

The Central Nervous System

The Brain, Spinal Cord and Cerebral Spinal Fluid (CSF)

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Central Nervous System

The Central Nervous system is the part of the nervous system consisting of the brain and spinal cord. The brain is encased in the skull and is protected by the cranium. The spinal cord is continuous with the brain and lies caudally to the brain and is protected by the vertebra. The brain makes up the largest portion of the central nervous system.

The adult human brain weighs on average about 1.5kg with a volume of 1130 cubic centimetres in women and 1260 cm³ in men. Although there is substantial individual variation, the human brain is composed of neurons, glial cells and blood vessels.

The dominant feature of the human brain is corticalization. The cerebral cortex is nearly symmetrical with the left and right hemispheres that are approximate mirror images of each other. Each hemisphere is conventionally divided into four “lobes”, the frontal lobe, parietal lobe, occipital lobe and temporal lobe.

The brain and spinal cord form the Central Nervous System. This cortex system is part of everything we do. It controls the things we choose to do. The Central Nervous System is also involved with our senses; sight, hearing, taste, smell and touch, as well as our emotions, thoughts, and memory. The brain is soft and spongy, made of nerve cells and supportive tissue. It has three major parts; the cerebrum, cerebellum, and the brain stem.

The Cerebrum is the largest part of the brain. It fills most of the upper shell, it has two halves; the left and right cerebral hemisphere. The cerebrum uses information from our senses to tell us what’s going on and tells our body how to respond. The right hemisphere controls the muscles on the left side of the body and the left hemisphere controls the muscles on the right side of the body. This part of the brain also controls speech, emotions, reading, thinking, and learning.

The Cerebellum is under the cerebrum at the back of the brain, which controls complex actions; balance, walking, and talking.

The Brain Stem connects the brain with the spinal cord. It controls our need of hunger and thirst. It also controls most body functions; body temperature, blood pressure, and breathing. The brain is protected by the bones of the skull and by a covering of three thin membranes called “meninges”. The brain is cushioned and protected by cerebrospinal fluid. This watery fluid is produced by special cells in the four hollow spaces in the brain, called “ventricles”. It flows through the ventricles and in spaces between the meninges. Cerebrospinal fluid also brings nutrients from the blood to the brain and removes waste products from the brain.

The Spinal Cord is a long thin, tubular bundle of nervous tissues and support cells that extends from the medulla oblongata in the brain stem. The spinal cord is made up of bundles of nerve fibres. It runs down from the brain through a canal in the center of the bones of the spine. The spinal cord begins at the occipital bone and extends down the space between the first and second lumbar vertebrae. It does not extend the entire length of the vertebral column. It is around 45 cm (18in) in men and 43 cm (17in) in women. The spinal cord has a varying width, ranging from 13 mm (0.5in) thick in the cervical and lumbar region, to 6.4 mm (0.25in) thick in the thoracic area. The spinal cord is located in the vertebral foramen and is made up of 31 segments, 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccyxgeal.

The spinal cord is supplied with blood by the arteries that run along its length. It starts in the brain with many arteries that approach through the side of the spinal column. The three longitudinal arteries are called anterior spinal artery, right and left posterior spinal artery. These travel in the subarachnoid space and send branches into the spinal cord.

The bones protect the spinal cord, like the brain, the spinal cord is covered by the meninges and cushioned by cerebrospinal fluid. Spinal nerves connect the brain with the nerves in most parts of the body. Other nerves go directly from the brain to the eyes, ears, and other parts of the head. This network of nerves carries meninges back and forth between the brain and the rest of the body.

The anatomy & physiology of the Brain and Spinal Cord- are covered by three meningeal membranes which are as follows from the outside inward: dura matter, arachnoid matter, and pia matter.

Cerebrospinal Fluid (CSF) is present in the subarachnoid space between the arachnoid matter and the pia matter. It circulates over the central hemisphere, downward the spinal cord. The total cerebrospinal fluid volume is 90-150ml in adults and 10-60ml in neonates. There is a constant turnover of cerebrospinal fluid with 50-500ml being formed every 24 hours. The cerebrospinal fluid acts as protective cushion for the underlying central nervous tissues. Other functions of the Cerebrospinal fluid include collection of wastes, circulation of nutrients and lubrication of the central nervous system. The choroid plexus epithelium and the endothelium of capillaries in contact with cerebrospinal fluid represent the anatomic aspect of the blood- cerebrospinal fluid barrier. The endothelium of capillaries regulates the passage of various substances into the cerebrospinal fluid from the blood.

The Cerebrospinal Fluid is a clear colourless fluid formed in the brain and spine. It is produced in the choroid plexus of the brain. It acts as a cushion and buffer for the brains cortex, producing a basic mechanical and immunological protection to the brain inside the skull. It serves as a vital function in cerebral auto regulation of cerebral blood flow. The CSF circulates in the subarachnoid space around the brain and spinal cord. The brain produces roughly 500ml of CSF per day. The fluid is constantly reabsorbed, so that only 100-160ml is present at any one time.

CSF circulates within the ventricular system of the brain. The ventricles are a series of cavities filled with CSF that reside within the brain. The majority of CSF is produced from within the two lateral ventricles. From here, the CSF passes through the intraventricular foramina (of Monro) to the third ventricle, then the cerebral aqueduct (of Sylvius) to the fourth ventricle. From the fourth ventricle, the fluid passes through the foramen to enter the subarachnoid space. It passes through the Foramen of Magendei on the midline and Foramen of Luschka laterally. The subarachnoid space covers the brain and spinal cord. The CSF moves in a pulsatile manner throughout the CSF system with nearly zero net flow.

It has been thought that CSF returns to the vascular system by entering the dural venous sinuses via the arachnoid granulations (or villi). However, some are suggested that CSF flow along the cranial nerves and spinal nerve roots allow it into the lymphatic channels. This flow may play a substantial role in cerebrospinal fluid reabsorption, in particular, in the neonate, in which arachnoid granulations are sparsely distributed. The flow of the cerebrospinal fluid to the nasal submucosal lymphatic channels through the cribriform plate is pertinent.

Hydrocephalus can be caused by impaired cerebrospinal fluid flow reabsorption, or excessive production of cerebrospinal fluid. Hydrocephalus can be colloqually termed as “water on the brain” and it’s of medical importance. Hydrocephalus is an abnormal accumulation of CSF in the ventricles or cavities of the brain, which may cause increased intracranial pressure (ICP) inside the skull. It may lead to enlargement of the cranium. If hydrocephalus occurs during development, it is most often accompanied by mental disability, sometimes compulsive episodes and tunnel vision. Hydrocephalus may become fatal if it is not corrected quickly. It is more common in infants and in the elderly.

Most studies of the CSF are based on a Lumbar Puncture, a relatively simple procedure. Due to the potential complications, the procedure should only be done for specific diagnostic or therapeutic purposes. Prior to the procedure, a clinical history and physical examination should be done. A lumbar puncture is contraindicated if there is an infection at the proposed puncture site. It may result in the spread of infection into the meninges. Septicemia or general systemic infection is relatively contraindication because spinal puncture may result in meningitis. The patient is in a lateral position, slightly higher in a sitting position. After the puncture is performed and before any fluid is withdrawn, a manometer is attached to record the opening pressure of the CSF. The normal pressure is 50-180mm.

A lumbar puncture is a medical procedure that is usually performed in order to obtain a sample of cerebrospinal fluid. At times, it is referred as a “Spinal Tap”. A lumbar puncture is used to diagnose certain medical conditions; Meningitis, Myelitis, Encephalitis, Syphilis, Brain Abscess, Multiple Sclerosis, Guillan-Barre Syndrome, Acute Leukemia, Spinal Cord and Brain Tumor, Lymphoma with Central Nervous System involvement, and Subarachnoid and Intracerebral Hemorrhage. In some instances, the procedure is also used to administer medication directly into the spinal canal.

The fluid is also tested for the presence of protein and glucose, also red and white blood cell levels. It is also analyzed to determine the occurrence of bacteria or virus. Any person who suspects a medical condition will benefit from a lumbar puncture, especially if it is query of meningitis or encephalitis. Once a diagnosis is made, a treatment plan can be initiated.

The most common side effect of a lumbar puncture is a head ache. Lying down for a few hours after the procedure may reduce the development of a headache. Epidural blood patches can be used to treat headaches.

A lumbar puncture is administered by the use of a needle and syringe. A tube is attached to the syringe in order to catch the spinal fluid. It is approximately 45 minutes to perform, and as follows:

1. Position the patient on his/her side
2. Sterilization- Cleanse the back with antiseptic solution to reduce the risk of infection
3. Numbing-A local anaesthetic is injected to a small section of the back, most cases the patient remains awake
4. Fluid Collection- A hollow needle is injected into the subarachnoid space; at the 3rd and 4th vertebrae. This is where the cerebrospinal fluid sample is obtained. The patient may feel some pressure at the site but usually not painful. The CSF then drips through the needle into a basket tube for collection and analysis.

A lumbar puncture is used to collect CSF for detection of diseases and measure CSF pressure to detect hydrocephalus. Lastly it also delivers contrast dye to the second canal during a myelogram.

There are possible adverse reactions to this procedure; infection, bleeding, reaction to anaesthesia, nerve damage and brain herniation (although rare).

Small transient changes in the pressure are noted with respiration, coughing and straining. These changes are normal and indicate patency of the channels through which the CSF flows. The CSF pressure may be decreased or increased by a variety of disorders. If the pressure is normal, up to 20ml can be removed without danger. Ideally the specimen should be divided into three samples, into sterile tubes and labelled sequentially;

Tube 1- used for chemical

Tube 2- used for microbiologic examination

Tube 3- used for cell count.

If the initial pressure is greater than 200mm, not more than 2ml of CSF should be removed.

If the disease is present the fluid may have a cloudy/turbid and bloody appearance. Turbid fluid may be pleocytosis (leukocyte count >200 cells/ml), microorganisms, RBC (>400 cells/ml) or increased protein. A fat embolism of the brain may be associated with fat globules of varying sizes in the CSF. When the CSF is pinkish red this usually indicates the presence of blood, may be resulted from subarachnoid hemorrhage, intracerebral hemorrhage or traumatic tap. It is extremely important to differentiate traumatic tap from pathologic bleeding.

A traumatic tap shows maximum blood in the first sample with a progressive decrease in subsequent samples. In subarachnoid hemorrhage, the blood is evenly mixed in the three tubes. The presence of crenated RBC's is not useful in differentiating traumatic tap from pathologic bleeding.

After the CSF is centrifuged, the supernatant fluid is clear in a traumatic tap, but it is xanthochromic in a subarachnoid hemorrhage.

A clot may be seen in the CSF when there is a very bloody traumatic tap, while subarachnoid hemorrhage per say is usually not associated with clot formation.

Xanthochromia of the CSF refers to a pink, orange or yellow colour of the supernatant after the CSF has been centrifuged. Two to four hours after a subarachnoid hemorrhage, lysis of the RBC occurs. Within 24 hours, haemoglobin to bilirubin giving a yellowish tint to the supernatant.

Causes of xanthochromia are subarachnoid and intracerebral hemorrhage, traumatic tap, jaundice, elevated protein (>150mg/dl), premature birth, hypercarotenemia, meningeal melanoma.

Normal CSF does not clot however, clotting may be seen when the CSF protein content is sharply elevated. As with Froins Syndrome, and with a very bloody traumatic tap. A Differential count should be done if a stained smear is formed in the CSF.

Normal CSF Differential Count

Cell Type	Adults	Neonates
Lymphocytes	60% ± 20	20% ± 15
Monocytes	30% ± 15	70% ± 20
Neutrophils	2% ± 4	4% ± 4

Normal Cells; a few RBC's are frequently found in the CSF due to contamination by blood from vessels injured during the lumbar puncture. The CSF normally contains small number of lymphocytes. Lymphocytosis of the CSF is seen in an array of infections and non infectious diseases. The causes of Cerebrospinal Lymphocytic Pleocytosis are; Viral Meningitis, Polyneuritis, Asptic Meningitis, Tuberculous Meningoencephalitis, Parasitic Disease, Multiple Sclerosis, and Guillain Barre Syndrome.

Appropriate microbiologic examination is essential in every patient, in which the clinical findings suggest the possibility of meningitis. The major reason for this is;

1. Untreated bacterial meningitis is a lethal disease, capable of rapid progression
2. Early treatment with appropriate antibiotic therapy is curative

The CSF should be cultured and a gram stained performed. 80-90% of the cases of bacterial meningitis are caused by H Influenza, Neisseria Meningitidis, and Streptococcus Pneumonia. The remaining 10-20% of the cases are caused by Staphylococcus Aureus, enteric organism, Anerobic and Microaerophilic Streptococci which are often associated with Epidural Empyema, Brain Abscess, neurosurgical procedures or head trauma.