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# Cerebrospinal fluid dynamics with its surgical implications

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## ABSTRACT

Cerebrospinal fluid (CSF) is largely (70-80%) produced by the choroids plexus of the ventricles and is considered as the plasma ultrafiltrate. While CSF formation, circulation, and composition appear to be physiological and physical, its absorption appears to be mainly physical. The formation, composition, circulation, absorption, and changes in pathological conditions of CSF are discussed briefly in this review article. The CSF pressure dynamics studies provide information about the tightness, elastance, or outflow resistance of the CSF in the CNS. We believe that the present study shall help to provide essential details of CSF physiology which are important to many disciplines including radiology, neurology, and neurosurgery.

## INTRODUCTION

Thorough knowledge of CSF dynamics is essential for understanding the intracranial -intraspinal changes due to pathologic conditions. Perhaps, the first time described was by Dandy in 1919 (1). However, years later three components of CSF dynamics was stablished by Czosnyka et al, wich are CSF formation, circulation, and composition. This, appears to be physiological and physical, and its absorption may be mainly physical. Since most of the surgical treatments involve manipulating the physical principles, it is important to understand the studies, which are emerged on the dynamics of CSF (2). Studies in patients with hydrocephalus and traumatic brain injury has contributed to understand the strong association between CSF dynamics, physical

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and surgical components (3). The main objective of this review is to review CSF dynamics and the association with surgical components.

## Physiology of CSF dynamics

Physiological principles include vascular, neuro-humoral, and sub-cellular regulation, while physical principles include all the fluid dynamics. Some of the well-known physiological principles include Cushing's reflex, which affects the cerebrovascular system. Pressure on ventricular walls affects the secretion of CSF at the aquaporin level of the choroid plexus. Sco-spondin, the peptide secreted by the SCO (subcommissural organ) will regulate the flow of CSF across the aqueduct of Sylvius. However, Sco-spondin is rudimentary in humans. There are approximately 150 ml of CSF, with a rate of 0.3-0.6 ml/min of production in an adult, distributed between 120 and 30 ml in cranial and spinal subarachnoid spaces, with daily volume produced between 500-600 ml (4). The extracellular space is about 15% of the brain volume and about 1500 ml of adult intracranial space consists of 1100 ml of intracellular space, 200 ml extracellular space, 140 ml of cerebrospinal fluid, and about 60 ml of blood at a given time (5). The choroid plexus in the ventricles is the main production site of CSF formation. However, there is a strong association between resistance of CSF and formation, which in many studies has shown to be the first parameter to consider in patients with intracranial hypertension (6–8). Perhaps, Large amounts of CSF are drained primarily into the blood through the arachnoid villi by penetrating the sinus, mainly into the superior sagittal sinus. Understanding this process, may contribute to be the key to comprehend surgical components. As surgery component, according to Monro-Kellie theory; a disbalance between CSF reabsorption and resistance may be the key to develop every illness related to CSF dynamics (9,10).

## Physiological responses

Hypothermia decreases the CSF volume by 11%, with each one-degree reduction in the temperature and hyperthermia increases the CSF volume. In general, the drugs that increase the cerebral blood flow consequently increase the CSF production; on the other hand, the aging process and some infections cause reduce in the CSF formation (11–14). However, the total CSF volume increases with age in both sexes, mainly due to the contribution by the cortical sulcal volume. These pressure gradients which are being created by continuous CSF secretion and facilitated by the arterial pressure pulsations have an important role for CSF circulation and absorption through the venous system (15). The respiratory variations and vascular pulsations emanating from the choroid plexus and cerebral arteries cause the ventricles to pulsate providing the additional movement to CSF. Although trans-mural migration of CSF across the pial arteries has been demonstrated in the animals, these do not contribute to the bulk of CSF absorption (16).

## Functions of CSF

This blood- CSF barrier maintains a chemically precise environment, which is necessary for the neurotransmitter and removes the metabolic products, unwanted drugs and pathological substance that may result in CNS injury (17,18). Changes in CSF Ca, Mg, K produce changes in the sympathetic and autonomic response, ventilation, muscle tone, and emotional state. In continuity with the brain interstitial fluid, CSF provides a stable supply of substrates, primarily glucose, even though the plasma concentration of the substrate is continuously changing. Transport of endorphins, hormones of the hypothalamus and pineal gland is facilitated by the CSF. Specialized ventricular cells and brain parenchymal neurons secrete neuroendocrine factors (19,20).

## Laboratory Investigation of CSF

Important information on CSF can be derived from the following parameters, opening pressure, gross appearance, total and differential cell count, bacterial culture and sensitivity, protein and glucose, analysis of immunoglobulins (to detect chronic CNS inflammatory conditions) and cytology (to detect malignant cells). Increased neutrophils in the CSF indicate bacterial meningitis (21). Other causes of increased neutrophil count include a cerebral abscess, seizures, and CNS hemorrhage. Increased lymphocytes in the CSF indicate viral meningitis. Lymphocyte counts are also elevated in meningitis, tuberculosis, syphilis, fungal and parasitic infections. Increased plasma cells is a feature of TB meningitis and chronic inflammatory disorders like multiple sclerosis. The presence of leukemic cells in the CSF indicates meningeal infiltration by leukemic cells (22).

Leukemic cells typically appear in the CSF after several remissions have been achieved by chemotherapy. Tumor cells can be detected by cytological studies and the sources of tumor cells can be from primary CNS tumors like medulloblastoma, or metastatic CNS tumors from lung, breast, GI tract, and melanoma. It may be necessary to determine if a nasal or ear fluid is found as a content in the CSF. CSF fluid contains a modified transferrin protein called β2-transferrin (tau protein), which is not present in plasma or other fluids. The presence of β2-transferrin in a fluid strongly suggests that the fluid is CSF, which may be used, by instance, to identify CSF leak after sinus surgery (22,23).

## Studies of CSF dynamics

In clinical practice, external lumbar drainage (Tap-test) is widely used to evaluate normal pressure hydrocephalus (NPH). Infusion tests, bolus injections, and isotope dilution methods are employed most often in experimental studies. ICP monitoring in acute conditions such as head injury and chronic conditions such as NPH is widely used. In the study on CSF dynamics by Ramesh et al. a simple, safe, and cost-effective method of infusion method to predict the VPS effectiveness was devised (24). Not only in NPH and PTH but also postmeningitic hydrocephalic patients seems to correlate and benefit from the pre-operative saline infusion studies. CT cisternography consists of the injection of radioactive agents into the subarachnoid space and serial CT scans are taken at different times depending on the clinical problem, such as CSF fistulae, NPH, etc. It is also used to evaluate the shunt function. It can also help in the evaluation of patients receiving intrathecal chemotherapy, evaluation of brain fluid-filled structures (arachnoid cysts, etc.), evaluation of CSF pumps for continuous delivery of medication. CT and MRI are useful to estimate intracranial compliance (25).

## Conclusion

This review briefs about the formation, composition, circulation and absorption of the CSF. The changes in CSF due to pathological conditions are highlighted. It is believed that the present study will offer the details about the physiology and dynamics of CSF, which is essential to the broad specialties including radiology, neurology, and neurosurgery.

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