The Ventricular System of the Brain

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The ventricular system is the extension of the spinal canal (canalis centralis) into the brain and consists of four chambers which are filled with cerebrospinal fluid (liquor cerebrospinalis). The paired lateral ventricles (ventriculi laterales I and II) are two of these four chambers and are connected to the unpaired third and fourth ventricle through the foramen interventriculare. The following article gives an overview on the topography of the ventricles, their structure, as well as the production and re-absorption of liquor.

Image: Rotating animation of the ventricular system consisting of four ventricles. By Life Science Databases (LSDB), License: CC BY-SA 2.5

The Cerebral Ventricles
The 3rd ventricle (ventriculus tertius) is connected to the 4th ventricle via the cerebral aqueduct (aqueductus mesencephali, mesencephalic duct, sylvian aqueduct or aqueduct of Sylvius) so that all ventricles are connected to each other. All ventricles together form the inner cerebrospinal fluid space. They are connected with the outer cerebrospinal fluid space, the subarachnoid space (spatium subarachnoidem), through the 4th ventricle via 3 apertures.

A total of 150 mL of cerebrospinal fluid circulates through the 2 cerebrospinal fluid spaces, including approx. 30 mL of cerebrospinal fluid in the inner and approx. 120 mL of cerebrospinal fluid in the outer cerebrospinal fluid space.

The cerebrospinal fluid is produced primarily by the plexus choroideus in each of the four ventricles and also partly generated by the specialized epithelium of the ventricles, the ependyma. The entire inner cerebrospinal fluid space is lined with ependyma.

Topography of the Ventricular System: The Inner Cerebrospinal Fluid Spaces

Topography of the Lateral Ventricles

The 2 lateral ventricles constitute the largest cavities of the ventricular system and are further subdivided. It is differentiated between the anterior horn (cornu frontale, anterius) the inferior horn (cornu temporale, inferius) and the posterior horn (cornu occipitale, posterius). The individual components are assigned to specific areas of the brain, depending on their topographic location.

The anterior horn is in close contact with the frontal lobe, whereas the inferior lobe is assigned to the temporal lobe and the posterior horn to the occipital lobe. The nucleus caudatus is located at the lateral front wall of the anterior horn, the thalamus. The thalamus is located on the dorsolateral wall of the anterior horn as well as the
The putamen, which is located along the lateral ventricle. The 2 lateral ventricles are each connected with the unpaired 3rd ventricle via the interventricular foramen, also known as foramen of Monro.

Topography of the 3rd Ventricle

The 3rd ventricle is associated with the interbrain (diencephalon = epithalamus, thalamus, and hypothalamus), which borders the lateral wall. The 2 thalami touch each other in the area of the interthalamic adhesion (also known as the intermediate-mass or middle commissure). However, this is not a functional connection and there are no commissural fibers between the 2 thalami. The cerebral aqueduct, which connects the 3rd and the 4th ventricles, is attributed to the mesencephalon.

Topography of the 4th Ventricle

The 4th ventricle is associated with the hindbrain (rhombencephalon = pons, cerebellum, medulla oblongata). The 4th ventricle is connected to the outer cerebrospinal fluid space via its apertures including paired lateral apertures of the 4th ventricle or the foramina of Luschka, and unpaired median aperture (also known as the medial aperture, and foramen of Magendie). Parts of the plexus choroideus even extend from the lateral apertures into the subarachnoid space. These parts are also referred to as ‘Bochdalek’s flower basket’. The 4th ventricle is connected with the spinal canal via the canalis centralis.

Functions of the Ventricular System

A major function of the ventricular system is the production of cerebrospinal fluid, which represents ultrafiltered blood that is produced by the choroid plexus of the 4 ventricles. The cerebrospinal fluid protects the brain against mechanical impact by substantially reducing the effective weight of the brain as the brain literally floats in it based on the principle of buoyancy. Furthermore, the cerebrospinal fluid supplies the brain with nutrients and eliminates the metabolites.

Structure of the Choroid Plexus

The choroid plexus is the primary site of cerebrospinal fluid production and is found in all 4 ventricles. Inside the 2 lateral ventricles, the choroid plexus originates at the base of the pars centralis as well as the roof of the inferior horn. Inside the third ventricle, the choroid plexus is located on the roof. Inside the 4th ventricle, it is found on the back wall as well as below the cerebellum.
The choroid plexus is formed by protrusions of the ventricle wall and by the ingrowth of capillary loops into the ventricular ependyma. Consequently, the choroid plexus is a fixed component of the ventricular wall and is only separated mechanically. If the choroid plexus is removed with a forceps, tear-off lines appear on the ventricle wall. The surface of the choroid plexus carries numerous folds and an apical brush border, both of which serve to enlarge the surface.

The plexus itself is lined by a single layer of cuboidal epithelium. The layer of connective tissue that forms the choroid plexus contains an abundance of vessels and is also referred to as tela choroidea. Approx. 500 mL of cerebrospinal fluid is produced per day.

**N.B.** The choroid plexus is found in all the four ventricles, but not inside the anterior and posterior horns of the lateral ventricles.

### Circulation of Cerebrospinal Fluid Inside the 2 Cerebrospinal Fluid Spaces

The liquor cerebrospinalis is produced in all 4 ventricles inside the inner cerebrospinal fluid space and transported via cilia carrying epithelium (ependyma). The cerebrospinal fluid passes from the inner to the outer cerebrospinal fluid space via the medial aperture and the paired lateral apertures of the 4th ventricle, from the ventricular system to the subarachnoid space.

The subarachnoid space shows numerous extensions that are also referred to as cisterns carrying the cerebrospinal fluid. The most important cisterns in this context include the cisterna cerebellomedullaris (= cisterna magna), the cisterna ambiens, the cisterna interpeduncularis, and the cisterna chiasmatica.
Cisterns that can be used to extract cerebrospinal fluid via puncture are of clinical significance. During a lumbar puncture, the cisterna lumbalis is punctured, whereas during a suboccipital puncture the cerebrospinal fluid is extracted from the cisterna cerebellomedullaris. A lumbar puncture is indicated, for example, in cases of suspected meningitis.

The subarachnoid space is drained in 2 ways. First, the cerebrospinal fluid flows across the arachnoid granulations (= Pacchioni granulations) into the venous plexus or the lymphatic system. Second, it is drained via the exits of the spinal nerves. The primary drainage, however, is via the arachnoid villi or granulations. The entire cerebrospinal fluid (approx. 150 mL) is exchanged twice to 4 times a day in this cycle.

Summary of the circulation of the cerebrospinal fluid: ventricle (inner cerebrospinal fluid space) – via apertures of the 4th ventricle – subarachnoid space (outer cerebrospinal fluid space) – arachnoid granulations/exits of spinal nerves – venous vessel system.

Circumventricular Organs

The foregoing choroid plexus belongs to the group of circumventricular organs or ependymal organs. These regions are unique in that they usually do not contain a blood-brain-barrier.

An exception is a subcommissural organ, which is also part of the circumventricular organs even though it contains the blood-brain barrier. The circumventricular organs include:

- Posterior pituitary (neurohypophysis)
- Corpus pineale
- Organum vasculosum laminae terminales
- Organum subfornicale
- Area postrema
Tissue Barriers inside the Brain

The tissue barriers of the brain protect the organ from harmful substances in the blood, including those caused by iatrogenic interventions or drug treatments.

The blood-brain-barrier

The blood-brain-barrier mainly consists of ‘tight junctions’ formed by the endothelial cells of the capillaries. Transporters along the blood-brain-barrier allow the diffusion of essential substances into the brain, for example, glucose.

The blood-liquor-barrier

The specialized ependymal cells of the choroid plexus are connected to each other via ‘tight junctions’ resulting in a barrier between blood and cerebrospinal fluid in that area, but not between cerebrospinal fluid and CNS. This barrier can only be penetrated by a few substances such as water, oxygen or carbon dioxide.

Diseases of the Ventricular System

Hydrocephalus

A pathologic enlargement of the cerebrospinal fluid spaces is called hydrocephalus (‘Water head’). The inner or the outer cerebrospinal fluid space is enlarged in a hydrocephalus internus or externus, respectively. Hydrocephalus internus is caused especially by a failure to drain the cerebrospinal fluid.
The physiological constrictions within the ventricular system such as the *aquaeductus mesencephali* or the apertures of the 4th ventricle are particularly vulnerable to drainage failure. A constriction may be triggered by tumors, bleeding as well as inflammation. Based on the pathogenesis, this type of hydrocephalus is also referred to as *hydrocephalus occlusus*.

An enlarged subarachnoid space (*hydrocephalus externus*) occurs especially during physiological aging and subsequent atrophy of the *cerebral parenchyma*. In this type of hydrocephalus, which is also referred to as *hydrocephalus e vacuo*, there is no increased cerebral pressure.

Adhesion of *arachnoid villi* and the resulting failure of cerebrospinal fluid reabsorption can result in enlarged inner and outer cerebrospinal fluid spaces also referred to as *hydrocephalus malresorptivus* and *hydrocephalus aresorptivus*, respectively, based on pathogenesis.

Increased secretion of cerebrospinal fluid can cause hydrocephalus, and is also known as *hydrocephalus hypersecretorius*. The over-production of cerebrospinal fluid can be triggered by the irritation of the plexus epithelium, for instance, as a result of inflammation. Clinically, symptoms such as headache, vomiting or nausea may appear due to the increased cerebral pressure.

By contrast, normal pressure hydrocephalus is not characterized by increased cerebral pressure. Instead, this type of hydrocephalus results in the typical clinical triad (Hakim’s triad) of gait disorder, urinary incontinence, and dementia.

**Therapy of Hydrocephaly**

Therapy focuses on the elimination of possible reversible causes, i.e., inflammation, as well as avoidance of constrictions eventually. Shunting is another therapy in which the
cerebrospinal fluid is artificially drained from the ventricular system inside the peritoneal space (ventriculoperitoneal shunt), for instance, or inside the right atrium (ventriculoatrial shunt). Shunting is indicated in cases of pediatric hydrocephalus or normal pressure hydrocephalus.

References


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