

Meninges, Ventricular System, and CSF

Coverings of the brain

As introduced in the 2nd lecture, the brain is covered by three layers namely: dura mater, arachnoid, pia matter. The dura mater is of significance due to the venous sinuses and is the toughest layer/s (two layers in fact) – and its upper layer is directly attached to the periosteum. The blood vessels travel between the arachnoid and pia mater. The arachnoid and pia mater together is called: leptomeninges.

Dural Folds (Nolte 5th Ed. Pp 81)

There are several folds of the dural mater into the cranial cavity, and these provide for the separations of the cranial cavity into different compartments. The falx cerebri is the reflection of the dura mater onto itself, and it splits the brain into its two hemispheres. Another significant fold is the tentorium cerebelli that extends between the hemispheres and the cerebellum. This defines the supratentorial & infratentorial compartments. The falx cerebelli partially separates the two hemispheres of the cerebellum.

Blood supply of the dura (Nolte 5th Ed pp 81)

The arterial supply of the dura mater comes from branches of the meningeal arteries. These meningeal arteries travel in the periosteal layer and supply the skull, and its branches penetrate into the dura mater. Laterally, branches of the middle meningeal artery supply the dura, anteriorly supplied by branches of the ophthalmic artery, and posteriorly it is supplied by branches of the occipital and vertebral arteries.

Dural venous sinuses (Nolte 5th Ed pp 81, Fig 4-5/7, Netter Plate 97)

Normally the two layers of the dura are attached quite tightly, but at the edges there are folds and therefore the resulting spaces become dural venous sinuses. The cerebral veins empty into these sinuses. Note: A sinus is another term for a big vein.

The superior sagittal sinus runs along the superior edge of the falx cerebri. The tentorium's separate the brain hemispheres from the cerebellum – so the transverse sinus runs along this edge. The straight sinus runs along the attachment of the cerebri and tentorium. Where all these sinuses meet is called the confluence of sinuses. Blood from the superior sagittal sinus, and straight sinus flows into the transverse sinus, and from there follows an S shaped pathway to drain into the IJV via a sigmoid sinus. The inferior sagittal sinus runs along the inner edge of the cerebri, and drains into the straight sinus. The occipital sinus runs along the attached edge of the falx cerebelli, and empties into the confluence of sinuses. The superior petrosal sinus runs along the outer edge of the tentorium, and it drains into the transverse sinus → sigmoid sinus → IJV. The inferior petrosal sinus (whose drainage arises from the cavernous sinus) runs along the groove of the temporal and occipital bones, and drains into the sigmoid sinus. (*draw diagram → easier to describe*)

Ventricles (Nolte 5th Ed pp 98, Fig 5-2)

The ventricles develop from the hollow neural tube during embryological development. Basically, different parts of the neural tube grow at different rates, - thus we have a system of spaces being developed due to the differences in rate growth – therefore ending up as a ventricular system. The ventricles are lined by ependymal cells.

The two hemispheres of the brain contain large lateral ventricles. These ventricles have an *anterior horn, body, atrium and a long narrow posterior horn*. The lateral ventricles connect to each other, and communicate with the third ventricle via the interventricular foramina. The third ventricle is somewhat doughnut shaped, and is best seen in a hemisected brain. The medial surface of the thalamus and hypothalamus form one of the walls of this ventricle. The optic recess extends anteriorly and inferiorly, and the cerebral aqueduct is a thin protrusion posteriorly and inferiorly, thereby communicating with the fourth ventricle. The fourth ventricle is sandwiched between the pons and medulla and the cerebellum. It has a rhomboid shaped fossa as its floor, and its rostral ends culminate as the cerebral aqueduct. The caudal end culminates as the central canal of the spinal cord. The fourth ventricle freely communicates with the subarachnoid spaces, via the median and lateral apertures. (*draw diagram – label all parts, easier to describe*).

The *subarachnoid space* contains most of the CSF and is not really considered as a ventricle, but functionally it is important as it suspends the brain delicately. Other important anatomical structures are the cisterns. These are formed because the pia mater closely follows the contours of the brain sulci and gyri, whereas the arachnoid does not follow this close pattern. Thus, leaving a gap with considerable amount of CSF. These are called cisterns. Refer to your lecture notes for more information (Nolte 5th Ed pp 87).

CSF (Nolte 5th Ed pp 103, Netter Plate 103)

CSF is colourless and is not an ultra filtrate of plasma as previously thought. It is produced by the choroid plexus located in the lateral (phantom), third and fourth ventricles. CSF does not have many cells, and is very low in protein. The total amount of CSF is about 125 ml. Most of this is in the subarachnoid space, only 25 ml is in the lateral ventricles – and only a minuscule 2ml is located in the 3rd and 4th ventricles.

The pathway for CSF is from the lateral ventricles → interventricular foramina → third ventricles → cerebral aqueduct → fourth ventricles → lateral and median apertures → cisterns → subarachnoid villi → superior sagittal sinus. Sometimes the CSF moves straight into the subarachnoid space from the fourth ventricles and moves into the venous circulation via the subarachnoid villi. CSF flow is not continuous and steady, its flow is prompted by each heart beat – due to the pulsations (Think of a stop and starting freeway). The choroid plexus contains choroid cells, which are just specialised ependymal cells. The plexus contains fenestrated endothelium and scattered pial cells and some collagen.

The *functions of the CSF* include:

- Allows brain to float thereby reducing its weight (effects of buoyancy)
- Provides spatial buffering as it lives inside a rigid skull
- CSF is in direct communication with the extracellular fluid of the brain, thereby secondarily controlling the environment in which the brain habitats.

Hydrocephalus (Nolte 5th Ed pp 116)

This occurs when there is excess CSF. The reasons for excess CSF may include: too much produce, too little reabsorption back into the venous system, blockage in flow. The last one is the most common cause. The result is an expansion of the ventricles thereby impinging on surrounding brain tissue. Sometimes tumours of the choroid plexus are associated with hydrocephalus, therefore resulting in excess production of CSF. A tumour may also cause obstruction. For example: obstruction of the cerebral aqueduct will expand the third and lateral ventricles significantly. In infants, the bones of the skull are not fully attached; therefore you see a significant rise in intracranial pressure, and an enlarged head. In adults increase in intracranial pressure results, and surrounding tissues are compressed. Treatment is to insert shunts to drain excess CSF into IJV, or peritoneal cavity.

Sometimes elevation of intracranial pressure is transmitted to subarachnoid space surrounding optic nerve, compression of central vein of occurs → thereby resulting in papilloedema (swelling of tributaries in retina).

Blood supply of the brain (Nolte 5th Ed pp 119, Fig 6-2/3, Netter Plate 131-135)

We have all heard the information about to be heard again. Did you know that the brain only weighs 2% of the body's weight, and consumes 20% of the total oxygen supply and 15% of the total cardiac output? Well take my word for it. Whoopadi whoop! Now let's get into the details of the blood supply of the brain.

The arterial supply of the brain is derived from the internal carotid and vertebral arteries. The internal carotid extends from the bifurcation of the external carotid from the common carotid. The internal carotid system supplies most of the telencephalon and diencephalon whereas the vertebral system supplies the cerebellum and brain stem, as well as parts of the diencephalon, spinal cord, and occipital and temporal lobes.

The internal carotid artery ascends along the neck, gives rise to the ophthalmic artery – which supplies the eyeball and other orbital structures. The internal carotid artery culminates as the

middle and anterior cerebral arteries. The internal carotid also gives rise to the posterior communicating artery which communicates with the posterior cerebral artery (part of the vertebral system), and the middle cerebral artery. The anterior cerebral artery travels medially and then arches posteriorly following the corpus callosum (known now as the pericallosal artery). The two anterior cerebral arteries are connected basally by the anterior communicating artery. (There is a good diagram in Nolte on pp 122).

The anterior cerebral artery supplies blood to the anterior + medial parts of the frontal lobes, parietal lobes. The posterior cerebral artery supplies the inferior parts of the temporal lobe, posterior and medial part of the occipital lobe. The middle cerebral artery runs in the lateral sulcus and supplies most areas of the cortex involving the frontal, parietal, temporal and occipital lobes.

Now let's look at the arterial supply in terms of the vertebral system. The basilar artery arises from the joining of the two vertebral arteries that travel up to the junction between the medulla and pons. Before joining the basilar artery, each vertebral artery gives rise to the following branches: posterior and anterior spinal arteries, posterior inferior cerebellar artery.

Venous drainage (Notes)

Basically all the venous drainage goes back into the right and left internal jugular veins. The superficial cortical veins drain into the superior sagittal sinus, deeper veins drain into the straight sinus. Both sinuses empty into the transverse sinus, which empties into the jugular veins.

Autoregulation (Nolte 5th Ed pp 129)

It is indeed vital for the brain to maintain a constant and adequate blood supply, regardless of the different areas of the brain receiving different amounts of blood. Collectively, the brain should receive a certain amount of blood and this is controlled via three main mechanisms:

- Autoregulation: We have studied this as part of the cardiovascular system and basically involves the reflex constriction of the blood vessels in response to increased blood pressure. This is an inherent system.
- Response to metabolites: If CO₂ in the brain's extracellular compartment increases, then blood flow to the brain increases to compensate for this and vice versa in response to O₂ levels.
- Autonomic fibres: This is largely not that significant. Basically, autonomic fibres control the smooth muscle cells surrounding the blood vessels. The inputs come from the brain too. The other two responses predominate.

Cerebrovascular Accidents (Strokes) (Nolte 5th Ed pp 129)

Strokes are one of the most common neurological problems, and the 3rd most frequent cause of death in adults. Strokes can result via many methods, but the most cause is by an occlusion (occlusive stroke) of an artery supplying a region of brain tissue. About 55ml/100g/min is the normal flow rate, but if this drops to about 20ml/100g/min – then neurons stop sending/receiving electrical signals. They can maintain this state for a few minutes, and after that irreversible damage occurs – generating rapid necrotic areas (called an infarct). Ischaemic strokes occur as a result of decreased blood supply to brain tissue, and the most common cause is the occlusion of an artery – maybe as a result of a thrombus or an emboli. Atherosclerosis can also cause a complete/partial occlusion of an artery.

At other times, ischaemic strokes result from aneurysm – causing haemorrhagic stroke. This causes a huge blood loss in the subarachnoid space. At other times, the aneurysm may occur without any haemorrhage – in this case – the expansion may compress surrounding brain tissue (similar to a brain tumour).

In a case of a stroke, it is important to be aware of the site of stroke – not only because of which brain areas are affected – but also to find out whether collateral supply is available. Stroke proximal to the Circle of Willis is more dangerous, for example, than a stroke distal to the Circle of Willis (due to collateral supply – Exploration 3).

Blood Brain Barrier (Nolte 5th Ed pp 139)

The blood brain barrier is responsible for the maintenance of nearly constant levels of substances within the brain's interstitial space compared to the brain's extracellular space. If plasma was in contact with the brain's interstitial space, then the excess potassium in the extracellular environment, will most definitely raise the resting membrane potential of the neurons closer to the threshold potential – thereby firing the neurons more often.

The blood brain barrier consists of an endothelium that in turn consists of tight junctions between the cells. Also there seems to be a lack of pinocytotic vesicles in the endothelial cells. The blood CSF barrier only allows lipid soluble substances, glucose, amino acids etc. Various transport mechanisms are involved in this. Although the blood brain barrier is vital in keeping nasties from the brain, it is also very effective in prevent pharmacological agents from getting there too. New research includes: selective inhibition of blood brain barrier to gain access to the brain directly, and also to develop pharmacological agents that can penetrate it (i.e.: modify drugs to use passive diffusion technique, or use already existing transport mechanisms).

CVA and Neurological deficits

From now on – you should be thinking about what function is affected if a particular part of the brain is stroked – depending on which artery is involved, its area of supply and the functional aspects of the area of supply.