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Striking the Right Balance

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As vestibular audiologists, Janine and I have to admit that we are dizzy with happiness due to all the positive feedback that we received about the vestibular issue of Canadian Audiologist. *As a result, we will be generating a regular column covering all things vestibular. Our first guest author, Dr. Dave Pothier, has written a beautiful synopsis of important things to bear in mind when working with vestibular patients. This is especially important right now, as we celebrate Balance Awareness Week (http://vestibular.org/BAW) in September. If you would like to be more involved in all things vestibular, please sign up for the Vestibular Special Interest Group, where you will be a part of a growing group of vestibular specialists sharing information – sign up by simply emailing CAAvestibular@gmail.com to let us know you want to be a part.*

Proposed Principles of Vestibular Function and Testing

Much is known about the cochlea and hearing. This is, of course, a good thing as hearing is fundamental to so many aspects of life. The vestibular system, on the other hand, is somewhat more obscure. Efforts to understand its function only really began in earnest with Barany in the early 20th century. The vestibular system has been misunderstood for many years and false assumptions about its function have become widespread. Although there are many things to say about it, a few principles of the vestibular system are worth mentioning to gain a better overall understanding of what we know and what we still need to discover.

Principle 1

Usually humans are known to have five “senses,” namely vision, hearing, smell, touch, and taste. It is entirely reasonable to name balance as the true “sixth sense” What makes balance different from the other senses is that it is not used to actively “investigate” or “probe” our surroundings in the same way the other senses are. Balance is automatic and subconscious until there is some disruption and symptoms develop. These symptoms are often substantial and can cause devastating effects on the quality of life of those affected.

Principle 2

The vestibular system has two broad functions – balance (the most well known) and the maintenance of stable gaze. The vestibular end organs comprise the otolith organs, (the utricle and saccule) and the three semicircular canals (lateral, superior and posterior). The semicircular canals are activated during rotational movements and the otolith organs during linear movements.

The semicircular canals are paired. While the lateral canals are paired with each other, the superior

canal on the left is functionally paired with the posterior canal on the right and vice versa. Eye movements are produced in the plane of the canal being stimulated. Stimulation of the semicircular canal occurs when the cupula is deflected as a result of endolymph within the canal remaining relatively still, as a result of its inertia, as the head is moved.

Principle 3

The vestibulo-ocular reflex (VOR) serves to maintain the visual field in a stable fashion on an area of interest. The area of high visual acuity afforded by the fovea centralis is relevantly small when compared to the entire visual field; the area of visual acuity necessary for clear vision is roughly the size of a thumbnail held at arms length. This area must be kept accurately directed towards the area of interest even during head and body movements. Voluntary eye movements are not sufficiently fast to allow this to undertaken using smooth pursuit alone and thus the vestibulo-ocular reflex is used to ensure that eye movements are produced that are equal and in an opposite direction to head movements. Defects in this reflex cause reduced dynamic visual acuity owing to the “retinal slip” caused by an image not being held consistently over the fovea.

Principle 4

Although there is substantial cross-over between the function of these systems, the otolith organs play the greatest role in the maintenance of an upright posture through the detection of body or head tilt while the semicircular canals play the an important role in the vestibulo-ocular reflex. This is important to bear in mind when considering a patient with imbalance who appears to have normal caloric responses and even normal results on more advanced testing such as video head impulse testing (vHIT) or magnetic scleral search coil testing.

Principle 5

Hair cells within the semicircular canals fire at a baseline rate when the head is at rest or at a constant velocity. When the head is moved in a rotational fashion, one of the pair of canals will increase its firing rate while the other will decrease. This differential will signal a head movement in the plane of that semicircular canal. In the case of the lateral canal, there will be an increased rate of firing of the hair cells on the side to which the head is being rotated and a decrease in the contralateral side. The eye movement produced by the vestibulo-ocular reflex will be the vector of the signals produced by the vestibular end organs, primarily the semicircular canals.

Principle 6

In most physiological conditions of head movement there is no clinically relevant upper limit on the rate of firing whereas the reduction in the rate of firing in the contralateral ear can reach easily zero, below which there is no further reduction possible. This limit results in the fact that the contralateral semicircular cannot provide accurate velocity signals alone at higher velocities. As a result, a unilateral lesion will affect the VOR if sufficient acceleration is applied to the affected ear.

Principle 7

The difference in firing rates of the semicircular canals is the determinant of the signal received by the central nervous system (CNS) when detecting head movement. In the case of a sudden, pathological loss of vestibular function there will be a sudden difference in firing rates between the paired canals ? the affected baseline rate would be zero, whereas the contralateral side would be still firing at its baseline rate. This differential would be interpreted by the CNS as the head being rotated in the direction of the unaffected ear. The VOR then produces a slow phase eye movement in the direction of the affected ear and a fast phase movement in the direction of the unaffected ear to reset. This is how nystagmus originates.

Principle 8

The vestibulo-ocular reflex is velocity/acceleration dependent. To maintain an equal and opposite eye movement, the central nervous system must receive signals from the vestibular system that are capable of delivering information on the velocity of the head movement, not just the direction. This is of importance when considering the results of caloric testing that assign a single value to a loss of vestibular function. This is by its very nature and insufficient assessment of vestibular function, even of a single semicircular canal.

Principle 9

Over time the CNS can compensate for changes in the baseline firing rate of an affected vestibular end organ, but the weakness will remain and, owing to the fact that the contralateral ear cannot compensate at higher velocities for the affected semicircular canal to which it is paired and the VOR will remain pathological. The development of “catch-up saccades” can allow the VOR to appear normal, but full function is not regained.

Principle 10

Testing of vestibular function is by no means reliable, exhaustive or complete. The semi-circular canals are most easily assessed, but the otolith organs are not easy to test and the tests that are currently available produce a very crude assessment of function. It is worth considering that the amount of neuroepithelium contained in the otolith organs is similar to that contained by the cochlea, yet current tests of otolithic function produce an output that determines whether a response is either “absent” or “present.” Clearly an audiogram that presented hearing in those terms would be unacceptable. No test provides a “gold standard” and no test is indicative of overall vestibular function.

Normal vestibular function testing does not exclude vestibular pathology and all abnormal test results should be viewed in a clinical context. It is, sadly, very common for patients to be told that there is nothing wrong with their balance system based on a normal caloric response. On many levels this is a claim that is not reliable and it is usually a good idea to bear in mind just how uncertain we are when it comes to the measurement of vestibular function.