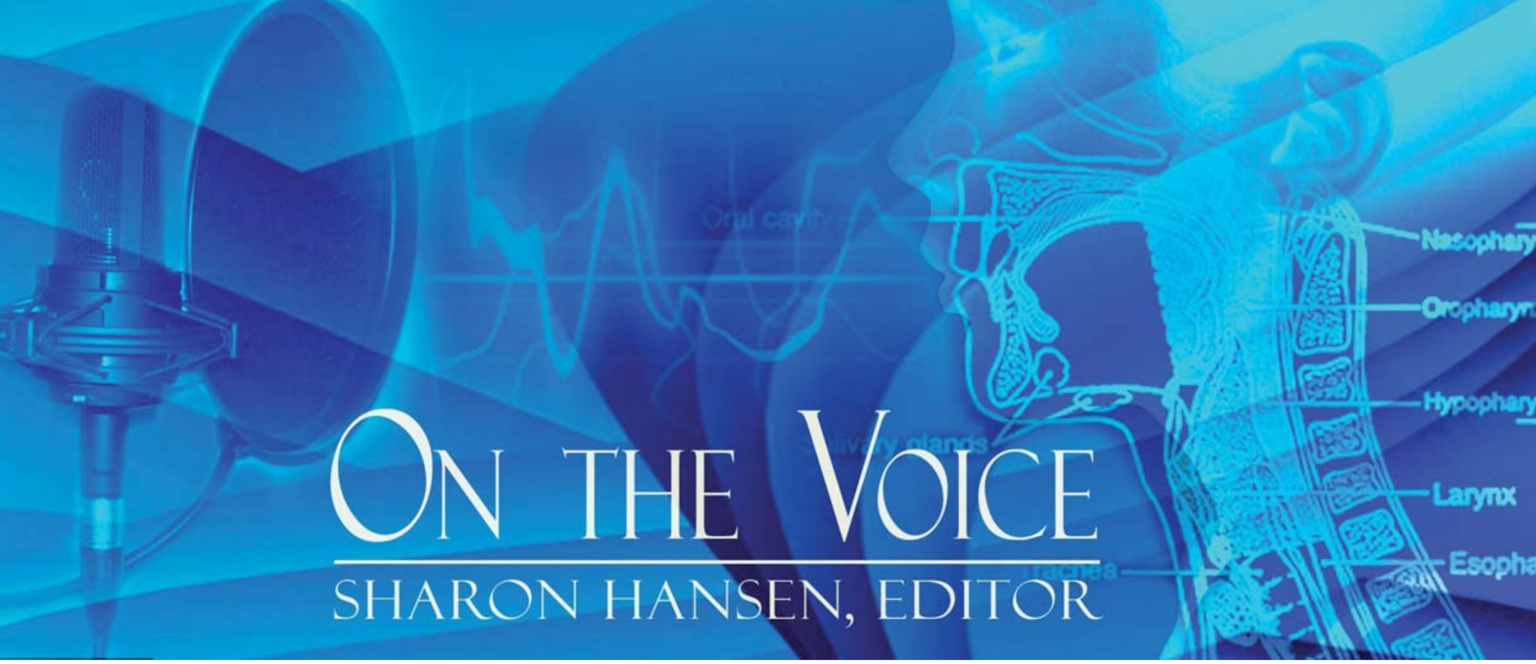

Viva La Vagus!

by

Miriam van Mersbergen

Lights, music, excitement: that is what Las Vegas has to offer. The bustle of the Vegas Strip dazzles and amazes. In all the drama of that city, however, little attention is given to the electricity that lights it up. When one thinks of Las Vegas, they may conjure many images, but probably none will be of the power cords that make that city run.

Similarly, when we wax eloquent or transcend through singing, we rarely give thought to the power cord making all of our efforts possible. Over the past fifty years we have developed rich voice training traditions, sophisticated theories of voice production, and a comprehensive understanding of laryngeal health. We have come a long way in appreciating the unique nature of the tissues of the vocal folds and protecting their delicate but strong vibrating edge.[1]

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We have ample evidence that voice training provides excellent protection from injury and harm and have begun to develop sophisticated motor theories especially for voice production.[2] Our multi-disciplinary perspective of voice science frequently takes for granted the nerve that supplies the vocal folds with power and gives them life.

The Vagus Nerve and its Home, the Nervous System

The nervous system is the communication network of our body. It sends commands for us to move, breathe, digest, pump blood, secrete hormones and chemicals, regenerate, feel, and even think.[3] It is divided into the Central Nervous System (CNS) and the Peripheral Nervous System (PNS).[4] The CNS houses the brain and spinal cord, and the PNS is comprised of the nerves that go out to the muscles, soft tissues, glands, and organs of the body.[5] The PNS helps maintain homeostasis, encourage metabolism, control muscles, release glandular secretions, and decode environmental phenomena into perceived reality (e.g. sight and hearing).[6]

The basic unit in the nervous system is called a nerve. Its main function is to communicate.[7] Nerves contain three basic parts: a cell body called a soma, dendrites that carry information from other structures (other nerves, glands, muscles, etc …) to the soma, and axons, which carry information away from the soma to the next structure.[8] The relay of messages along these nerves can be simple as a reflex.[9] However, nerve communication is often much more complicated, involving many nerves to and from the brain in an elaborate bucket brigade of signals.[10]

Nerves communicate with each other by way of electrical signals generated in the soma and traveling down the axon to an end point.[11] At this end point the electrical signal releases a chemical into the space between the axon and the next structure (usually another nerve but sometimes a muscle or gland).[12] Depending on the chemical, the next structure is either activated or shuts down. Subsequent sets of electrical signals travel along dendrites into the soma of the next nerve.[13] This form of electrical communication continues until the system completes is function.

Most peripheral nerves travel in bundles, similar to electrical wires, and exit the CNS from the spinal cord. However, twelve peripheral nerves, called Cranial Nerves, exit the brainstem. They regulate the muscles, glands, and sensory organs of the head and neck and are identified by Roman Numerals.[14] Cranial Nerve X, the largest of these nerves, is called Vagus Nerve.[15] Beginning in the brainstem, the nerve travels through the jugular foramen (the large hole at the bottom of the skull), into the neck, and down through the thoracic cavity to the abdomen.[16] *Vagus,* the Latin for "wandering," appropriately reflects the nerve's meandering pathways.[17]

Leaving the brain stem, the vagus nerve branches off in different directions and extends as far down as the abdomen.[18] Many of these branches are named according to their function, such as the auricular branch, which conveys sensory information from the skin inside the external ear canal and tympanic membrane, and the laryngeal branch, which innervates the larynx.[19] Most branches of the vagus travel far below the larynx into the thorax and abdomen and assist in the regulation of the organs, glands, and soft tissue of these regions.[20]

The vagus nerve carries messages from the CNS to the body (efferent/motor) and relays messages to the CNS from the body (afferent/sensory).[21] The cell bodies of this nerve are housed in four large areas in the brain stem, creating a hub where nerves from different parts of the body communicate with each other.[22] The proximity of nerve cell bodies in this area allow various parts of the body to communicate complicated information with each other, allowing for sophisticated processing of information.

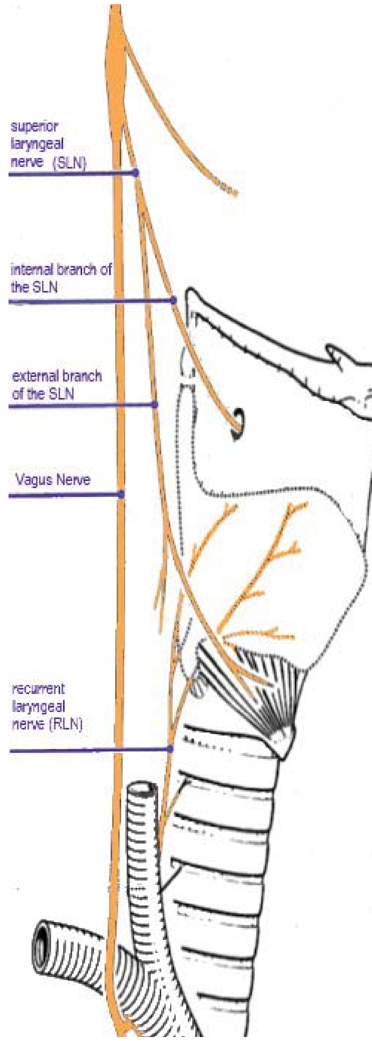
The Vagus Nerve and Voice Production

Three branches of the vagus nerve are involved in voice production: the pharyngeal branch, the recurrent laryngeal branch, and the superior laryngeal branch.[23] When the pharyngeal branch leaves the brainstem and deviates, it travels to the mucous membranes and muscles of the pharynx, carrying sensory information from this area to the brain.[24] When you have a throat infection, for example, the vagus nerve carries the information that lets you know your throat is sore. The pharyngeal branch also innervates most of the muscles of the pharynx and allows the palate to lift, maximizing the resonating space in our throat and creating those rounded tones we desire.

The recurrent laryngeal branch leaves the larger laryngeal branch and terminates in the larynx. It is called *recurrent* because it travels past the larynx into the thorax and loops up into the larynx from below. On the right side, the nerve travels around the subclavian artery (right below the right clavicle), circling back into the larynx. The left side

travels further, winding around the aorta before returning back to the larynx.[25] The implications of right and left differences will be discussed later. The recurrent laryngeal nerve innervates most of the muscles in the larynx, particularly the muscles responsible for opening and closing the vocal folds, which is necessary for voicing.[26] This nerve also innervates some of the muscles of the lower pharynx and esophagus to assist in swallowing. It transmits sensory information from the mucous membrane of the upper trachea right below the vocal folds.[27]

The superior laryngeal nerve also exits the larger laryngeal branch, splitting off into two smaller branches.[28] The intrinsic branch, which carries sensory information about the mucous membranes of the larynx, is active in providing information during a cough response. The extrinsic branch innervates the cricothyroid muscle, a laryngeal muscle responsible for pitch control during voicing.[29]



Vocal Difficulties from Vagus Nerve Damage

Voice impairment arises when the vagus nerve is damaged. The most devastating impairment arises when damage occurs to the recurrent or superior laryngeal nerves.[30] Injury to the recurrent laryngeal nerve impairs the ability of the vocal folds to open and close by weakening or paralyzing the muscles responsible for these actions. At best, poor closure of the vocal folds leaves a speaker or singer with a soft, breathy, asthenic voice—unable to sustain sound for more than 4–5 seconds at a time. It can cause irregular vibration of the vocal folds, leaving the voice not only weak but hoarse, with pitch breaks, cracks, and diplophonia (two pitches at once). Individuals with recurrent laryngeal nerve injuries frequently complain of feeling out of breath during speaking and singing. The cause of nerve injuries arises from complete severing of the nerve, partial tearing of the nerve, stretching the nerve, compressing the nerve, or disease residing in the nerve cell body.[31] Because the recurrent laryngeal nerve travels into the thorax, any thoracic surgery places an individual at risk for injury.[32] As discussed earlier, the left sided recurrent laryngeal nerve travels around the aorta. So, injuries on the left-side can be seen often in cardiac surgeries when the surgeon has to stretch the nerve to retract it or to gain access to the heart.[33] Sometimes the nerve is severed during tumor removal. At times viral infections reside in the cell bodies of the recurrent laryngeal nerve, causing damage to nerve functioning.[34]

Recovery from recurrent laryngeal nerve injury is directly related to the degree and extent of the damage.[36] Damage from a mild stretch or compression of the nerve may resolve quickly, and normal voicing may return within a few months. When damage is considerable, however, recovery might not be complete and normal functioning my never return, rendering an impaired voice.[37] Treatment for larger nerve injuries includes surgical procedures that can assist in vocal fold closure, therapy to facilitate optimal voicing and reduce poor compensations for weakness, and a combination of both. Such treatments are available at regional and national voice centers where an individual may consult with a laryngologist (an ear, nose, throat physician specializing in voice), a speech language pathologist specializing in voice, a registered nurse, and occasionally a singing teacher who works directly with the medical team.

Superior laryngeal nerve injuries have similarly devastating effects on voicing. Because the superior laryngeal nerve is responsible for sensation in the larynx, damage to this nerve can either leave an individual with hyposensitivity, placing him or her at risk for aspiration because saliva and food can enter the airway without proper detection.[38] Additionally, some superior laryngeal nerve damage can leave a larynx with hypersensitivity, which causes an individual to have excessive coughing with minor sensory changes.[39] In some cases individuals can develop excessive coughing reactions after smelling faint odors, breathing in deeply, or changing neck positions. The superior laryngeal nerve also innervates the cricothyroid muscle, which is responsible for pitch changes. A hallmark symptom of damage to this nerve is the inability to raise pitch above mid-range, despite Herculean efforts.[40] The vocal folds also have difficulty closing completely, because while the cricothyroid muscle stretches the vocal fold, it places the vocal folds on a different plane. When one vocal fold remains unstretched due to damage, this plane difference creates a gap, allowing for air leakage. Superior laryngeal nerve injury also arises from severing, tearing, and stretching the nerve. Because the superior laryngeal nerve travels through the thyroid gland, thyroid surgeries place an individual at risk for damage. Recovery and treatment of the superior laryngeal nerve, similar to recovery and treatment of the recurrent laryngeal nerve, is available at regional and national voice centers. Although vocal fold closure can be achieved surgically, pitch functioning, which is necessary for singing, unfortunately cannot be surgically repaired.[41]

Injuries to the pharyngeal branch of the vagus nerve are far less common.[42] Although such an injury does not directly affect voice functioning, it can impair an individual's ability to elevate the soft palate and move the muscle of the pharynx to create the necessary space for optimal resonance. Damage can leave an individual sounding hypernasal with a soft, muffled quality.[43] Prosthetic devices can assist an individual in maintaining a moderately elevated velum, but at this point they cannot assist in volitionally elevating the velum or widening the pharynx during singing.

Master of our Well Being

Traveling down past the neck and into the body, the vagus nerve performs some of its most vital tasks. Its main function is to regulate the Autonomic Nervous System (ANS), a special part of the nervous system that maintains the homeostasis of body functions, such as heart rate, respiration rate, blood pressure, body temperature, and digestion.[44] When homeostasis is disrupted through exercise, illness, or stress, a subsystem of the ANS, the Sympathetic Nervous System, kicks in and prepares the body to move, respond, or adapt to the change.[45] This state of readiness is also known as the Fight or Flight System. When the stress is over, the Parasympathetic Nervous System down-regulates the body, bringing its functions back to baseline. Working in opposition to the Fight or Flight System, the Parasympathetic Nervous System is known as the Rest and Digest System.[46]

We can thank the vagus nerve for keeping the heart rate from elevating too high for too long, maintaining blood vessel constriction (which regulates blood pressure) during activity, reactivating the digestive system after being shut down, and stabilizing the respiration rate and making sure it coordinates with the heart. When these branches are disrupted, individuals can experience arrhythmias (irregular heart beat), dizziness, shortness of breath, and a variety of digestive disorders, such as irritable bowel syndrome.[47]

New Mysteries Unfolding

Because of its communication between the viscera and the brain, the vagus nerve plays an important role in body/brain interactions. Recently, neuroscientists have found a link between the presence of good gut bac-

teria (probiotics) and elevated mood and improved cognition. In a series of animal and human studies, researchers have found that organisms with bad gut bacteria show signs of depression and poor attention, but that this state can be reversed by introducing healthy bacteria.[48] Apparently, good bacteria produce approximately 95 percent of the body's serotonin, a neurotransmitter responsible for improved mood.[49] At first researchers were puzzled by the suggested link between gut bacteria and mood. But a growing understanding of the vagus nerve's role in communicating gastrointestinal information to the brain has made the brain-gut connection an exciting new area of research.[50]

The vagus nerve appears to also assist in regulation of inflammatory responses from the body. Vagal communication between inflammatory responses and the brain can also allow the brain to regulate this inflammation and promote adaptations to acute injury and chronic irritation. Taylor and colleagues[51] noted that vagal tone, a measure of the vagus's ability to regulate the PNS, is associated with depression and inflammation in individuals who smoke tobacco, confirming a relationship between vagus nerve functioning and regulation of inflammation.

The vagal body/brain connection does not stop there. The vagus nerve can promote healing following strokes. Anti-inflammatory agents produced by the spleen are transmitted to the brain via the vagus nerve and have been found to reduce extraneous swelling in the brain after stroke. Lee at al.[52] found that simply producing these agents into the brain after stroke was not affective; it was the vagal pathway from the spleen to the brain that was necessary to achieve this anti-inflammatory effect. Other researchers[53] have found that the production of anti-inflammatory agents from the spleen have been important in regulating inflammation observed in arthritis, pancreatitis, and additional inflammatory diseases. Vagal connections with the visceral organs have also promoted regulation in the endocrine system. Dockery[54] recently published an article outlining the role of vagal nerve pathways in diabetes, obesity, and nutrient transfer in the stomach.

Because of its function in communicating visceral activity with the brain, the vagus nerve has been used to assist in controlling the communication between body and brain when the brain malfunctions. Vagal nerve stimulators, like pace makers, send regular, clear messages to the brain, allowing the brain to respond in more adaptive ways. The stimulator is a small coil that is wrapped around the nerve and is controlled by a small magnet placed directly under the skin on the chest.[55] Vagal nerve stimulators have been used to control drug resistant epilepsy, relieve intractable depression, which is unresponsive to any forms of medical and behavioral therapy,[56] and may even regulate behavioral symptoms of autism.[57] Recent applications to vagal nerve stimulators assist in controlling anxiety, improving cognitive function in patients with Alzheimer's, and managing migraines.[58]

The vagus nerve's influence in brain/body interaction has led psychologists and neuroscientists to develop theories of how the vagus nerve is responsible for emotional development in children. The polyvagal theory[59] is one such theory that suggests that the vagus supports social interaction between individuals by preparing an organism to interact with

others. The theory suggests that the vagal role in the parasympathetic nervous system assists in reducing stress reactions that might occur with increased physical proximity or communication that occurs in unknown situations. The vagal down-regulation of stress responses can explain why individuals appear to have reduced heart rate and blood pressure when interacting with other individuals and animals, lending support to the notion that petting our furry or feathered companion is good for our cardiovascular health.[60]

The vagus nerve is a truly amazing nerve, the superhighway of life responsible for keeping us alive and thriving in an ever-changing environment. Recent research points to the vagus nerve as an indispensable link in communication between the brain and body. However, vagal functioning truly shines in its ability to allow us to voice and speak, to communicate our wants, needs, and desires. What further evidence do we need than the transcendence of singing to place voicing as a vital part of the human condition. *Viva la Vagus!* CJ

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