Cerebrospinal Fluid (CSF) System

The entire cavity enclosing the brain and spinal cord has a volume of approximately 1650 mL; about 150 mL of this volume is occupied by CSF, and the remainder is occupied by the brain and spinal cord. This fluid, as shown in Figure 61–1, is found in the ventricles of the brain, the cisterns around the brain, and the subarachnoid space around both the brain and the spinal cord. These chambers are interconnected, and the pressure of the CSF is regulated at a constant level**.**

CSF Cushions the Brain. The brain and the CSF have about the same specific gravity. The brain therefore essentially floats in the CSF. A blow to the head moves the entire brain simultaneously with the skull, causing no single portion of the brain to be momentarily contorted.

Formation and Absorption of CSF About 500 mL of CSF is formed each day. Most of this fluid originates from the choroid plexuses of the four ventricles. Additional amounts of fluid are secreted by the ependymal surfaces of the ventricles and the arachnoidal membranes. The choroid plexus is a cauliflower-like growth of blood vessels covered by a thin layer of epithelial cells. This structure projects into the temporal horn of each lateral ventricle, the posterior portion of the third ventricle, and the roof of the fourth ventricle. The CSF is absorbed by multiple arachnoidal villi that project into the large sagittal venous sinus as well as into other venous sinuses of the cerebrum. The CSF empties into the venous blood through the surfaces of these villi.

The Perivascular Space Functions as a Lymphatic System for the Brain. As the blood vessels that supply the brain penetrate inward, they carry with them a layer of pia matter. The pia is only loosely adherent to the vessels, and this creates a space between the pia and the vessels called the perivascular space. The perivascular space follows both the arteries and veins into the brain as far as the arterioles and venules but not to the level of the capillaries. Protein that leaks into the interstitial spaces of the brain flows through the perivascular spaces into the subarachnoid space. On reaching the subarachnoid space, the protein flows with the CSF and is absorbed through the arachnoidal villi into the cerebral veins.

CSF Pressure CSF is formed at a nearly constant rate; therefore, the rate of absorption of this fluid by the arachnoidal villi determines both the quantity of fluid present in the ventricular system and the level of CSF pressure. The arachnoidal villi function like one-way valves that allow CSF to flow into the blood of the venous sinuses but prevent the flow of blood into the CSF. Normally, the valve like action of the villi allows CSF to flow into the venous sinuses when the pressure in the fluid is approximately 1.5 mm Hg greater than the pressure of the blood in the venous sinuses. When the villi become blocked by large particulate matter or fibrosis, CSF pressure can rise dramatically. The normal CSF pressure is 10 mm Hg. Brain tumors, hemorrhage, or infective processes can disrupt the absorptive capacity of the arachnoidal villi and cause CSF pressure to increase to levels three to four times normal.

Obstruction to the Flow of CSF Causes Hydrocephalus . This condition is often defined as communicating hydrocephalus or non-communicating hydrocephalus. With communicating hydrocephalus fluid flows readily from the ventricular system into the subarachnoid space, whereas with non-communicating hydrocephalus the flow of fluid out of one or more of the ventricles is blocked. The communicating type of hydrocephalus is usually caused by blockage of fluid flow into the subarachnoid space around the basal regions of the brain or blockage of the arachnoidal villi themselves. The non- communicating type of hydrocephalus is usually caused by blockade of the aqueduct of Sylvius as a result of a congenital defect or brain tumor. The continual formation of CSF by the choroid plexuses in the two lateral ventricles and the third ventricle causes the volume of these ventricles to increase greatly. This flattens the brain into a thin shell against the skull. In neonates, the increased pressure also causes the entire head to swell because the skull bones have not yet fused.

Blood-CSF and Blood-Brain Barriers The constituents of the CSF are not exactly the same as those of the extracellular fluid elsewhere in the body. Furthermore, many large molecular substances do not pass from the blood into the CSF or into the interstitial fluids of the brain. Barriers called the blood-CSF barrier and the blood-brain barrier exist between the blood and the CSF and brain fluid. These barriers are highly permeable to water, carbon dioxide, oxygen, most lipid-soluble substances such as alcohol, and most anesthetics; they are slightly permeable to electrolytes such as sodium, chloride, and potassium; and they are almost totally impermeable to plasma proteins and most non–lipid-soluble large organic molecules. The cause of the low permeability of these barriers is the manner in which the endothelial cells of the capillaries are joined to one another. The membranes of the adjacent endothelial cells are tightly fused with one another rather than having extensive slit pores between them, as is the case with most other capillaries of the body. These barriers often make it impossible to achieve effective concentrations of therapeutic drugs, such as protein antibodies and non–lipid-soluble com- pounds in the CSF or parenchyma of the brain. In some areas of the hypothalamus, pineal gland, and area postrema, substances diffuse with greater ease into the tissue spaces. The ease of diffusion in these areas is important because they have sensory receptors that respond to specific changes in the body fluids, such as changes in osmolality and in glucose concentration, as well as receptors for peptide hormones that regulate thirst, such as angiotensin II.

Brain Edema One of the most serious complications of abnormal cerebral hemodynamics and fluid dynamics is the development of brain edema. Because the brain is encased in a solid vault, accumulation of edema fluid compresses the blood vessels, resulting in decreased blood flow and destruction of brain tissue. Brain edema can be caused by greatly increased capillary pressure or by a concussion in which the brain's tissues and capillaries are traumatized and capillary fluid leaks into this tissue. Once brain edema begins, it sometimes initiates a vicious circle. The edema fluid compresses the vasculature, which in turn decreases the blood flow and causes brain ischemia. The ischemia causes arteriolar dilation with further increases in capillary pressure. The higher capillary pressure causes more edema fluid, and the edema becomes progressively worse. The reduced blood flow also decreases oxygen delivery, which increases the permeability of the capillaries, allowing more fluid leak- age. Decreased oxygen delivery depresses brain metabolism, which turns off the sodium pumps of the brain cells, causing them to swell. Once this process has begun, heroic measures must be taken to prevent total destruction of the brain. One measure is to administer an intravenous infusion of a concentrated osmotic substance such as mannitol. This pulls fluid from the brain tissue through osmosis and breaks the vicious circle. Another procedure is to remove fluid quickly from the lateral ventricles of the brain through ventricular puncture, thereby relieving intracerebral pressure.