try to develop the big picture!

On this slide review the locations of the carotid artery (and component parts) and the various arteries of the anterior circulation.

CC14-2 Right Anterior circulation angiogram-lateral view

Internal carotid artery
Bifurcation of internal carotid
Anterior cerebral artery and branches along interhemispheric fissure
Middle cerebral artery and branches

CC14-2 Left Anterior circulation angiogram-frontal view

Internal carotid artery
Bifurcation of internal carotid
Anterior cerebral artery and branches along interhemispheric fissure
Middle cerebral artery and branches
(Note aneurysm of anterior communicating artery)

H-8 Posterior circulation

To be posted on WWW

M-6 Magnetic Resonance Angiography (MRA)

Cerebral angiography is an invasive procedure that involves intravascular injection of radio-opaque material. This material can produce neurological complications and therefore is not without risk. Recently, MR imaging has been applied to the study of brain vasculature because it can detect motion of water molecules. This is termed magnetic resonance angiography or MRA, which selectively images blood in motion. The entire cerebral circulation can be reconstructed from the locations of cerebral arteries or veins at multiple levels. The MR angiogram on this slide is a reconstruction in the horizontal plane. With the help of your instructor, identify the following arteries: internal carotid, anterior cerebral, middle cerebral, posterior cerebral, and basilar. The left posterior communicating artery is poorly imaged, whereas its counterpart on the right appears to be absent.

H-13 Production and Circulation of Cerebrospinal Fluid

This slide shows the path taken by the CSF from its production in the ventricles to the subarachnoid space. Review this path. What intraventricular structures secrete CSF? Note also the major subarachnoid cisterns: cisterna magna, quadrigeminal cistern, and interpeduncular cistern.

chorplex Choroid plexus (movie)

The choroid plexus are intraventricular organs that produce cerebrospinal fluid (CSF). The choroid plexus in the lateral ventricle has a C-shaped configuration, as does the ventricle.

What is the “hole” in the third ventricle?

Key:

choroid plexus=red

fornix=white

third and fourth ventricles=aqua

hippocampal formation=purple

anterior commissure=gray

chorplexhippothal Choroid plexus, ventricles, and others (movie)

Check out the choroid plexus on this animation, which shows other brain structures besides the ventricles and hippocampal formation. Note the pre- and postcommissural fornix.

Key:

choroid plexus=red

fornix=white

third and fourth ventricles=aqua

hippocampal formation=purple

anterior commissure and corpus callosum=gray

thalamus and rest of brain=brown

X-20 Myelin-stained section through medulla

Identify on the brain stem model the level of section and approximate locations of PICA and vertebral arteries. Outline on the sections the areas supplied by PICA and vertebral arteries. Discuss the key neurological signs produced by occlusion of these arteries.

X-30 Myelin-stained section through pons

Identify on the brain stem model the level of section and approximate locations of basilar artery. Outline on the sections the areas supplied by the paramedian, short circumferential, and long circumferential branches. Discuss the key neurological signs produced by occlusion of these arteries.

X-120 Myelin-stained section through cerebral hemispheres and diencephalon

Identify the plane and level of section. At this level, what cerebral artery/arteries supply/supplies the various parts of the internal capsule? Discuss

the key neurological signs produced by occlusion of the arterial supply of the internal capsule.

Key Structures and Terms

GENERAL VASCULATURE:

Anterior (Carotid) System
Posterior (Vertebrobasilar) System
Collateral Circulation
"Border Zone" Infarct

ARTERIAL SUPPLY:

Vertebral Arteries
Anterior and Posterior Spinal Arteries
Posterior Inferior Cerebellar Artery (PICA)
Basilar artery
Anterior Inferior Cerebellar Artery (AICA)
Superior Cerebellar Artery
Posterior Cerebral Artery
Circle of Willis
Posterior Communicating Arteries
Internal Carotid Artery
Middle Cerebral Artery
Anterior Cerebral Artery
Anterior Communicating Artery

DURAL SINUSES AND VENOUS DRAINAGE:

Superior Sagittal Sinus
Inferior Sagittal Sinus
Straight Sinus
Transverse Sinus
Occipital Sinus
Great Cerebral Vein

CEREBROSPINAL FLUID:

Choroid Plexus
Lateral Ventricle
Interventricular Foramen
Third Ventricle
Cerebral Aqueduct
Fourth Ventricle
Central Canal

CISTERNAE:

Lumbar
Cisterna Magna
Quadrangular (superior)
Interpeduncular