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SPECIAL COMMUNICATION

Lymphatic Drainage of the Neuraxis in Chronic Fatigue Syndrome: A Hypothetical Model for the Cranial Rhythmic Impulse

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The cranial rhythmic impulse is a palpable, rhythmic fluctuation believed to be synchronous with the primary respiratory mechanism. The precise physiologic mechanism of the cranial rhythmic impulse is not fully understood. Based on traditional and current views of the cranial rhythmic impulse, animal studies, and clinical findings in patients with chronic fatigue syndrome, the author argues that the cranial rhythmic impulse is the rhythm produced by a combination of cerebrospinal fluid drainage from the neuraxis (brain and spinal cord) and pulsations of central lymphatic drainage induced by the sympathetic nervous system. In addition, evidence is provided to demonstrate that a disturbed, palpable, and visible neurolymphatic process leads to chronic fatigue syndrome. This process may also explain the pathophysiologic mechanisms leading to other disease states. Finally, the author's proposed manual treatment protocol for patients with chronic fatigue syndrome is described.

J Am Osteopath Assoc. 2007;107:218-224

Central to the principles of osteopathic medicine in the cranial field is the presence of the primary respiratory mechanism, which involves a separate palpable rhythmic motion in addition to the motion of normal breathing.[1,2] Also referred to as the cranial rhythmic impulse (CRI), the primary respiratory mechanism is palpable throughout the body.[2] Woods and Woods,[3] who coined the term "CRI," recorded the average rate of the CRI as 12.47 beats, or cycles, per minute (bpm), with the rate for healthy adults ranging from 10 bpm to 14 bpm. This rate has been quoted by several authorities in the cranial field.[4-6] Other studies,[7,8] relying on palpation of the CRI, have recorded values between 3 bpm and 9 bpm. Nelson and coauthors[9] recorded a mean palpated CRI rate of 4.54 bpm. They suggested that the common neurophysiologic pathway for many low-frequency oscillations exists via activity of the sympathetic nervous system.[9]

An interesting area of exploration has arisen on the involvement of cerebrospinal fluid and lymphatic drainage in patients with chronic fatigue syndrome (CFS).[10] During the past 2 decades, I have observed hundreds of patients with this disorder who had CRIs and lymphatic drainage disturbances that were similar to each other and, apparently, intrinsically linked. These observations—together with a review of previous studies involving the CRI—led to the hypothesis investigated in the present study:

> *The cranial rhythmic impulse is the rhythm produced by a combination of cerebrospinal fluid drainage from the neuraxis (brain and spinal cord) and pulsations of central lymphatic drainage induced by the sympathetic nervous system.*

In the present article, I also discuss evidence that CFS results from a disturbed, palpable, and visible neurolymphatic process. Furthermore, this process can be managed clinically with the combination of manual techniques I outline.[11]

Cranial Rhythmic Impulse

A number of attempts have been made to explain the CRI.[12,13] Nelson[13] suggested that the intrinsic movements of cranial bones, fascia, and organs may be caused by local venomotor pulsation, the reflection of which may be palpable at the skin surface. However, the absence of contractile tissue in the veins and sinuses of the brain makes this theory difficult to accept. The cerebral veins are unique in that they possess no muscular tissue in their thin walls and have no valves.[13] Any palpable venous pulsations in the head are possibly mere remnants of larger vasometric pulsations of the inferior vena cava and iliac vein.

The cerebral veins descend from the brain into the subarachnoid space by penetrating the arachnoidea mater and the meningeal layer of the dura mater, thereby draining into the cranial venous sinuses.[14] However, as proposed by Vern and colleagues,[15] other underlying processes may also be at work. Their experiments, which directly measured cortical cytochrome-*c* oxidase redox fluctuations in unanesthetized cats, "...strongly suggest that the cyclic increases in cortical oxidative metabolism represent the primary oscillatory process, followed by reflex hemodynamic changes."[15]

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Submitted August 3, 2006; final revision received January 18, 2007; accepted January 29, 2007.

Contrary to the traditional concept that lymph has no pump of its own, the main lymphatic vessels are now known to be under sympathetic control.[14,16] When the smooth muscle wall of the thoracic duct is stimulated, a wave of contraction is produced that aids lymphatic drainage into the subclavian vein.[16-20] This drainage, in turn, produces negative pressure along the lymphatics, further assisting the process. The resulting peristaltic wave within the normal human thoracic duct was found to occur at 4 bpm with a maximum pressure of approximately 10 mm Hg, building up to 50 mm Hg when obstructed.[17]

Investigations of the Fluid Drainage System

Although it has been established that the central nervous system does not contain a true lymphatic system, there is considerable evidence for a robust fluid drainage system that is in many ways analogous to that of the lymphatic.[20-37] Through this system, cerebrospinal fluid drains into the facial and spinal lymphatics.[20-37] Sutherland[2] emphasized the importance of the choroid plexus in the chemical exchange between cerebrospinal fluid and the blood, but he also stressed the role played by the lymphatics in the drainage of toxins from the neuraxis. He wrote:

> When you tap the waters of the brain by compressing the fourth ventricle, see what happens in the lymphatic system. Visualize the lymph node that is holding some poison that has gathered there, changing the constituency before the lymph is moved along into the venous system.[2]

The founder of osteopathic medicine, Andrew Taylor Still, MD, DO,[38] discussed the importance of examining disturbed fluid motion in the head to determine the pathogenesis of such symptoms as dizziness, headache, and memory loss—all of which are associated with CFS. As he wrote, "We strike at the source of life and death when we go to the lymphatics."[38] Dr Still emphasized that, along with sufficient blood supply, it is equally important to have perfect drainage.[38]

In 1869, Schwalbe[21] demonstrated in rabbits that there was a connection between the subarachnoid spaces and cervical lymphatics. Sutherland[1] postulated that gentle pumping action caused by one or more bones around the facial sinuses drains the mucus that is produced in the goblet cells of the sinus epithelial lining. This drainage facilitates the wafting action of ciliated epithelium, forcing the mucus into the nasopharynx.[1] When mechanical or other forces damage this mechanism, the sinus is less able to drain mucus. As a result, the mucus pools and thickens, rendering the patient prone to infection.[1] The nasal mucosa may then become continually inflamed with an abundance of purulent mucus and associated enlargement of the tonsilla pharyngea.[1] Speransky[22] first described the existence of a direct link between the cerebrospinal fluid, nasal lymphatics, and cervical lymphatic vessels. It has since been determined that lymphatic vessels in the submucosa of the nasal sinuses are the initial recipients of the drainage of cerebrospinal fluid through the cribriform plate.[23]

Quinke[39] hypothesized in 1872 that there was drainage of cerebrospinal fluid from the subarachnoid spaces through small passages along the nerve roots. Other researchers[24-26] have shown a small but significant drainage that takes place via the dural lymphatics, which run parallel to the spinal cord. Tracer material injected into the brain's cerebrospinal fluid in rabbits accumulates in the cuffs around the spinal nerve roots, which form a link between the subarachnoid spaces and the lymphatics.[26] It has also been shown in rabbits that there is a flow of fluid from the brain to the deep lymph nodes of the neck, as well as a flow of fluid from the nasal mucosa to the brain.[26]

The spinal component of cerebrospinal fluid accounts for approximately 25% of total cerebrospinal fluid transport in sheep.[24] The cerebrospinal fluid of sheep is drained out of the spine via the microscopic spinal granulationes arachnoideales, which are similar to the granulations found in the choroid plexus of the human brain's superior sagittal sinus.[24]

The system of cerebrospinal fluid drainage in humans is believed to be similar to that in other mammals, though the cerebrospinal fluid's lymphatic component is proportionally much smaller in humans.[20,23,35] As in other mammals, the drainage of cerebrospinal fluid in humans includes pathways from the cranial and spinal subarachnoid spaces across the arachnoid villi. The pathways then continue to the dural sinuses and along the cranial nerves—mostly via olfactory pathways through the cribriform perforations—and along the spinal nerves to the lymphatics (*Figure 1*).[20,23,35]

This bidirectional movement of cerebrospinal fluid is poorly understood. However, the movement is ultimately dependent on the relative pressures in the subarachnoid spaces at different parts of the neuraxis and in the central nervous system's parenchyma.[28] In the rabbit, approximately 30% of the total normal cerebrospinal fluid drainage occurs via these routes, while this proportion is 10% to 15% in the cat.[29] It has also been shown that almost half of the total volume of cerebrospinal fluid in sheep drains into the extracranial lymphatics, especially in the cervical region.[30] In addition, the cerebrospinal fluid drainage into the cervical lymphatic system increases with greater intracranial pressure.[30]

By tilting the angle of an experimental animal's head by 20 degrees horizontally to the right or left, the drainage from the brain to the cervical lymph can be markedly increased.[31] This demonstration indicates that gravity affects the flow of lymph. Such drainage may further act as a valve to relieve intracranial pressure, which would explain why pressure did not build up until the "breaking point" was reached in a study of hydrocephalic rats.[32]

Pathogenesis of Chronic Fatigue Syndrome

Based on the detection of mechanical dysfunction in the cranium and spine of patients with CFS—as a result of past trauma (*Figure 2*) and postural disturbance (*Figure 3*)—I propose that these pathways of cerebrospinal fluid drainage are mechanically compromised as part of the common pathogenesis in patients with this condition.[10,40] Cervical and thoracic lymphatic engorgements can be palpated in most patients with CFS, with some patients also showing visible surface varicosities (*Figure 4*).

Lymphatics and Fluid Mechanics

As early as the 1890s, Dr Still[38] noted, "The lymphatics are closely and universally connected with the spinal cord and all other nerves, and all drink from the waters of the brain." From the earliest days of osteopathic medicine, the importance of adequate lymphatic drainage in the thoracic duct has been considered paramount to sustaining health. Dr Still[38] wrote:

> At this point I will draw your attention to what I consider is the cause of a whole list of hitherto unexplained diseases, which are only effects of the blood and other fluids being prohibited from doing normal service by constrictions at the various openings of the diaphragm. Thus prohibition of the free action of the thoracic duct would produce congestion of the receptaculum chyli, because it would not be able to discharge its contents as fast as received.

The thoracic duct pump acts as suction for the lymphatics throughout the body[16-20] and influences the drainage of toxins from the central nervous system.[23-27] Together with the average adult pulse rate (50-100 bpm)[41] and the overall influence of ventilation (10-18 breaths/min),[41] a separate underlying rhythm is induced: the source of the CRI.

Cerebrospinal fluid moves intracranially at the same rate as the beating of the heart.[42] In addition, it normally flows within the ventricular system of the brain at approximately 600 cm per minute.[43] The approximate blood flow in the carotid bodies in the neck (ie, in 100 g of tissue), just after leaving the heart, is 2000 mL/min (selective perfusion), whereas normal blood flow in the brain is about 65 mL/min (selective cerebral perfusion).[41] The flow of lymph in the thoracic duct is known to be between 1 mL and 2 mL per minute between meals, though it may increase by up to ten times that rate during ingestion and absorption of a meal.[44] These influences of fluid mechanics in drainage are summarized in *Figure 5*.

Using known parameters and computerized models of the biomechanical influences affecting the lymphatic drainage of the brain, a study is being planned at Manchester Metropolitan University in England to calculate a reference range of values for this drainage rhythm. The study will also investigate how this rhythm compares with the many values postulated for the CRI.[3-8]

Clinical Findings

There have been various explanations for the CRI focusing on other rhythmic pulses, such as the Traube-Hering-Mayer oscillation, which is associated with blood pressure feedback.[44]

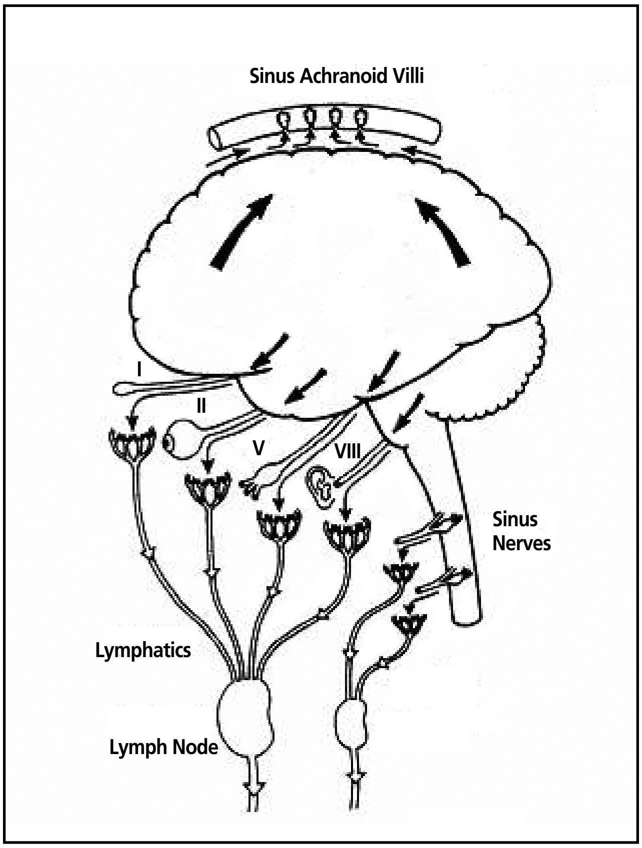

Figure 1. *Cerebrospinal fluid drains from the human brain in three main pathways: into the sinus arachnoid villi, down the spine into the paravertebral lymphatics, and along the cranial nerves (I, olfactory; II, optic; V, trigeminal; VIII, vestibulocochlear). The cerebrospinal fluid then flows into the facial, cervical, and thoracic lymphatics. Reprinted with permission from: Knopf PM, Cserr HF, Nolan SC, Wu TY, Harling-Berg CJ. Physiology and immunology of lymphatic drainage of interstitial and cerebrospinal fluid from the brain.* Neuropathol Appl Neurobiol. *1995;21:175-180, Blackwell Publishing.*

It has even been shown that cranial manipulation has an effect on the Traube-Hering-Mayer frequency component of blood flow velocity.[45] However, clinical assessment of hundreds of patients using palpatory techniques similar to those described by Sutherland[2] has revealed an arrhythmic, restricted, and sometimes almost nonexistent CRI in individuals with CFS. The CRI in these patients was palpated by placing the palmar surfaces of the hands on the parietal bones to determine sidebending or rotation patterns.[2] This palpation was also used to determine proprioception of the occipitoatlantal squamae as a way of analyzing anteroposterior shifts.[2] Clinical findings in these patients coincided with lymphatic pump reversal leading to palpable engorged varicose lymphatics (*Figure 4*).

Congestion results in an impaired CRI. Alternatively, the cause could be the reversal of flow of the cerebrospinal fluid

Figure 2. *Multiple scarring on the forehead of a man with chronic fatigue syndrome (CFS) resulting from old trauma predating the onset of CFS symptoms.*

Figure 4. *Left subclavicular varicose lymphatic vessels under the skin at the anterior medial aspect of the left shoulder in a patient with chronic fatigue syndrome. Lymph fluid is creamy white in color, containing no red blood cells. Thus, the surface varicosities are the same color as the surrounding skin and do not have the bluish-purplish hue seen in varicose veins.*

Figure 3. *Posturomechanical disturbance in the thoracic spine of a patient with chronic fatigue syndrome (CFS). This disturbance—minor scoliosis in the lordotic region—represents the most common postural presentation in patients with CFS.*

into the lymphatics. Both processes may lead to a buildup of toxic debris that could affect normal cerebral function. As Dr Still stated more than a century ago, "Harmony only dwells where obstructions do not exist."[46]

Manual Treatment Protocol

The treatment program I developed for patients with CFS is designed to increase neurolymphatic drainage, thereby reducing toxicity within the central nervous system and restoring proper health.[11,47] The manual treatment protocol consists of the following six stages:

1. Effleurage techniques directed toward the subclavian region, aiding drainage of the cervical and thoracic lymphatics and resulting in increased central drainage of the lymph into the subclavian veins to reverse backflow
2. Long- and short-lever techniques to achieve gentle articulation of the thoracic and upper lumbar spine as well as the ribs
3. Soft-tissue massage of the levator scapulae, paravertebral muscles, respiratory muscles, rhomboids, and trapezii
4. High- and low-velocity manipulation of the thoracic and upper lumbar spinal segments with combined supine and side-lying leverage and thrust techniques
5. Functional manipulative techniques to the suboccipital region and the sacrum
6. Stimulation of the CRI by compression of the fourth ventricle

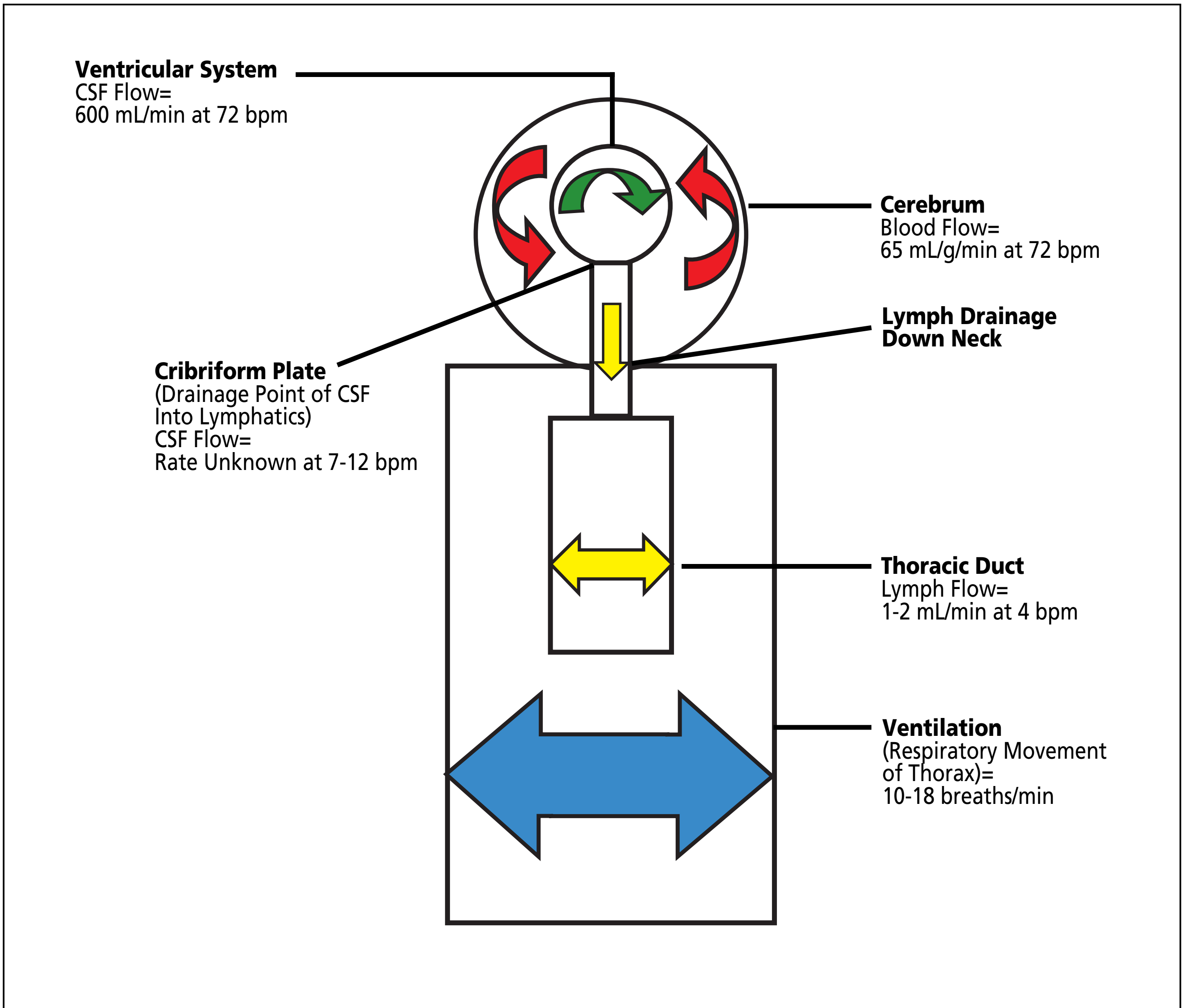

Figure 5. *Schematic diagram demonstrating the influences of fluid mechanics involved in the drainage of cerebrospinal fluid from the neuraxis. Flow rates shown are averages for healthy adults.* ***Abbreviations:*** *bpm, beats per minute; CSF, cerebrospinal fluid.*

In addition to the techniques described, patient self-care is recommended in the form of prescribed exercises designed to improve mobility in the thoracic spine.

Conclusion

Besides its importance to the combination of manual techniques recommended for patients with CFS,[11,47] the lymphatic drainage of the neuraxis also forms the basis of other treatment modalities in osteopathic medicine.[41,48] However, the manual techniques used in other treatments (eg, abdominal and thoracic pump)[49] as well as the Vodder technique,[50] act primarily to increase sluggish lymphatic flow. Although retrograde flow is usually presumed to be prevented by valves,[51] this biomechanical protection is not evident in patients with CFS. In these patients, clinical findings, which include photographic evidence, demonstrate that lymphatic reflux can weaken these valves, resulting in palpable varicose lymphatic vessels that are occasionally visible at the skin surface (*Figure 4*). Also, any treatment that stimulates lymphatic flow carries the risk of advancing the lymph further in the retrograde direction. That is why part of the proposed treatment modality involves direct stimulation of lymphatic drainage using effleurage aimed toward the subclavian veins and against the backflow.

An improvement in the main symptoms of CFS coincided with an improvement in central lymphatic drainage—and a stronger, more rhythmic CRI. This finding supports the view that the neurolymphatic flow described in the present article is identical to the CRI. If this view is proven correct in subsequent studies, the ramifications for the future of osteopathic medicine are immense—providing a probable scientific basis for the use of manual treatment not only in patients with CFS, but for those with a variety of other disorders.

Acknowledgments

I thank the David and Frederick Barclay Trust for providing funds for this study's original research, and the Fund for Osteopathic Research into Myalgic Encephalomyelitis for its continuing funding and support. In addition, many thanks to Will Podmore, chief librarian at the British School of Osteopathy, for his assistance with the references and editing of this article.

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