Vibration Perception Thresholds in Entrapment and Toxic Neuropathies

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Due to the ever-increasing problems associated with carpal tunnel syndrome in the workplace where exposure to neurotoxic substances may also occur, measure of nerve function addressing both of these neuropathies is needed. Limitations in the standard neurological examination and nerve conduction studies have resulted in efforts to develop portable instruments for quantitative sensory testing. Fingertip vibration perception is altered in carpal tunnel syndrome and toxic neuropathies. Vibration perception is described for the median-innervated II digit and the ulnar-innervated V digit using an Optacon tactile stimulator. Discussion focuses on the interaction between toxic and entrapment neuropathies as reflected by vibration thresholds.

The role of the neurologist in neuroepidemiology has been aptly described: "The concept of neuroepidemiology arose because of the nature of neurology versus other branches of medicine. In other fields, the signs and symptoms lead directly to diagnosis. In neurology this is not the case; signs and symptoms reflect the localization of lesion(s) in the nervous system. When one part of the brain or spinal cord is malfunctioning, the same clinical phenomena will be seen whether the cause of the malfunction is a tumor, an infarct, or a demyelinating placque. The ability to, first, localize the lesion and, second, assign it to a specific cause defines the neurologist. Consequently, the neurologist must play an essential part in any inquiry into the epidemiology of neurological diseases . . . . The neurologist is responsible not only for the label, but also for what that label implies in course and treatment. These aspects, and the biological 'feel' for the illness, are of major importance to the conduct of an epidemiological study of neurological disease."[1] However, establishing a label and biological "feel" is not sufficient in occupational neurology where the ability to quantify an impairment for monitoring is needed, especially for longitudinal follow-up.

Toxic and entrapment neuropathies are frequent problems encountered in occupational neurology and are difficult to objectively quantify. Peripheral neuropathies have classically been evaluated with the neurological examination, a relatively sensitive tool. However, there exists a lack of standardization in its administration and interpretation. One objective test, nerve conduction velocity, is used for documenting the severity of an impairment in the peripheral nervous system and is dependent upon the nature of the underlying pathology.

There are several factors that influence the speed with which the action potential is transmitted along the length of the nerve. Optimal ratios of myelin-to-axon occur when the axonal diameter is about 60% of the total nerve fiber diameter. Alterations in myelin thickness by various disease status are reflected in decreased conduction velocity. Internodal length is a direct reflection of the size of myelinated nerves with the large myelinated nerves having long internodal distances, whereas small fibers have shorter lengths. In remyelination, shorter internodal lengths exist, producing slower conduction velocities due to the short internode lengths on large axons. Temperature, a confounding variable, must be carefully controlled or, otherwise, it will result in abnormal conduction velocities in healthy persons. Effect of age on nerve conduction velocities results in a reduction in the mean conduction rate of approximately 10% at 60 years. Aging also causes a decrement in sensory conduction and changes in the shape of the evoked potential.

Toxic neuropathies usually produce axonal degener-

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ation, resulting from widespread metabolic derangement throughout the entire neuron, which manifests itself as distal axonal breakdown. The resulting clinical picture is that of a polyneuropathy, frequently involving the longest and largest fibers.[2] Nerve conduction studies may be insensitive early in the disease process due to the predominantly axonal and not myelin pathology.[3]

Entrapment neuropathies initially produce segmental demyelination with sparing of the axon. Acute conduction loss occurs without structural change in the axon.[4] Fibers usually recover promptly, although the conduction velocity may be slowed for a time if there is associated demyelination. Chronic entrapment is also associated with focal demyelination. However, in this condition, even after treatment, conduction may remain abnormal or partially improve following treatment. Pathological studies have demonstrated axonal loss of large fibers predominantly at the site of compression accompanying those demyelinative lesions.[5]

In carpal tunnel syndrome, entrapment of the median nerve at the wrist, the loss of large axons has been demonstrated to extend to the digital nerves in the fingers.[6] This pathology in the median-innervated digits overlaps in location with that found in toxic neuropathies where the greatest axonal pathology is located distally in the largest axons.

Sensory signs and symptoms are usually the only manifestations of early stages of disease in the peripheral nervous system. Limitations in nerve conduction studies, especially when screening for early evidence of peripheral neuropathy, have resulted in efforts to develop portable instruments which can quantitate sensory impairment. These instruments can employ sensitive and precisely defined quantifiable stimuli, as well as the best available methods of testing and scoring, to assess sensation accurately and objectively. They can be automated to obtain optimum efficiency and eliminate both testing and observer variability, thus eliciting responses that are both quantifiable and reproducible. The frequency range and the disappearance time of vibrations from a tuning fork used by earlier observers have been supplemented by threshold determinations made by means of electromagnetic devices.[10–17] Dyck et al[18] developed a system for sensory evaluation in which vibration was assessed with a stimulus whose waveform could be precisely defined and quantified and which would vary over a wide range. This system is not subject to damping, one of the major problems with the electromagnetic vibrators. Furthermore, stimuli are applied at discrete skin points rather than to bony protuberances, thereby preventing transmission by long bones to anatomical sites distant from the test site. This elegant system is impractical for screening in the workplace due to the size of the equipment and time necessary for testing.

The modified Optacon[7] tactile stimulator is a portable, battery-powered unit weighing 4 pounds. It was originally designed for use in concert with a camera module to enable blind persons to read independently of Braille.[19] The stimulator consists of 144 miniature rods organized into a matrix of six rows with 24 pins, with a 2-mm horizontal and 1-mm vertical interod spacing. Each rod protrudes through a contoured plastic plate and contacts a discrete portion of the skin. The rods vibrate continuously at 230 Hz; the height that the rods extend above the plate and the amplitude of vibration vary as a function of voltage. The Optacon is believed to stimulate the rapidly adapting mechanoreceptors, the pacinian corpuscle, because its maximum sensitivity occurs at 200 to 300 Hz. Impairment of vibration sensibility, starting distally in the limbs, may be an early sign of peripheral neuropathy.[8,9] Measurement of perception thresholds can be used as an index of subclinical disease from metabolic-nutritional disorders or environmental toxic agents, where patients themselves are unaware of the defect. Because vibration sensation is mediated by the largest afferent nerve fibers, the vibration threshold reflects the functional integrity of these sensory fibers.

The hand is positioned within the Optacon stimulator so that approximately 2 cm of the ventral surface of the finger pad is in contact with the stimulating surface. The subject's forearm, wrist, and hand rest on a platform which is positioned parallel to the surface of the Optacon. Each subject is instructed to allow his or her finger to rest on the vibrating surface without exerting any downward force. This is critical because the pressure of the finger on the pins not only can affect the efficacy of the touch receptors in the skin, but can also influence the pin movements because the piezoelectric activators have no feedback control and thus the pin excursions are very much load-dependent. Prior to testing, subjects are given a period of suprathreshold stimulation so that they become familiar with the stimulus. Goldberg and Lindblom[17] found that the variance of the vibration perception threshold was less than that of the disappearance threshold and therefore determination of perception threshold alone was felt to be sufficient.

Six ascending series are obtained and the subjects wear earphones to mask the sounds that result from the higher intensity vibrations. The time of the ascending trials is varied to avoid providing a temporal clue, and the subject is prevented from viewing the intensity knob or the voltmeter to eliminate any visual artifact. On approximately one sixth of the trials, a "sham" series is run in which the stimulus is not delivered. The total testing time per subject is approximately 10 to 15 minutes.

Arezzo and Schaumberg[7] initially used the modified Optacon and were able to demonstrate a steady increase in vibration perception threshold with age but no sex difference in a control group. In the same study, a group of diabetic subjects was examined. The increased threshold was found in 38%, correlating with the peripheral neuropathy found on physical examination. Subsequently, the Optacon was used to screen workers in an acrylamide factory, because the pacinian corpuscle has been demonstrated to have exquisite vulnerability to acrylamide.[20]

Another study of 150 asymptomatic government workers attempted to correlate vibration perception thresholds obtained with the Optacon by comparison

with a standardization neurological examination and routine nerve conduction studies.[21] An age effect with increasing thresholds was again demonstrated. However, when vibration perception thresholds were compared between subjects having normal physical examination results and electrodiagnostic studies and subjects having evidence of peripheral neuropathy, considerable overlap was observed. The routine neurological examination and electrodiagnostic studies appeared to be more sensitive indicators of idiopathic peripheral neuropathy.

A common toxic neuropathy, secondary to increased alcohol intake and poor nutrition, was examined in 56 subjects who were selected solely by their availability in an alcohol outpatient clinic.[22] Subjects were tested with the Optacon prior to a neurlogical examination by a neurologist (M.L.B). The comparison group of 56 normal volunteers showed no evidence of peripheral neuropathy by examination and no history of neurological disease, diabetes mellitus, thyroid dysfunction, or heavy alcohol abuse. Only two workers among those who had a physical examination in the alcohol outpatient program showed no evidence of peripheral nerve dysfunction. The remaining 54 subjects had been enrolled in the clinic from 2 weeks to 9 years, and all had diminished sensation in a stocking distribution frequently accompanied by a decrement in the tendon reflex at the ankle. Diminished sensation in a glove distribution was present in 62%.

The Table shows the mean voltage at threshold in the index finger and the SDS of these scores for the normal group and those with peripheral neuropathy. The mean scores systematically increase as a function of age in both groups. The variability of the data was constant across all age groups. Patients with a peripheral neuropathy had significantly elevated thresholds ($P < .001$). The Optacon detected sensory pathology in the upper extremities in 38% of the workers where it had not been appreciated by neurological examination. Considerable loss of sensory nerve fiber can occur before there is clinically detectable sensory loss.[3] Patients who had been in the alcoholic rehabilitation program for longer periods had milder peripheral neuropathies and a tendency towards lower threshold scores.

As mentioned previously, carpal tunnel syndrome may result in loss of large axons in the digital nerves.[6] This presents an interesting problem in workers exposed to neurotoxic substances and cumulative repetitive trauma of the upper extremities. These workers have two etiologies for loss of large axons in the index finger, namely, toxic and entrapment. In carpal tunnel syndrome, vibration perception thresholds in the compromised index finger may be compared with the ipsilateral uninvolved ulnar-innervated fifth digit. Dellon[23] found this comparison in vibration perception to be one of the earliest nonprovocative signs of carpal tunnel syndrome.

Table
Mean and SD of Voltage at Threshold for Normal Subjects and Those With Neuropathy

Age	N	Normal		N	Neuropathy	
		$\bar{x}$	± SD		$\bar{x}$	± SD
21–30	14	2.9	0.74	11	4.69	0.75*
31–40	13	3.67	0.93	20	5.40	1.15*
41–50	16	4.17	0.85	11	5.74	1.22
51–60	13	4.5	0.5	12	6.45	1.33*

*$P < .001$

When the Optacon was used to measure the vibration perception threshold in the second (II) and ipsilateral fifth (V) digit, a difference of 0.39 Hv + 0.21 ($\bar{x} \pm$ SD) was obtained in 19 control hands. Therefore, 1 Hv was established as the upper limit of normal.

In 48 hands with clinically apparent carpal tunnel syndrome, a normal II to V difference of 0.44 + 0.26 Hv ($\bar{x} \pm$ SD) was found in ten hands, whereas the remaining 38 hands had significantly increased II to V difference of 2.25 + 1.24 Hv ($\bar{x} \pm$ SD) ($P < .01$). As an objective measure of nerve dysfunction in carpal tunnel syndrome, the Optacon had a sensitivity of 79% and a specificity of 100%. This closely agrees with Dellon's results using a tuning fork where 72% of the patients with carpal tunnel syndrome had an abnormal perception of vibratory stimuli.

These results address a problem not previously given much attention. In the occupational setting, where workers are exposed to neurotoxic and ergometric stresses, screening tools should be used to differentiate toxic polyneuropathy from entrapment neuropathy. In the alcoholic polyneuropathy, even though vibration sensitivity is significantly elevated, the II to V interval was normal, as all nerves were equally affected. Theoretically, carpal tunnel syndrome overlying a polyneuropathy would produce both an elevation in absolute vibration perception threshold and an increased II to V interval. Interaction between toxic and entrapment neuropathies could be studied using this approach. This comparison of ulnar and median nerve function is similar to the technique used in nerve conduction studies, in which conduction velocities of the median and ulnar nerves within a hand are compared to establish a secure diagnosis.

Studies with the Optacon are limited, but, given that the large-diameter axons that carry vibration sense are most commonly affected following exposure to exogenous neurotoxins and cumulative repetitive trauma, the need for a portable device for measuring vibration sensitivity cannot be underestimated. With this tool, detection and quantification of sensory abnormalities in the workplace may be followed serially, allowing for measuring of deterioration or improvement of sensation. Future studies are needed of neuropathies with known pathology, besides evaluating possible confounding variables such as temperature, skin thickness on the fingertips, and exposure to vibration.

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Reevaluating Father

The ongoing relationship between a new father and his own father is particularly important. Psychologically, the process is often called "de-idealization," which means that we come to see our fathers more clearly, understanding their own struggles, gaining a new perspective from going through the kind of dilemmas they have experienced. When we de-idealize a father he becomes more real, a human figure with strengths and weaknesses rather than the godlike or devil-like creature of our imagination whom we both adore and rebel against. Becoming a father may foster the process of de-idealization in at least two ways: It helps the grown son to understand more of his father's behavior and may also help retrieve memories of his father as a caring, nurturant figure.

. . . In becoming fathers we gain a new perspective on our own fathers. The man comes to see that being a father is a constant struggle to hold onto family amid competing demands to be a success at work. From that the man may understand more of his own father's silent, hidden struggle, a view from the other side to which he was not privy as a child. In finding himself to be a good-enough father, the man may come to know that his own father was good-enough as well.

—From *Finding Our Fathers* by Samuel Osherson. The Free Press, New York, 1986.