Cerebrospinal Fluid

What It Is and Where To Find It

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The brain is about 80% water, and about 20% of that water is extracellular. In addition to the water, the cranial cavity contains blood, lymph and cerebrospinal fluid. Each of these fluids serves very specific needs related to functions of the brain, the spinal cord and/or all other intracranial structures.

The cerebrospinal fluid is secreted into the craniosacral system by the choroid plexuses, which are located primarily in the lateral ventricles of the brain. Inconsistently, there is seen small patches of choroid plexus tissue in the third and fourth brain ventricles and, on rarer occasions, in other areas of the meningeal membrane system.

The structure of the choroid plexus is rather similar to the distal and collecting tubules of the kidney. It consists of minute tufts of tiny blood vessels, mostly capillaries, although there are some arterioles and venules present. These tufts are part of the pia mater, which projects as a sort of mat into the ventricular spaces. All of the tufts are covered by ependymal epithelial cells. The blood supply to the choroid plexuses is from the choroidal branches of the internal carotid arteries. Clearly, carotid artery insufficiency can result in a reduction of cerebrospinal fluid production. This may be compensated by reducing outflow from the craniosacral system, but a degree of stasis is inevitable when this compensatory mechanism is active.

The choroid plexus not only secretes cerebrospinal fluid into the craniosacral system, it also helps to maintain the chemical stability of the cerebrospinal fluid. In this stabilizing role it not only conducts various biochemical substances into the craniosacral system, it also, by specific active conduction, removes some biochemical ions and molecules from the cerebrospinal fluid and deposits them into the venous drainage of the choroid plexus structures. Most materials that are removed from the cerebrospinal fluid by this reverse action of the choroid plexus are metabolic by-products, or waste and toxic materials that somehow gained entry into the craniosacral system.

Once secreted into the craniosacral system, the cerebrospinal fluid flows from the lateral ventricles of the brain through the interventricular foramina (of Monro) into the third ventricle, where some more cerebrospinal fluid may be added by the few choroid plexuses located in that ventricle. From the brain's third ventricle, the cerebrospinal fluid then flows through the cerebral aqueduct (of Sylvius) into the brain's fourth ventricle. (In congenital hydrocephalus it is usually this cerebral aqueduct that is not competent. When this is the case, the surgical placement of a shunt is usually mandatory.)

From the fourth ventricle, the cerebrospinal fluid then passes through the foramina of Luschka, which are paired, and Magendie, of which there is only one. The latter foramen (Magendie) is located on the midline in the roof of the fourth ventricle. The former two foramina (Luschka) are located bilaterally in the lateral aspects of this fourth ventricle. The existence of choroid plexus structures in this fourth ventricle is much more sparse than even in the third ventricle. From the fourth ventricle, the cerebrospinal fluid empties into the subarachnoid space through these three foramina and directly into the central canal of the spinal cord. The cerebrospinal fluid which enters this subarachnoid space then bathes the brain, the spinal cord and the spinal nerve roots only as far distally as dural sleeves extend on these nerves. In the spinal area these dural sleeves end at the intervertebral foramina.

This latter situation continues to be somewhat controversial. From its time of origin, the Osteopathic Cranial Academy taught that cerebrospinal fluid followed all of the nerves out of the spinal cord to their destinations in the periphery. This is the explanation they gave for the perceptible cranial motion that they felt all over the body. This is a nice, easy explanation, but it is simply not true. It is true that the olfactory and optic cranial nerves (known as the Ist and IInd nerves) are bathed in cerebrospinal fluid through to their end points. However, these first two cranial nerves are not really nerves. They are extensions of brain tissue because they are not synaptically separated from brain tissue. Thus, we might say that these brain extensions, throughout their length, maintain their relationship

with dura mater and the cerebrospinal fluid which flows within this tough watertight sheath. The other cranial nerves, III through XII, have the luxury of the cerebrospinal fluid bath only as far as they have the luxury of the sheath of dura mater, which is not throughout their entire course.

How can I be so sure of this when some "authorities" still maintain the idea that the cerebrospinal fluid follows all nerves to their destinations? Over 20 years ago, while I was in the biomechanics department at Michigan State University, a good friend and colleague, Irvin M. Korr, Ph.D. (physiology), was researching this very question. We had neighboring offices and we shared many hours of conversation. Dr. Korr was interested in the trophic (vitalizing) influence of nerves upon their end organs. As most of you know, when a nerve becomes dysfunctional for any reason, be it disease, being cut, entrapment, etc., its end organ begins to atrophy, or to become dystrophic. Dr. Korr was the creator of the facilitated segment concept. He had observed mild dystrophic changes related to the end organs of the nerves from facilitated segments, and his research was leading him into the investigation of the cause of these dystrophic end-organ responses.

Dr. Korr injected radioactive tracers into the glossopharyngeal nerve nuclei of guinea pigs. The glossopharyngeal nerve is the IXth cranial nerve. It goes to the tongue in both guinea pigs and humans. He found that the radioactive tracers took about two days to travel from the glossopharyngeal nucleus to the guinea pigs' tongues. He also found that the radioactive tracers were attached to protein molecules that were traveling through the glossopharyngeal axons to the tongues of the guinea pigs. The rate of motion was between 1 and 2 millimeters per hour. He reasoned that the trophic influence of the nerve, which he observed in his work with facilitated segments, was quite possibly related to the protein substances which we now know are manufactured in the nerve cell body and transported via the reticulum tubes and the vesical systems, which travel throughout the length of each axon to its end organ. When there is an intervening synapse en route, it seems that the presynaptic protein somehow signals the postsynaptic neuron to manufacture and send similar, if not identical, proteins to its (the postsynaptic neuron's) axonal destination.

As a part of this same work, Dr. Korr injected radioactive tracers into the guinea pigs' brain ventricles. He allowed me to join him in this work because of my interest in what became the craniosacral system. We monitored nerve trunks beyond the end of the dural sleeves, and not once did we find radioactivity distal to these dural sleeve terminal points. We did, however, find radioactivity throughout the length of the spinal cord, the dural tube, and out the dural sleeves as far as the intervertebral foramina.

At this same time I was preparing my first research proposal to the National Institutes of Health in Washington, DC. I made a very thorough search of the literature at that time, and found several confirmatory pieces of research that used both intraventricular dye injection as well as the injection of radioactive tracers. No one found either the dye or the radioactive tracers beyond the dural compartment.

This, of course, left the question of what makes the total body reflect the craniosacral rhythm. I believe that this whole-body response is probably due to the pumping effect of the cerebrospinal fluid upon the motor system, which causes a rhythmical tonification and detonification of the myofascial system in response to rhythmically fluctuating nerve signals. This concept seems supported by more recent research that has traced the flow of cerebrospinal fluid, in response to its pressure fluctuations, deep into the brain's sulci and deep into the depths of the cerebral cortex through the Virchow-Robin spaces. These are perivascular spaces which do carry the cerebrospinal fluid (all within the dural envelope) into the interstitial spaces of the brain. An apparent free diffusion of small molecule solutes occurs in these spaces. This obviously facilitates the removal of metabolic by-products, as well as delivery of those substances which the cerebrospinal fluid carries. I feel reasonably safe when I say that this

fluid fluctuation would have an effect upon the motor cortex.

Now, let's look at what does happen to the cerebrospinal fluid if it doesn't exit the craniosacral system via all of the post-root nerve trunks. Incidentally, if it were ultimately to be true that cerebrospinal fluid goes throughout the body with the nerves, this does not contradict the Pressurestat Model, which explains the mechanics of the craniosacral system. It only offers an expansion of the controlled outflow of cerebrospinal fluid from the craniosacral system. However, in my eyes the evidence supports the arachnoid system as that which returns cerebrospinal fluid to the blood vascular system. The major absorption of cerebrospinal fluid from within the dural envelope is through the arachnoid villi and, to a lesser extent, through the arachnoid granulation bodies, also called pacchionian granulations.

The arachnoid structures are typically found in clusters that are encased in a sac of arachnoid membrane which protrudes through "pores" in the dural membrane and into the lumina of the venous sinuses of the brain. The sinus which has the greatest density of arachnoid granulations is the superior sagittal sinus. The arachnoid granulation bodies that we refer to are concentrated at and near the anterior end of the straight venous sinus. We know these granulation bodies have the ability to raise or lower venous sinus back pressure, therefore changing the rate of cerebrospinal fluid outflow from within the dural envelope (which forms the boundary of the craniosacral system) into the venous blood.

It is not yet totally clear how the arachnoid granulation system works to return cerebrospinal fluid into the venous blood of the brain's sinus systems. My own preferred idea is that the membranes of the arachnoid granulations, which separate the cerebrospinal fluid from the venous blood, are selective because of the size of the pores they have. Thus, these membranes would reject the passage of the larger molecules and cells into the craniosacral system from the blood. Therefore, the blood remains more dense or concentrated because it has many more cells and large molecules than does cerebrospinal fluid. Influenced by osmotic pressure and the forces of diffusion, the cerebrospinal fluid attempts to dilute the blood. In this attempt, cerebrospinal fluid passes through the membrane over to the blood side as it constantly seeks an equilibrium. Since more concentrated blood is continually moving into the regions of the arachnoid villi, the constant quest for equilibrium produces a dominant flow of cerebrospinal fluid into the venous blood.

Other possibilities which are yet to be confirmed or rejected include a system of tubules, or channels, that might cross the barrier between the cerebrospinal fluid and the venous blood. Similar to the tubule concept, but less open and requiring more energy, is the possibility of vacuoles filling with cerebrospinal fluid on one side of the cellular barriers and emptying into the venous blood on the other side. This latter possibility would be an active transport system and thus require a well-designed and rather complex control system, as well as a lot of available energy. In as much as Mother Nature usually has multiple back-up systems, it would not be surprising to see any or all of these three systems operative, as well as some yet undiscovered systems.

The composition of cerebrospinal fluid is in a "steady state" with the extracellular/interstitial fluids of the brain. In fact, from the point of view of fluid composition, they are the same fluid. They are named differently according to location, but I feel quite safe in saying that cerebrospinal fluid is the extracellular/interstitial fluid of the brain and spinal cord. Incidentally, the fluid between the dural and arachnoid membranes is, according to composition, also cerebrospinal fluid. I believe that both of these mythical man-made divisions of fluids will soon be gone.

Because of its singular and continuous fluid system, in order to bathe the neurons and glial cells of the brain, it is essential that cerebrospinal fluid flow not be impaired. If an area of brain tissue is even partially deprived of optimally effective cerebrospinal/extracellular/interstitial fluid motion and flow, that brain area will be forced into some degree of functional compromise.

This cerebrospinal fluidic circulation removes metabolic waste products as well as toxic substances from brain tissue. In this way it serves a function which is similar to the extradural lymphatic system, yet these two fluids (cerebrospinal and lymphatic) are different. The cerebrospinal fluid also floats the brain, thus countering the forces of gravity. An in situ brain floating in cerebrospinal fluid weighs about 50 grams under normal circumstances. A brain taken out of the body and not floating weighs on the order of 1 to 1.5 kilograms. Remember, it takes a thousand grams to make a kilogram, so the extracorporeal brain weighs 20 to 30 times more than the in situ brain.

In addition, the cerebrospinal fluid serves as a shock absorber in head "jolts." It also serves as a vehicle for the transport of hormones and peptides of all kinds.

The pH of the cerebrospinal fluid has marked effects on the breathing control centers of the brain, thus influencing rate and depth of pulmonary respiration. It also, through its pH, influences cerebral blood flow. As you can see, cerebrospinal fluid has several important roles that are known. How much is yet to be found out?

If we compare some of the components of cerebrospinal fluid and blood serum, we can see the importance of the choroid plexuses and the arachnoid villi and granulation bodies. Differentials in components and pH are necessary because brain tissue has qualitatively and quantitatively different requirements than other body tissues.

Let's look at a few of the differences between cerebrospinal fluid and blood serum:

	Cerebrospinal Fluid	Blood Serum
Water	99%	93%
Protein mg/dl	35±	7000±
Glucose mg/dl	60±	90±
Sodium mg/l	138±	138±
Potassium mg/l	2.8±	4.5±
Calcium mg/l	2.1±	4.8±
Magnesium mg/l	0.3±	1.7±
Chloride mg/l	119	102
pH	7.33	7.41

mg = milligram dl = deciliter l = liter

Before I conclude, it seems appropriate to briefly describe blood plasma, blood serum, lymph, and what makes them differ individually. The difference between whole blood and blood plasma is that plasma is blood with the cells removed. This makes plasma a much less rejected substance to give to a person who requires additional blood volume in a hurry when there is no compatible whole blood available. It restores blood volume, contains many nutrients and vitamins as well as proteins, lipids, hormones, peptides, etc., but no cells. This means that the needy patients who receive plasma may remain anemic and low on white blood cells, but they won't die in hypovolemic shock.

Blood serum has all the stuff of plasma except the fibrin and other factors involved in clotting. The cells have been removed, just as in plasma. Blood serum is the fluid upon which most blood chemistry analyses are performed. Whole blood is, of course, required for the blood cell count procedures. Since both whole blood and plasma have clotting ability, anticlotting substances are added to them when the clot is unwanted.

Lymph is a colorless fluid found within the lymphatic system. It is derived from extracellular/interstitial fluid by absorption by the lymph capillaries. The size of the pores in the lymph capillary walls is significantly larger than the pores in blood vascular system capillaries. Therefore, larger molecules which are rejected by the blood vascular capillaries are found in lymph.

The composition of lymph includes water, a variety of dissolved salts, dissolved proteins and a variety of fat molecules, all of which are in suspension rather than in solution. Lymph also contains a potpourri of metabolic by-products, toxic substances, infectious by-products, etc. These substances end up in lymph because, in essence, lymph is the vacuum cleaner of the intercellular spaces of the body, excluding the brain and spinal cord. The lymph capillaries drain either into lymph nodes or become tributaries to tubular vessels which then may drain into lymph nodes.

The lymph nodes serve as filtration stations. After they have done their purification work, they send the cleansed lymph into lymph vessels which form a system of tributaries that ultimately returns the lymph to the venous side of the blood vascular system. The whole lymphatic system has its own rhythmical pumping action which aids in its fluid transport. When the infectious materials, be they live or by-products, toxic materials, etc., are too much for the lymphatic system, you may see painful swelling of overburdened lymph nodes, etc. Often these swollen nodes then become fibrous and may ultimately be excluded from the lymphatic system.

The chemical composition of lymph is extremely variable because of its clean-up duties. It is, therefore, not often used for chemical assessments. It is influenced almost moment to moment by what is going on in the body. It is influenced by digestive processes, infectious processes, toxic processes and so on. It is called interstitial or extracellular fluid until it enters the lymphatic system. It is then called lymph because of its location rather than its composition.

In addition to the aforementioned aspects of the mechanisms that keep cerebrospinal fluid separate and different from other body fluids, we have a brain protector called the "blood-brain barrier." Paul Erlich was the creator of the blood-brain barrier concept. He injected dyes into blood that attached to serum albumin molecules. He found that most internal organs were stained by the dyes but not the brain. Further study has confirmed that the blood-brain barrier is another system of protection for the brain. It is located in specialized endothelial cells of the capillaries of the cerebrovascular system. These specialized cells are contacted by astrocyte projections from the brain side of the system. Somehow these astrocytes let the capillary endothelial cells know which molecules in the blood are allowed to cross over into the cerebrospinal fluid and the brain tissue, and which are not.

The entire system is quite ingenious and rather strict about the enforcement of its immigration laws. Who made the laws? Who trained the enforcers? Somebody a lot smarter than me, that's for sure.

Addendum

Since the first printing of *Cerebrospinal Fluid: What It Is and Where To Find It* in 1998, a couple of very significant pieces of information have come to my attention:

1. During our CranioSacral Dissection classes, we have been able to demonstrate that less than an ounce of weight placed on the dura mater tube running within the spinal canal obstructs the transmission of forces between the sacrococcygeal complex and the intracranial dural membrane system. We demonstrated this phenomenon by dissecting away the spinous processes and about half of the laminae on each side of the spinous processes from the upper cervical spine through the lower lumbars. The brain had been carefully removed in a way that preserved the intracranial membrane system (falx cerebri, falx cerebelli and tentorium cerebelli).

We accessed the intracranial membrane system by palpating via bilateral windows that were cut into the parietal bones without damaging the sutures. We then applied small forces digitally at separate times to the intracranial membranes, and then to the lumbar dural tube using forceps. Forces applied in a cephalad direction upon the falx cerebri were perceived by the person monitoring the inferior dural tube. Then caudad forces were applied upon the lumbar dural tube.

The person who applied the forces in both directions and the person who perceived the forces at the other end of the dural membrane system were each accomplished CranioSacral Therapists. They did not communicate except when the "receiving" therapist announced that he or she was feeling a pulling force in the dural membranes. (These pulling forces were subjectively estimated at between 5 and 10 grams.) Both therapists worked with their eyes closed. A third person would then place a 5-gram weight upon the dural tube in the thoracic region. The placement of this weight (unbeknownst to the therapists monitoring the dural system) caused an interruption in the transmission of force past the weight. The "receiving" therapist could no longer feel the forces applied by the "sending" therapist.

This clinical experiment led to the observation that very small oppressive forces upon the dura mater system can and do interrupt the conduction of small forces through the system. It is a short jump then to the idea that as we accumulate traumas that leave small or moderate residua in the craniosacral system, whether it is the intracranial division or that part of the system that resides within the spinal canal, these residua will impair craniosacral system function. In my opinion, these impairments compromise the flow of cerebrospinal fluid through the craniosacral system to some extent. This lessening of fluid flow then reduces total replacement of cerebrospinal fluid within the craniosacral system.

It is estimated that a normal adult (age 35 to 40) receives a total replacement of cerebrospinal fluid four times each day. At 65 to 70 years of age, a person's total replacement of fluid is reduced by about 50%. This reduction of flow increases cerebrospinal fluid stasis within the system, which results in a reduction of nutrients and accumulation of metabolic by-products, waste materials and toxic substances. This compromising of nutritional supplies coupled with an accumulation of metabolic by-products, wastes and toxins probably contributes significantly to what we call "the aging process" that, though considered normal, contributes to "senile brain changes" as well as Parkinson's and Alzheimer's diseases.

2. In supporting and expanding on the concepts mentioned above, we now know that cerebrospinal fluid contains rather small protein molecules that function as chelators. These chelator molecules combine with atoms of metals such as lead, mercury, arsenic, aluminum, etc., to neutralize the metal atoms and float them out of the craniosacral system. Obviously, the better the cerebrospinal fluid is circulating, the more efficient the chelation process will be.

It seems quite clear to me that CranioSacral Therapy applied effectively enhances the flow of cerebrospinal fluid, thus increasing the number of times per day that the total volume of cerebrospinal fluid is replaced. This enhancement of fluid flow also increases the supply of nutrients to brain and spinal cord cells, and it improves the removal of metabolic by-products, as well as other wastes and toxic substances.

Good CranioSacral Therapy enhances the chelation of toxic mineral deposits by a mechanism inherent to each of us. Since CranioSacral Therapy is essentially risk-free, why not give it a try?

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