Medical Neuroscience | Tutorial Notes

Blood Supply to the Brain

MAP TO NEUROSCIENCE CORE CONCEPTS[1]

NCC1. The brain is the body's most complex organ.

LEARNING OBJECTIVES

After study of the assigned learning materials, the student will:

1. Identify the major blood vessels that comprise the anterior and posterior circulation of the brain.
2. Discuss the source of blood to the anterior and posterior circulation.
3. Sketch the anastomotic ring of blood vessels (the circle of Willis) at the base of the brain.
4. Identify the major blood vessels that supply the spinal cord.
5. Describe the system of vessels for venous drainage of blood from the brain into the jugular veins.

NARRATIVE

by Leonard E. WHITE and Nell B. CANT
Duke Institute for Brain Sciences
Department of Neurobiology
Duke University School of Medicine

Overview of the anterior and posterior circulation

This tutorial contains a brief overview of the distribution of blood supply to each subdivision of the brain and to the spinal cord. Lesions involving the different vessels and their branches lead to specific syndromes that are easy to understand if you learn the distribution patterns of the vessels and the organization of the brain and spinal cord subdivisions that they supply.

The brain receives its arterial supply from two sources: the **internal carotid arteries** and the **vertebral/basilar arteries** (the two vertebral arteries join to form the basilar artery at the base of the pons). Both the internal carotid arteries and the vertebral/basilar arteries give rise to four main branches, commonly referred to as the *anterior circulation* and the *posterior circulation*, as depicted in the chart (next page; see also **Figures A15 & A16**[2]. This chart accounts for the major branches of the carotid and vertebral/basilar arteries. The two systems of arteries are joined at the junction between

[1] Visit **BrainFacts.org** for *Neuroscience Core Concepts* (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

[2] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

the posterior communicating artery and the posterior cerebral artery. In most humans, the posterior cerebral artery receives its blood supply from the vertebral/basilar system. In some people, the posterior communicating artery is quite large, and the posterior cerebral artery may be perfused significantly by the carotid artery.

Generally speaking, the anterior circulation supplies the forebrain (the cerebral hemispheres and the diencephalon), and the posterior circulation supplies the brainstem and the upper spinal cord. However, for most people, the arterial supply to the CNS is not quite that simple. As just mentioned, the posterior cerebral artery supplies the posterior forebrain, including some deep structures, and it also supplies parts of the midbrain in the brainstem. Thus, as indicated in the chart (by listing the posterior cerebral artery twice, once in each group), the posterior cerebral artery contributes to both the anterior and posterior circulations. As you study this tutorial, you should learn the distributions of these 8 arteries listed in this chart.

Supply	Cerebral artery	Group
Internal carotid	1. Anterior cerebral artery 2. Middle cerebral artery 3. Anterior choroidal artery 4. Posterior communicating artery 5. Posterior cerebral artery	Anterior circulation
Vertebral / Basilar	5. Posterior cerebral artery 6. Superior cerebellar artery 7. Anterior inferior cerebellar artery 8. Posterior inferior cerebellar artery	Posterior circulation

The anterior circulation

The four major arteries that arise from the **internal carotid artery** plus the posterior cerebral artery form the *anterior circulation*. The pattern of branching of each artery is similar: each gives rise to branches that supply cortical structures and each gives rise to branches that penetrate the ventral surface of the brain and supply deep structures (the basal ganglia, thalamus and internal capsule), as illustrated in the **Figures A17 & A18**. (The branches that supply deep structures are known collectively as perforating arteries, central arteries, striate arteries, or ganglionic arteries.)

An extensive region of the central and lateral cerebral hemispheres is supplied by the **middle cerebral artery** (green shade in **Figure A18**). Included in this region are the sensorimotor areas that govern the upper extremities and face, and the language areas of the left hemisphere (Broca's area and Wernicke's area). The **anterior cerebral artery** supplies regions in the medial aspect and dorsal and orbital margins of the frontal lobe, and the medial aspect and dorsal margin of the anterior parietal lobe (yellow shade in **Figure A18**). Included in this extended territory are sensorimotor areas in the paracentral lobule that govern the lower extremity, accessory motor areas in the cingulate gyrus that govern the upper face (see **Box 17A** in *Neuroscience, 5th Ed.*), and limbic areas in the medial frontal lobe. The **posterior cerebral artery** supplies regions in the posterior parietal lobe, inferior temporal lobe and occipital lobe (blue shade in **Figure A18**). Included in this region are primary and associational (higher-order) visual areas in each lobe and 'limbic' regions in the posterior cingulate and parahippocampal gyri.

At this point, you should recognize that this tutorial on blood supply affords the opportunity to review what you have already learned regarding the localization of function in the cerebral cortex. One of the main goals of this course is to understand the functional consequences of injury to various structures in the human central nervous system. One of the most prevalent forms of brain injury is attributable to cerebral vascular disease (i.e., cerebral vascular accident or stroke). To prepare you for considering clinical cases involving stroke (which we will do later in the course), work to become thoroughly familiar with the distributions of the major cerebral arteries relative to the cerebral cortex. Refer back to previous tutorials and review as many of the specific functional areas of the cerebral cortex as were identified (note the bold terms, including Broca's and Wernicke's areas). More generally, as you study the distribution of the cerebral vessels and what you now know about the four lobes of the cerebral cortex, see if you can predict what kinds of neurological signs and symptoms might result from stroke involving the right or left anterior, middle or posterior cerebral arteries.

Each of the four major branches of the internal carotid artery give rise to penetrating branches, in addition to the superficial branches just described, that supply gray and white matter structures deeper in each hemisphere. These deep branches follow a reasonably straight-forward, anterior-to-posterior pattern of branching (see **Figure A18**). We will introduce the deep structures of the cerebral hemispheres in a later tutorial; here, you should simply learn the basic pattern of deep supply outlined below. The anterior cerebral artery supplies the anterior caudate and putamen, the nucleus accumbens, and the anterior limb of the internal capsule—all structures in the anterior deep forebrain. The middle cerebral artery supplies the body of the caudate and most of the putamen, most of the globus pallidus, the middle part (or genu) of the internal capsule, and the anterior hypothalamus—all structures near the middle of the deep forebrain. These deep penetrating branches of the middle cerebral artery are usually called the **lenticulostriate arteries** (see **Figure A18**). The **anterior choroidal artery** supplies the amygdala, hippocampus, the anterior part of the thalamus, part of the globus pallidus, the posterior limb of the internal capsule, and the choroid plexus of the lateral ventricle—all structures that are also in middle of the deep forebrain, but mainly just posterior to the distribution of the lenticulostriate arteries. Lastly, the posterior communicating and posterior cerebral arteries supply the posterior hypothalamus, most of the thalamus, and the choroid plexus of the third ventricle—all structures in the posterior deep forebrain. (Branches of the posterior cerebral artery also supply the midbrain as described later.)

The good news is that it is not necessary to remember all of these details! You should, however, know the arteries in bold font above, and you should remember that the deep structures of the forebrain are divided approximately into four sectors progressing from anterior to posterior, and each sector is perfused by a different artery.

The posterior circulation

The pattern of arterial distribution is similar in all three subdivisions of the brainstem, as illustrated schematically in **Fig. 1** below. The specific pattern in each subdivision is shown in *Neuroscience, 5th Ed.*, **Figure A19**.

The brainstem blood supply can be loosely divided into median and paramedian perforating arteries, lateral perforating arteries and dorsal perforating arteries. The vertebral and basilar arteries and their four major branches give rise to these perforating arteries. As their names imply, the three cerebellar arteries also supply the cerebellum.

Each of the three subdivisions of the brainstem can be divided into medial and lateral 'wedges' of tissue that are supplied by different perforating branches. Vascular lesions that affect individual wedges of

brainstem tissue lead to distinct neurological syndromes, as you will study later in this course in the context of understanding the organization of long pathways in the brainstem and the distribution of cranial nerve nuclei. For now, note that most vascular lesions of the brainstem are usually *unilateral*, since each side of the brainstem is supplied by different sets of circumferential vessels. However, this may not be true if the basilar artery itself is blocked, since it gives rise to vessels that supply both sides.

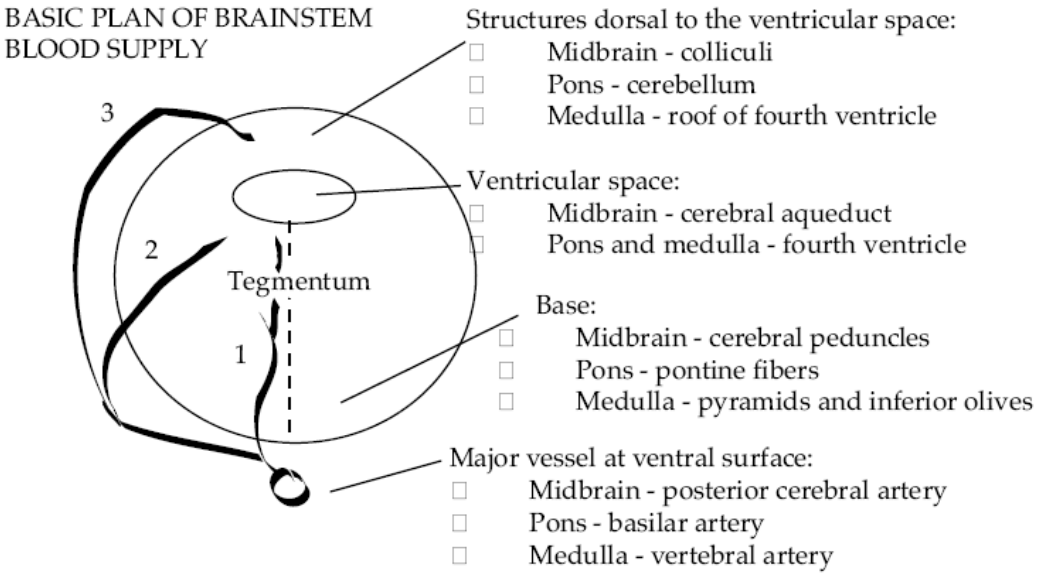

Fig. 1. The basic plan of blood supply to the brainstem. The major vessel on the ventral surface of the brainstem gives rise to:

1. median and paramedian perforating arteries
2. lateral perforating arteries (short circumferential arteries)
3. dorsal perforating arteries (long circumferential arteries)

Drainage of venous blood

Figure A15A (*Neuroscience, 5th Ed.*) illustrates the system of veins that provides for the drainage of venous blood from the brain and cranium. This figure provides an overview of the means by which blood completes its passage through the brain from the arterial vasculature back to the heart via the internal jugular veins. In brief, the more superificial veins of the cerebrum drain into the **superior sagittal sinus** along the dorsal midline of the hemisphere, or the **cavernous sinus** in the base of the cranium. The deeper veins of the brain drain into the **inferior sagittal sinus** at the inferior margin of the falx cerebri, and the great vein of Galen, which in turn join to form the straight sinus. The major venous sinuses inside the cranium are formed by a separation of the two layers of dura mater. The superior sagittal sinus and the straight sinus drain into a pair of **transverse sinuses**, which are oriented roughly in the horizontal plane along the posterior margin of the tentorium. The transverse sinuses then turn in the inferior direction, becoming the **sigmoid sinuses**, which finally exit the cranial vault as the **internal jugular veins**.

The arterial supply of the spinal cord

The arterial blood that supplies the spinal cord comes from two sources: the vertebral arteries (and/or posterior inferior cerebellar arteries) and segmental arteries that arise from branches of the aorta. These arteries join the **anterior** and **posterior spinal arteries** (as illustrated in **Figure A16**). At the level of the medulla, the vertebral arteries give off branches that merge to form the single anterior spinal artery. Approximately 10 segmental arteries (that arise from various branches of the aorta) join the anterior spinal artery along its course. These segmental arteries are known as medullary arteries. [Other segmental arteries supply the dorsal root ganglia but do not join the spinal artery; these are known as radicular arteries]. It is important to realize that if any of the medullary arteries are obstructed or damaged, blood supply to part of the spinal cord may be compromised and neurological damage will result. The pattern of damage depends on whether the supply to the posterior arteries or anterior artery is interrupted. An anastomotic network of vessels known as the **vasocorona** connects these two sources of supply and sends branches into a narrow zone of white matter around the margin of the spinal cord. The vasocorona may be sufficient to supply the most lateral white matter in cases in which the anterior spinal artery is occluded. The anterior spinal artery gives rise to about 200 sulcal arteries that branch to supply the anterior two-thirds of the spinal cord. Thus, the anterior spinal artery supplies the ventral horn and the surrounding ventral and lateral columns of white matter.

The vertebral arteries (or the posterior inferior cerebellar artery) also give rise to paired posterior spinal arteries that run along the dorsal (posterior) surface of the spinal cord. As for the anterior spinal artery, medullary arteries supply the posterior spinal artery (actually an anastomotic network of arteries) along its length. The posterior spinal artery gives rise to branches that penetrate the posterior one-third of the spinal cord and so supply much of the dorsal horn and the dorsal columns.

STUDY QUESTIONS

Q1. A patient presents with “foot drop”, meaning that when the person walks, one foot is “floppy” requiring exaggerated movements to compensate for weak ankle dorsiflexion during ambulation. (There were no other major complaints or impairments.) There are different possible etiologies for this particular neurological dysfunction, including peripheral neuropathy. However, you should also consider a stroke involving **blood supply to the cerebral cortex**.

Of the possible stroke syndromes attributable to major cerebral arteries, which one is most likely to give this patient **foot drop**?

A. anterior choroidal artery
B. middle cerebral artery
C. posterior cerebral artery
D. anterior cerebral artery
E. vertebral artery

Q2. The supply of blood to the **spinal cord** is derived from which vessels?

A. the vertebral arteries only
B. medullary (segmental) arteries only
C. posterior inferior cerebellar arteries only
D. radicular arteries only
E. medullary (segmental) arteries and vertebral arteries