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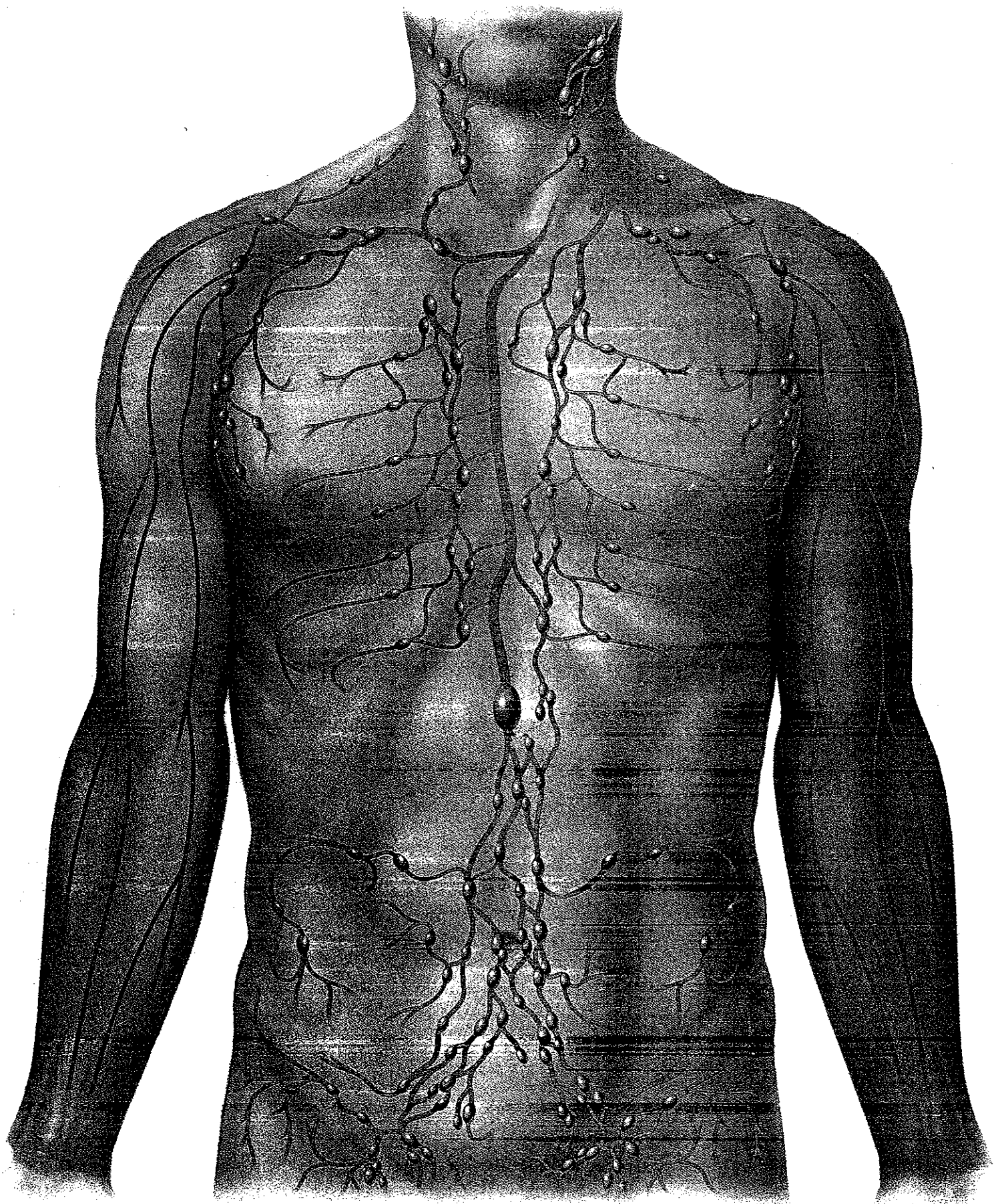
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*The lymph system*

# The Circulation Between Cerebrospinal Fluid, Cerebral Interstitial Fluid and Lymph, Part One

*With Clinical Applications of Lymph Drainage Therapy for  
Drainage of the Central Nervous System*

*by Bruno Chikly, M.D.*

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**T**his article will inspire massage therapists interested in lymph and cranial work, or those just seeking to deepen their knowledge of the fascinating anatomy related to the connections between the central nervous system and the periphery of the body.

The author explains how, by very gentle, non-invasive hands-on techniques, massage therapists can help enhance/optimize fluid circulation between the deepest parts of the central nervous system and the rest of the body. These specific techniques are important and yet not often addressed. Further, they can address very common conditions, such as inflammation, swelling and chronic pain; and help with immune-system function, detoxification and tissue regeneration.

These techniques may help in numerous clinical situations that are usually or traditionally difficult to work with, such as brain- and spinal-related pathologies, including headaches, trauma, whiplash, closed head injury, cognitive behavioral dysfunctions and some birth difficulties or trauma.

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Health practitioners are usually familiar with the organization of the central nervous system and the circulation of cerebrospinal fluid, but rarely know much about the lymphatic system. It should come as little surprise then that the specialized topic of cerebrospinal-fluid drainage through lymphatic pathways, and the clinical implications of that action, draw blank stares from even some extensively trained specialists.

Lymph Drainage Therapy™ is a manual therapy that enables trained practitioners to effectively identify and

stimulate the specific rhythm, direction and depth of the lymphatic circulation. Recent scientific discoveries on the physiology of the lymphatic system verify that the Lymph Drainage Therapy process utilizes the precise rhythm and pressure needed to optimally activate lymph flow.

Activation of natural lymphatic drainage can be used in many clinical situations to help fluid circulation between the central nervous system and the periphery of the body. In the text that follows, we will review the properties of the central nervous system, cerebrospinal fluid and cere-

stitial fluid, and then specifically examine the lymphatic drainage plays in their proper functioning.

### *Organization of the central nervous system: A review*

Before we begin, you should know that the exact organization of the central nervous system is still being debated within medical circles. The central nervous system—encompassing the brain (or encephalon) and spinal cord—is an exceptional system in that all five major circulating systems of the body are present: arteries, veins and lymph (contained within their respective vessels), and the cerebrospinal fluid and cerebral interstitial fluid (in their specific extracellular fluid compartments).

At the time of René Descarte (1596-1650), only three circulatory systems were known: arteries, veins and nerves. The latter was thought to have an internal circulation comprised of liquid, a kind of "nervous fluid circulation."

The central nervous system is insulated from the rest of the body by three membranes, or meninges. They are the dura mater (named for its coarse aspect), the arachnoid mater (which is spiderweb-like), and the pia (or frail) mater. The arachnoid and pia maters have many cellular similarities. They share a common origin (neuroectoderm) that is different from the dura, and together they constitute the leptomeninges. Let's take a closer look at two important functions these membranes serve within the central nervous system.

### *The blood/cerebrospinal fluid barrier*

Five or six layers of tightly junctioned arachnoid cells separate the dura from the arachnoid layer and constitute a dura-arachnoid "barrier" that prevents the cerebrospinal fluid from escaping to the dura mater in physiological conditions. The arachnoid mater sends web-like bridges, called trabeculae, to the pia mater. This complex defines another intracranial space: the subarachnoid space. The subarachnoid space gives passage to the cerebrospinal fluid, as well as to major arteries and veins that vascularize the brain.

### *The blood-brain barrier: Is there a blood-brain interface?*

It appears that the pia mater plays a crucial role in the blood-brain barrier. The pia is a lining consisting of one-to-three layers of loosely connected cells that follows the contour of the outermost aspect of the cerebral tissue (or brain parenchyma) into its sulci. Under the pia mater and the membrane gliae limitans lies the brain tissue (parenchyma). This extracellular compartment has been evaluated to be about 15 percent of the total brain volume. The cerebral interstitial fluid is the other extracellu-

lar fluid present between—or in the interstices of—the cerebral cells. The cerebral interstitial fluid seems capable of having significant exchanges with the cerebrospinal fluid, since its composition is similar to the cerebrospinal fluid.

In 1885 P. Erlich showed that dyes injected into the systemic circulation of animals didn't stain the central nervous system; this was confirmed by Goldmann in 1909. Later, T.S. Reese and M.J. Karnovsky demonstrated that the tracer commonly used today—horseradish peroxidase—did not enter into the central nervous system when injected intravenously. The question therefore arises: What mechanism prevents substances from entering the brain, or forms the so-called blood-brain barrier—the selective barrier that protects the central nervous system?

The continuous endothelial membranes of intracranial capillaries organize into the blood-brain barrier. The endothelium of the cerebral capillaries consists of very specific blood vessels, differing in many aspects from blood capillaries in the rest of the body. The cells of the endothelium present strongly connected, nonleaking, tight junctions, with a strong basal lamina that filters exchanges. Intracytoplasmic vesicles are extremely rare. These blood vessels are biochemically different because of the unique presence of gamma-glutamyltranspeptidase and alkaline phosphatase.

Recent studies by J.C. Partridge and M.B. Segal, however, demonstrate that the blood-brain barrier is actually permeable to many components—water, ions, peptides, plasma proteins, immune cells, hormones, etc., and should be more accurately called a "blood-brain interface."

### *General characteristics of cerebrospinal fluid*

Cerebrospinal fluid is a beautiful liquid, one of the most noble liquids of the body. A.T. Still, known as the father of osteopathy, wrote in *The Philosophy and Mechanical Principles of Osteopathy*, "The cerebrospinal fluid is one of the highest known elements contained in the body."

Cerebrospinal-fluid volume, which is about 123 ml total in adults, is divided 25 ml in the ventricles and 98 ml in the subarachnoid spaces that bathe the brain and spinal cord. There is a great degree of variability between individuals. Cerebrospinal-fluid volume needs to be in constant homeostasis between production and reabsorption.

The production of cerebrospinal fluid has been traced to the choroid plexus and an undetermined source of extrachoroidal origin.

The choroid plexus, the major source of cerebrospinal-fluid secretion, is a highly specialized structure in the

central nervous system that manifests in the lateral (third and fourth) ventricles of the brain. It is highly vascularized, and consists of pia-arachnoid tissue that has invaginated into the overlying ventricular ependyma.

The vascular side consists of a single layer of secretory epithelia that is devoid of active, tight junctions (fenestrated endothelia). Intracerebral capillaries, on the other hand, possess tight junctions and constitute the blood-brain barrier. On the ventricular (apical) side, a lining of ependymal cells is contiguous with the choroid epithelium. The ependyma presents tight junctions and covers the cells' active cilia, helping to homogenize the cerebrospinal fluid in the ventricular cavity.

Plasma is exchanged as an ultrafiltrate through the endothelium of the capillaries and is later transformed by secretion through the epithelium of the choroid. The rate of production of cerebrospinal fluid is about 500 ml/day. Cerebrospinal fluid has specific characteristics that are different from blood ultrafiltrate. For example: The concentration of potassium is actively maintained in low concentrations, while magnesium is maintained in high concentrations. Parasympathetic stimulation can increase the production of cerebrospinal fluid up to 100 percent, while sympathetic fibers lessen the cerebrospinal-fluid flow by about 30 percent.

While the choroid plexus is responsible for 60 to 85 percent of the total production of cerebrospinal fluid, experimentation has shown that about 15 to 30 percent of cerebrospinal fluid is produced from an extrachoroidal origin. W. Brightman, D.P. Rall and K. Welch cite the capillary endothelium of cerebral tissue as a probable major source of extrachoroidal cerebrospinal-fluid production. The intracerebral arteries seem to be the other structures capable of filtering plasma from blood to produce 15 to 30 percent of extrachoroidal cerebrospinal fluid.

### *Absorption of cerebrospinal fluid*

In order to preserve perfect homeostasis, cerebrospinal fluid must be reabsorbed at a rate parallel to its production. The three main sources of reabsorption are the choroid plexus, arachnoid villi and granulations, and lymphatic pathways.

The function of the choroid plexus has been compared to the function of the proximal renal tubule that can both absorb and secrete many substances. A. Sahar, K. Welch and K. Sadler found that the choroid plexus may absorb about one-tenth of its secretion.

The exact role of the arachnoid villi and granulations for reabsorption of cerebrospinal fluid is still unclear. Each is a protrusion of the arachnoid tissue through the dura into the lumen of the neighboring intracranial venous sinus. Some arachnoid villi can be found in the spinal

canal, and they are shown to absorb 16 percent of the cerebrospinal fluid in animals. Arachnoid granulations can be seen with the unaided eye.

Villi and granulations are covered by a specific epithelium with tight junctions. Channels up to 100 microns in diameter have been described at the apical cap of the arachnoid granulations. They seem to be continuous with the subarachnoid space, and connect the arachnoid bodies to the venous side. Pinocytosis, or vesicles, seem to be another possible mechanism of cerebrospinal-fluid absorption in these areas.

Lymphatic vessels are present in the dura, pia (Mascagni's pathway), pituitary capsule, nasal mucosa, orbit of the eye and the middle ear. To date, no lymphatic system has been described in the brain. Some type of lymphatic-like drainage is nevertheless necessary to drain the small amount of protein in the cerebrospinal fluid and cerebral interstitial fluid—100 to 500 percent less protein than in the blood.

This paucity of protein in the cerebrospinal fluid actually gives it its "crystal clear" physiological aspect. The elevated protein level can be significant in cases of edema, trauma, hemorrhage or infection inside the central nervous system.

A fluid drainage pathway is needed to help the proteolytic work of the scavenger cells (macrophages and microglia). Indeed, the central nervous system needs alternate pathways that can rapidly drain the system; this is necessary to aid the passage of immunocompetent cells (lymphocytes) that lead to lymphatic nodes and/or the spleen, as well as to activate specific immunological responses.

With the lymph/cerebrospinal fluid connection established, let's take a look now at the history of lymphatic drainage as it pertains to cerebrospinal fluid.

### *First discoveries*

In 1869 the German scientist G. Schwalbe did experimentation involving the injection of Berlin blue dye into a dog's subarachnoid space. He was the first to conclude that the major pathways to absorb cerebrospinal fluid were the lymphatic pathways.

In 1872 H. Quincke proposed that the cerebrospinal fluid leaves the subarachnoid space through small spaces surrounding the nerve roots.

In 1875 Key and Retzius were the first to describe a connection between the cerebrospinal fluid and the nasal mucosa. Using gelatin colored with Berlin blue, they demonstrated circulation of cerebrospinal fluid through the arachnoid granulations into lymphatic vessels and on into the frontal sinus, the nasal mucosa and along cranial nerves.

This model persisted until 1914 when L.H. Weed—

## Glossary

- Adventitia:** external layer of a blood vessel
- Anastomosis:** a communication between two vessels of the body
- Antigen:** any substance recognized by the organism as an aggressor, a foreign substance. Antigens stimulate an immune response from the body.
- Atrophy:** decrease in the size of a tissue or organ due to lack of supply.
- Benign:** not malignant (cancerous) tumor
- Cervical:** a) related to the neck b) related to the cervix of an organ.
- Diffusion:** the natural, random migration of the particles of a substance diffuses naturally from an area of higher concentration to an area of lower concentration. It is a process that doesn't require external energy.
- Edema:** defined by a condition where there is an excessive accumulation of tissue fluid (hydro-colloid) in a local or generalized part of the body.
- Endothelium:** the epithelium that cover the internal layer of a vessel or organ.
- Epineurium:** connective tissue sheath of a nerve.
- Epithelium:** surface layer of a tissue, i.e., epidermis of the skin.
- Evagination:** emergence or protrusion of a tissue or organ from its regular location.
- Etiology:** the cause, origin of disease.
- Filtration:** process that transports a substance through a semi-permeable membrane.
- Hydrostatic pressure:** the pressure of fluid in equilibrium.
- Hyperemia:** increase in the quantity of blood flowing in an area. Usually the region becomes more red and warmer.
- Hypertrophy or hypertrophia:** increase in the size of a tissue or organ.
- Intercellular spaces or interstitium:** the potential space between cells in the organs and tissues of the body.
- Lumen of a vessel:** the space within a vessel.
- Lymphocyte:** lymph cell, part of the white cells of the body.
- Lymphoid:** something that resembles lymph or lymphatic system.
- Lymphology:** the science that studies the lymphatic system.
- Lymphotome (sometimes called territories):** a segmental area of the skin that is drained by the same node group. The lymphotome are separated by watersheds.
- Malignant:** usually cancerous or deadly.
- Osmosis:** the simple diffusion of water through a semi-permeable membrane (a membrane that is not totally permeable to at least one solute substance) between two solutions of different concentrations. It is comparable to diffusion but migrates in one specific direction.
- Perineurium:** sheath of connective tissue around the fasciculus, or bundle of nerve fibers.
- Periorbital:** surrounding the socket of the eye.
- Periosteum:** fibrous membrane that covers the outer aspect of a bone except at the cartilaginous articulations.
- Peristaltism:** smooth, muscular synchronous wave-like movement (e.g. in the intestinal tract).
- Phagocytosis ("cell eating"):** ingestion and digestion of a substance. The substance is surrounded by a huge "seizing foot" and becomes enclosed inside a membrane. Example: the trapping of exterior substances by macrophages.
- Pinocytosis ("cell drinking"):** a substance is contained and solute in a fluid-filled vesicle.
- Polypoid:** in the shape of a polyp; tumor with a pedicule.
- Proteolytic:** the lyse or dissolve proteins.
- Reabsorption (or resorption):** absorption of a substance that has usually been filtrated previously.
- Sclerosis:** fibrous process taking place in a tissue or an organ that hardens its constitution.
- Tunica media:** intermediary layer of a blood vessel, made of smooth muscle cells.
- Ultrafiltration:** filtration in which some substances, but not the liquid, are held back on one side of a membrane.
- Uvea:** middle layer of the eye.
- Vasa-vasorum:** "vessels inside a vessel." The little vessels present in the wall (adventitia) providing nutriments to the vessel and disposing of metabolic wastes.
- Watershed:** the separation lines between lymphatic draining in different territories.

—Bruno Chikley, M.D., D.O. (hon.)

judiciously using two different solutions that would cause precipitation of blue crystals into the lateral ventricles of cats and rabbits—concluded that the arachnoid villi were the dominant way for cerebrospinal fluid to be reabsorbed.

If we re-examine Weed's experiments, we find that while he did see a certain amount of dye coloring the course of cranial nerves and cervical lymphatics, he incorrectly concluded that the lymphatics were an "accessory pathway." In the time since the publication of Weed's model, those beliefs about lymphatic-drainage pathways of the central nervous system have slowly been discarded.

Many other mistakes in standard studies have also minimized the role of lymph in cerebrospinal fluid reabsorption. In 1951 F.C. Courtice and W.J. Simmonds injected radio-labeled albumin, recovering about 5 percent in the cervical lymph nodes. They alleged that 95 percent was reabsorbed by arachnoid villi; in truth, they only recovered 14 percent of all radioactive substances. After new calculations, it is estimated that 30 percent was actually reabsorbed in the cervical lymphatics.

In 1968 the clinician and physiologist M. Földi was one of the first scientists to use ligation of the cervical lymphatics to provoke experimental lymph stasis in dogs (lymphostatic encephalopathy).

Many studies demonstrate that in humans, 47 to 50 percent (or even more) of cerebrospinal fluid can be absorbed through lymphatic pathways under certain circumstances. To give you a comparison, that rate is approximately 30 percent in rabbits and sheep. This reabsorption occurs through both superficial and deep cervical retropharyngeal lymph nodes.

In 1997-1998 M. Boulton and his team demonstrated that about one-half (48 percent) of the protein tracer injected in the lateral ventricles of sheep was transported into extracranial lymphatics. After several experiments, they also showed that at least 50 percent of cerebrospinal fluid is reabsorbed through lymph rather than arachnoid villi.

The increase in cerebrospinal fluid intraventricular pressure even augments the amount of cerebrospinal fluid

drained by lymphatics, and recovery seems to depend on the molecular weight.

Clinical observations help clarify that some of the components of cerebrospinal fluid are reabsorbed in the periphery of the body. J.G. McComb observed that children with hydrocephalus presented with nasal congestion along with facial and periorbital edema when their shunts developed an obstruction.

Strong scientific evidence from human studies is still insufficient to confirm these hypotheses. Smith showed that various tumors of the central nervous system (medulloblastoma, glioblastoma) can metastasize into the lymphatic system; Ogilvy observed gliomas spread to deep cervical lymph nodes.

Even though research continues to explore the relationship that exists between the lymphatic system and cerebrospinal fluid, we can still take a look at what scientific studies have shown us to date—specifically, various known pathways for drainage of cerebrospinal fluid. M

We will continue our exploration of cerebrospinal fluid, cerebral interstitial fluid and lymph in the July/August issue.

*Bruno Chikly, M.D., D.O. (hon.), of France, has trained extensively in both traditional medicine and complementary techniques. He earned the prestigious Medal of the Medical Faculty of Paris VI for his research on the lymphatic system and lymph-drainage technique. He has conducted workshops and lectured on lymph-drainage therapy in France, Belgium, Switzerland, Tunisia, Israel, Canada, Brazil, China and the United States. Dr. Chikly is a member of the International Society of Lymphology and an associate member of the American Academy of Osteopathy and The Cranial Academy.*

This article contains excerpts from *Silent Waves: Theory and Practice of Lymph Drainage Therapy*, by Bruno Chikly, M.D. (The Upledger Institute, 2001.)

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## To learn more...

### Books:

*Silent Waves: Theory and Practice of Lymph Drainage Therapy*, by Bruno Chikly, M.D. (The Upledger Institute, 2001)

*Milady's Guide to Lymph Drainage Massage*, by Ramona Moody French (Milady Publishing Co., 2003)

*The Lymphatic System (Systems of Human Anatomy)*, by Thomas Braem (Bryan Edwards Publishing, 1994)

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