

Cerebrospinal Fluid

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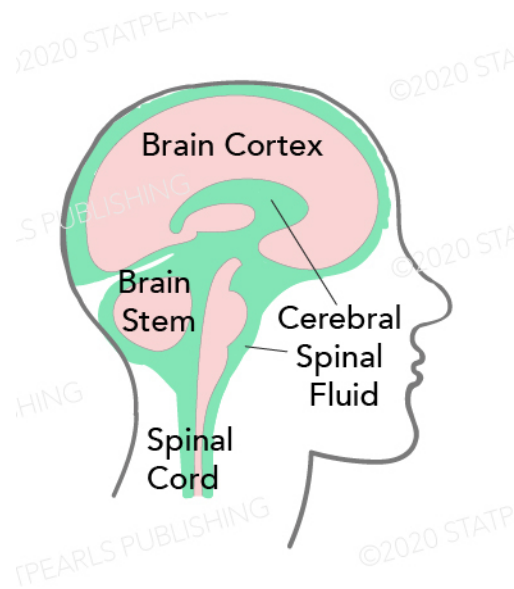


Figure 1: Cerebrospinal Fluid Distribution

CSF is a clear, colorless fluid that appears similar to water, but don't let its simple appearance fool you. This plasma-like substance has a carefully regulated composition that remains remarkably constant under normal conditions. The specific gravity ranges from 1.003 to 1.008, making it slightly denser than water, while the pH stays between 7.31 and 7.40, maintaining a slightly alkaline environment crucial for proper brain function.

Under normal circumstances, CSF contains no bilirubin and extremely low cholesterol levels. This absence is significant because the presence of these sub-

stances immediately signals abnormal conditions requiring medical attention.

Composition

Healthy CSF contains very few cells. The normal white blood cell count should be less than 5 cells per microliter, with the majority being lymphocytes and monocytes. Red blood cells should be completely absent. When these numbers change, they provide crucial diagnostic clues.

The appearance of white blood cells, particularly neutrophils, often indicates infection or inflammation. In bacterial meningitis, for instance, white blood cell counts frequently exceed 1,000 per microliter, with polymorphonuclear leukocytes predominating. Viral infections typically produce a milder elevation with lymphocyte predominance.

Glymphatic System

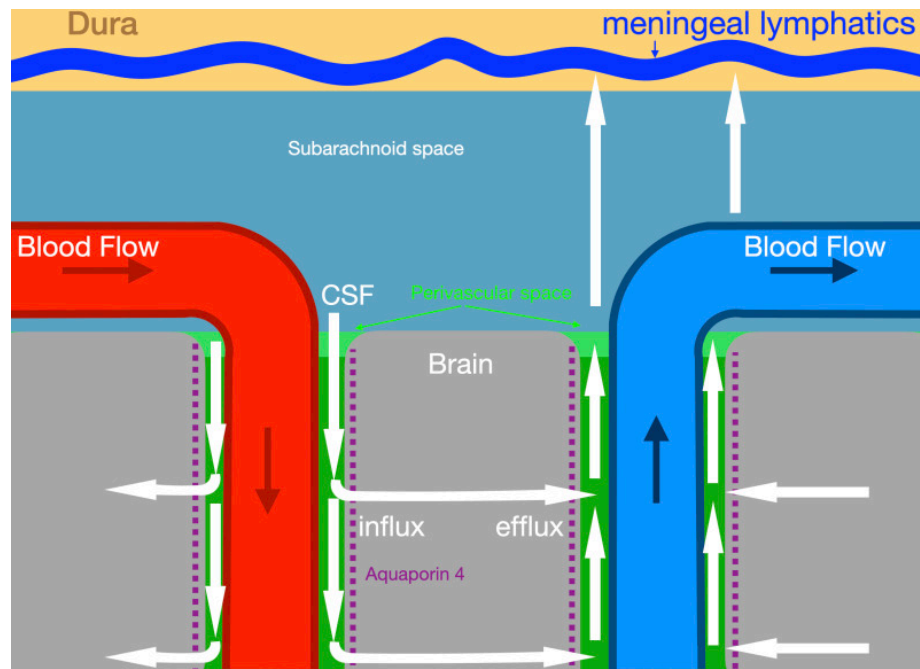


Figure 2: Glymphatic System

The illustration shows glymphatic fluid flow (white arrows) along periarterial and perivenous pathways. Labeled structures include the dura, meningeal lymphatics, subarachnoid space, brain parenchyma, arterial and venous circulation, and aquaporin 4 channels mediating influx and efflux. Contributed by Konstantinos Margetis MD, PhD

Constituents

- Concentration of sodium, potassium and urea are similar to those found in the plasma.
- Sodium and chloride are the most abundant ions.
- The normal adult CSF volume is about 130 mL.
- Glucose serves as the brain's primary fuel source measuring from 60-80% of blood glucose levels.

Normal ranges for CSF components are:

Additionally

- Glucose - 3.3 to 4.4 mmol/L; normally at least two thirds of the blood glucose levels
- Chloride, 122 to 128 mmol/L
- Lactate less than 2.8 mmol/L
- Pressure less than 200 mm CSF
- Protein less than 430 mg/L, with an albumin:globulin ratio of approximately 8:1
- Lymphocytes less than 4 per cubic millimetre.
 - In the neonatal period this figure can be up to 25, and in a bloody tap one extra white cell can be allowed for every 500 red cells.
- Polymorphs - none
- pH 7.31

Circulation

CSF changes in other neurological conditions

Beyond infections and hemorrhage, CSF composition helps diagnose various neurological disorders. In multiple sclerosis, the presence of oligoclonal bands, specific proteins that appear only in CSF and not in blood, now substitutes for traditional disease progression criteria in patients younger than 50 years with typical clinical presentations.

Guillain-Barré syndrome produces a characteristic pattern called albuminocytologic dissociation, where protein levels rise significantly while cell counts remain normal. This finding appears in 50% of patients during the first week, increasing to 75% by three weeks.

Why normal values matter

Understanding normal CSF composition provides the foundation for recognizing disease. Your body produces approximately 500 mL of CSF daily while maintaining a constant volume of 125 to 150 mL, completely replacing the fluid

CSF Circulation

- CSF is produced from blood and is returned to the blood
- CSF passes from subarachnoid space to dural sinuses via arachnoid villi

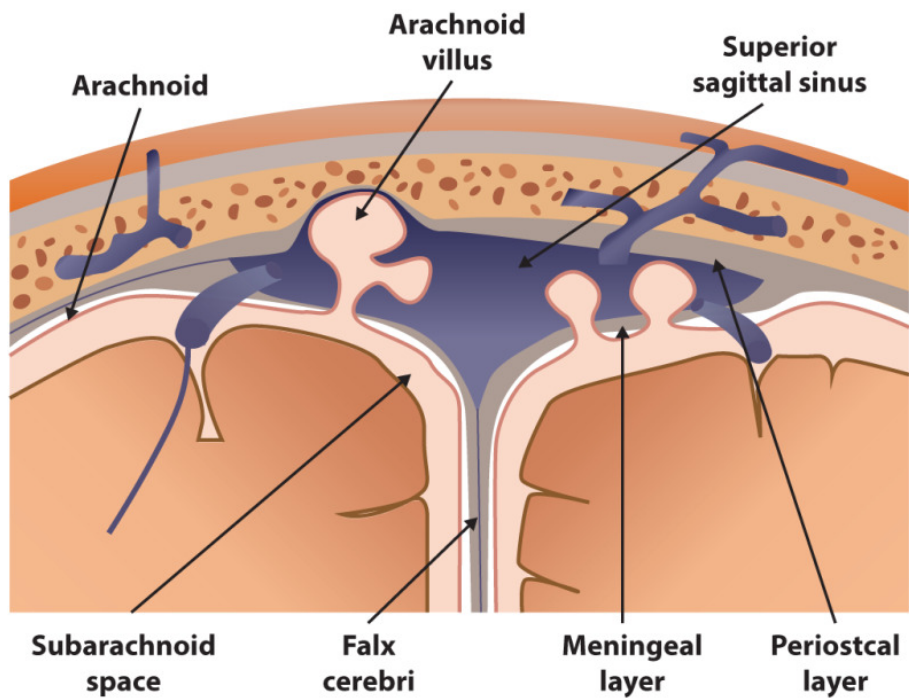


Figure 3: Cerebrospinal Fluid Circulation

every 7.5 hours. This constant turnover ensures that changes in composition rapidly reflect ongoing disease processes.

The blood-brain barrier tightly regulates what enters CSF, maintaining its unique composition. When disease disrupts this barrier, plasma proteins leak into CSF, electrolyte ratios shift, and cells that normally stay in blood vessels migrate into the fluid. Each change tells part of the diagnostic story.

Collection Technique

The collection technique also matters. Opening pressure measured during lumbar puncture provides valuable information about intracranial conditions. Multiple tubes collected in sequence help distinguish true bleeding from traumatic taps. Proper handling and rapid analysis preserve cellular elements that deteriorate if samples sit too long.

How the Test is Performed

There are different ways to get a sample of CSF. Lumbar puncture (spinal tap) is the most common method.

To have the test:

- You will lie on your side with your knees pulled up toward the chest, and chin tucked downward. Sometimes the test is done sitting up, but bent forward.
- After the back is cleaned, your health care provider will inject a local numbing medicine (anesthetic) into the lower spine.
- A spinal needle will be inserted.
- An opening pressure is sometimes taken. An abnormal pressure may indicate an infection or other problem.
- Once the needle is in position, and after the CSF pressure is measured, a sample of 1 to 10 milliliters (mL) of CSF is collected in 4 or more vials.
- The needle is removed, the area is cleaned, and a bandage is placed over the needle site. You may be asked to remain lying down for a short time after the test.

Normal Results

Normal values typically range as follows:

- Pressure: 90 to 180 mm H₂O
- Appearance: clear, colorless
- CSF total protein: 15 to 60 mg/dL (0.15 to 0.60 g/L)
- Gamma globulin: 3% to 12% of the total protein
- CSF glucose: 50 to 80 mg/100 mL or 2.77 to 4.44 mmol/L (or greater than two thirds of blood sugar level)

- CSF cell count: 0 to 5 white blood cells (all mononuclear), and no red blood cells
- Chloride: 115 to 130 mEq/L

Normal value ranges may vary slightly among different labs. Talk to your provider about the meaning of your specific test results.

What Abnormal Results Mean

If the CSF looks cloudy, it could mean there is an infection or a buildup of white blood cells or protein.

If the CSF looks bloody or red, it may be a sign of bleeding or spinal cord obstruction. If it is brown, orange, or yellow, it may be a sign of increased CSF protein or previous bleeding (more than 3 days ago). There may be blood in the sample that came from the spinal tap itself. This makes it harder to interpret the test results.

CSF PRESSURE

- Increased CSF pressure may be due to increased intracranial pressure (pressure within the skull).
- Decreased CSF pressure may be due to spinal block, dehydration, or CSF leakage.

CSF PROTEIN

- Increased CSF protein may be due to blood in the CSF, diabetes, polyneuritis, tumor, injury, or any inflammatory or infectious condition.
- Decreased protein is a sign of rapid CSF production or systemic loss of protein.

CSF GLUCOSE

- Increased CSF glucose is a sign of high blood sugar.
- Decreased CSF glucose may be due to hypoglycemia (low blood sugar), bacterial or fungal infection (such as meningitis), tuberculosis, or certain other types of meningitis.

BLOOD CELLS IN CSF

- Increased white blood cells in the CSF may be a sign of meningitis, acute infection, beginning of a long-term (chronic) illness, tumor, abscess, or demyelinating disease (such as multiple sclerosis).
- Red blood cells in the CSF sample may be a sign of bleeding into the spinal fluid or the result of a traumatic lumbar puncture.

OTHER CSF RESULTS

- Increased CSF gamma globulin levels may be due to diseases such as multiple sclerosis, neurosyphilis, or Guillain-Barré syndrome.

Additional conditions under which the test may be performed:

- Chronic inflammatory polyneuropathy
- Dementia due to metabolic causes
- Encephalitis
- Epilepsy
- Febrile seizure (children)
- Generalized tonic-clonic seizure
- Hydrocephalus
- Normal pressure hydrocephalus (NPH)
- Pituitary tumor
- Reye syndrome

Considerations

This test is more dangerous for people with:

- A tumor in the back of the brain that is pressing down on the brainstem
- Blood clotting problems
- Low platelet count (thrombocytopenia)
- Individuals taking blood thinners, aspirin, clopidogrel, or other similar medicines to decrease the formation of blood clots.

Looking ahead

CSF analysis continues evolving as new biomarkers emerge. Researchers are exploring circulating tumor DNA, microRNA, and metabolites for diagnosing malignancies affecting the nervous system. Neurofilament light proteins show promise for monitoring disease activity in multiple sclerosis. These advances build on our fundamental understanding of normal CSF composition.

The seemingly simple fluid surrounding your brain and spinal cord contains a wealth of diagnostic information. Its precise composition reflects the delicate balance necessary for nervous system function, and deviations from normal values guide physicians toward accurate diagnoses and appropriate treatments. Whether detecting life-threatening infections, identifying bleeding, or diagnosing complex neurological conditions, CSF analysis remains an indispensable tool in modern medicine.