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Neuroanatomy, Cerebrospinal Fluid

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Introduction

Cerebrospinal fluid (CSF) is a clear liquid that can be found around and within the organs of the central nervous system. It has been estimated that there is approximately 125 mL to 150 mL of CSF in the body at any given time. However, it should be noted that CSF is continuously generated and reabsorbed. Depending on the rate of production and absorption (which varies person to person), the supply of CSF can be replaced about every 7.5 hours. Most this fluid is produced in the ventricles of the brain by the choroid plexus. However, a smaller portion is produced by the ependymal cells which line the ventricles. After production, the fluid travels through the ventricles and then around the brain and spinal cord. It is then reabsorbed directly into the blood through structures in the arachnoid mater called arachnoid villi (arachnoid granulations). Importantly, this fluid can be examined clinically through a lumbar puncture. With a lumbar puncture, physicians can look for abnormalities in the CSF, which can be helpful when creating a differential diagnosis.

Structure and Function

CSF is thought to have several important functions. One of these is functions is to provide a buoyant force to support the brain. The brain has a significant amount of mass (approximately 1400 gm) while at the same time being relatively malleable. However, since the CSF surrounds the brain, it dissipates a lot of the downward force that would normally act on the organ. This reduces the stress on the brain and allows for it to maintain its shape. Another function of CSF that comes from its physical properties as a fluid is to protect the brain from damage that would result from a sudden movement of the skull. Any rapid acceleration/deceleration of the head has the potential to injure the delicate contents that are contained within. The CSF helps reduce the potential damage in such an event by acting as a cushion and a shock absorber. Since CSF is being produced and absorbed continuously, it is also thought to help clear waste products from around the brain and regulate intracranial pressures. This dynamic process can be controlled by either increasing or reducing production to match the needs of the central nervous system at any given time. A similar regulatory mechanism can also reduce ischemia in central nervous system (CNS) tissues. In times of ischemia, it is possible for the volume of CSF to decrease, and therefore, decrease intracranial pressures. This decrease in intracranial pressure reduces the mechanical stress on blood vessels and may reduce ischemia.

Embryology

It is not currently known when the production of CSF first begins. However, the choroid plexus can be seen developing at around 32 days of development. Also, the arachnoid villi are beginning to form around the 35 weeks with continued development during the first 18 months of life.

Clinical Significance

Lumbar Puncture

An important clinical test that clinicians use to monitor the CSF is the lumbar puncture (spinal tap). In this procedure, a long, hollow needle is typically inserted into the subarachnoid space of the lumbar spine just below where the spinal cord ends (usually below L2). The needle can then be uncapped, and samples of CSF can be obtained. The first thing that is noted when doing a lumbar puncture is the opening CSF pressure. A high opening pressure can suggest various conditions including hydrocephalus, intracranial mass, and idiopathic intracranial hypertension. When there is a high CSF pressure, there is a risk of causing damage to the brain by reducing the pressure too quickly. For this reason, care is often taken to make sure that there are no masses pressing on the brain before performing this procedure. A low CSF pressure can also be clinically significant. This can be seen in conditions that allow for CSF to leak into surrounding tissues. CSF can leak due to physical trauma, previous lumbar punctures, or without an obvious physical cause (spontaneous cerebrospinal fluid leak).

Several analyses can be done on the contents of CSF obtained from a lumbar puncture. Since CSF should be transparent, the color is often noted. A cloudy appearance can suggest an infectious cause, and a red color can suggest the presence of blood. Cultures can be taken from this fluid to look for different infectious agents that can cause meningitis. Additionally, molecular analyses can be done to look for protein abnormalities. These tests can be used to diagnose a wide variety of diseases affecting the central nervous system.

Hydrocephalus

Hydrocephalus is one important clinical disorder of cerebrospinal fluid. In this disorder, there is an increased intracranial pressure due to an overabundance of CSF. This abundance is usually caused by an obstruction in the flow of CSF through the brain. In an adult, this can be caused by several different things. A few examples of possible culprits include neoplastic growths, infections (meningitis), traumatic brain injury, and hemorrhage. Hydrocephalus can also occur at birth causing an acute enlargement of the child's head, or it can be acquired later in life. Increased intracranial pressure is not as dangerous in an infant since the cranial bones fuse later in life. For this reason, an infant with hydrocephalus can present with an enlarged head. When a child is born with this condition, it is usually due to a defect in the formation of the neural tube or stenosis of the cerebral aqueduct.

The treatment of hydrocephalus involves removing whatever is causing the obstruction of CSF flow. In cases where there is recurrence or difficulty in ensuring a non-obstructed flow of CSF, a shunt can be placed to help drain excess fluid from the intracranial cavity. These shunts most often drain the CSF into the peritoneal cavity, but they can also be placed in other locations such as the pleural cavity, gallbladder, and the right atrium of the heart.

Idiopathic Intracranial Hypertension

Idiopathic intracranial hypertension is characterized by an increased intracranial pressure (usually detected through lumbar puncture) that has no discernable cause. In other words, it is unclear what is causing the increased CSF pressures. Patients often experience symptoms such as a headache, vision changes, pulsatile tinnitus, weakness, nausea, vomiting, etc. The diagnosis is generally made based on the history and physical exam. However, neuroimaging investigations and a lumbar puncture are often done to rule out other potential causes.

Chiari Malformations

Arnold-Chiari, also known as Chiari malformation, is the name given to a group of deformities of the hindbrain (cerebellum, pons and medulla oblongata). There are two types recognized:

- **Chiari Type I Malformation**
 - Occurs in 1 in 1,000 births; more common than type II malformations
 - Genetic syndromes related or more commonly idiopathic reduced volume of the posterior fossa leads to a displacement of the cerebellar tonsils into the spinal canal.
- **Chiari Type II Malformation**

- Invariably results in the setting of myelomeningocele. Leakage of cerebrospinal fluid (CSF) to the myelomeningocele yields herniation of the hindbrain into the spinal canal which disturbs the cerebrospinal fluid normal flow and subarachnoid adhesions.

Questions

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