The Relevance of the Vestibular System to Human Brain Functions: Describing the Pathological Effects of Vestibular Dysfunction on the Brain in Patients Managed in a Neurotological Practice

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The Aim of this Talk is to Emphasize or Increase Awareness of the Role of the Vestibular System in Brain Function

I will provide some background information, some clinical experiences with patients with vestibular disorders and cite some research and literature to accomplish my aim.

This is not a Talk about Vestibular Disorders, although my experiences with such disorders have resulted in an increased awareness of the diffuse role this ancient system plays in Brain function. I will look at Brain function as it is influenced by Vestibular inputs.

I have written an Article on the Classification and Management of Vestibular Disorders which is available to any of you if you so request. There are references in that paper to which I will refer.

The Vestibular System

We are familiar with the 5 Senses… Sight, Sound, Taste, Touch and Smell which transmit sensations of identifiable external stimuli to the Brain.

The Vestibular System, sometimes called the Sixth Sense, transmits information from an external source, Vibrations or Sound Waves transmitted in air or in fluid environments and an External Physical Field, Gravity, to the Brain. It also transmits Internal information, Head and Body Movements to the Brain

The Peripheral Receptors of the Vestibular System are located in the Inner Ear

Diagram of the Ear

The Vestibular Organs perceive both Linear Acceleration in the Vestibule of the Inner Ear (which is why the system is called Vestibular) and Angular Acceleration in the Semicircular Canals of the Inner Ear. Vestibular Contributions to the Central Nervous System date back over 500 Million Years

The Organ of Hearing is also contained in the Inner Ear… and may be viewed as providing more sensitive inputs when vibrations or Sound Waves are transmitted in Air rather than water.

The Vestibular inputs travel through the Brain Stem, downwards to the Spinal Cord, controlling head and body position, and upwards to the Brain.

One commonly described Brain connection is to the Oculomotor Nuclei. The Vestibular and Visual Systems are intimately linked such that focus is maintained when the head moves. This is an amazingly precise operation.

There is a crucial connection of vestibular inputs to the Cerebellum, which is the Integrator of Inputs for Position and Movement and the Source and Controller of Movement.

Inputs to the Thalamus and Cortex have also been described.

The inputs for Balance and Spatial Orientation are Visual, Vestibular, Proprioceptive and Touch.

These inputs account for the Brain's ability to maintain balance and spatial orientation and are the crucial inputs to account for in the evaluation and management of patients with vestibular disorders.

However, some patients with vestibular disorders also complain about visual symptoms that are present despite normal vision, complain about cognitive difficulty even without head injury and experience affective symptoms of anxiety, personality changes, depersonalization, fear and phobias.

One, or all, of these symptoms can be expressed by patients with vestibular dysfunction, or can be found to be present if the questions are asked.

The occurrence of these symptoms in patients with vestibular disorders has been verified clinically and has led scientists to the discovery of vestibular pathways to the affected areas.

The most common syndrome involving vestibular dysfunction with associated brain dysfunction is a Triad.

There are Vestibular symptoms and signs… dizziness and imbalance, but there is also

Cognitive dysfunction, especially difficulty with short term memory and multitasking and

Visual difficulties, especially disorientation in large spaces, stores and malls and difficulty reading.

There are affective symptoms with vestibular disorders, even if there is no Triad.

I asked a patient of mine, an Engineer, to record her symptoms before and after ear surgery in 2005. The occurrence of the Triad and the Affective symptoms is described. This is not uncommon in my patient population, many of which have suffered head or neck injury, with resultant injuries to the Inner Ears. I have seen the Triad in patients without trauma as well, but more commonly with trauma. Improvement or resolution of the symptoms has occurred with surgery or with medical management with a loop diuretic.

She stated…I suffered Head and Neck injuries in an MVA in 2004. I had problems with thinking, memory, dizziness, nausea and headaches. I could not think straight, could not sort mail, could not pay bills, could not organize my family's schedule, was anxious and fatigued, cried a lot, lost track of time and had short term memory loss.

I could not multitask as I did before, could not do simple math in my head, was emotionally up and down, was disoriented and dizzy, had difficulties on the computer, difficulty in stores and scanning, could not make dinner for my family. Insurance forms overwhelmed me.

I had difficulty reading and writing, could not retain information, could not find the correct words, flipped letters and lost my vocabulary. Maps confused me and I got lost easily when driving.

Right Ear Surgery was performed in February 2005.

Afterwards, my husband remarked that my personality had come back. I started to focus better. I could file my own insurance papers, do some household chores, better organize my schedule, remember new information better and my sense of direction improved. After the Ear Surgery my self esteem improved and I could socialize with friends and family.

She concludes that her Cognitive, Emotional and Personality problems were helped by the Ear Surgery and that these symptoms were linked to her Vestibular disorder.

Hanes and McCollum, in a Paper that I will make available, describe vestibular patients performing significantly worse than normal on tests involving organization of extensive information and multitasking. They reference studies confirming the existence of polysynaptic vestibular pathways to the hippocampus and activation of the hippocampus by vestibular stimulation in humans.

They describe strong evidence for an effect of vestibular disorders via the hippocampus on spatial memory and the ability to navigate through a spatially organized domain. They describe vestibular projections to cortical areas including the somatosensory and parietal cortices, as well as to the posterior insular region which corresponds to the Primate Parietoinsular Vestibular Cortex (PIVC).

They described the VIP, the ventral intraparietal area, as receiving strong vestibular activity. The intraparietal sulcus has been identified as a principal area involved with arithmetic and counting tasks.

They describe interactions between the vestibular and visual cortical areas. They conclude that the studies cited indicate a clear physiological and anatomical substrate for their hypothesis of a direct contribution of vestibular signals to cognition.

Balaban described a link between balance control and anxiety, identifying the parabrachial nucleus as an important node in a network that processes convergent vestibular, somatic and visceral information to mediate avoidance conditioning, anxiety and conditioned fear responses.

Brandt described a visual-vestibular interaction resulting in spatial disorientation, apparent motion and imbalance and nausea.

My experience with patients with visually induced dizziness, manifested by difficulties in large spaces such as stores and malls as well as other visual symptoms, has been that the eyes are normal to Ophthalmologic examination. The dysfunction is secondary to a centrally induced distortion of the Visual System.

My Neuro-Optometric colleague has explained it thus:

The Visual System is a dual operating system consisting of

1. **A central or focal processing that identifies details, color perception and depth discrimination**
2. **A peripheral or ambient awareness of contour recognition, movement awareness and depth perception.**

All visual processing lies along a shared continuum whereby increased awareness of focal processing will decrease awareness of ambient processing, and vice versa. Ambient processing is automatic, extensive, fast, transient and present at birth. Focal processing is attentive, intensive, slow, sustained and developed during the early years of life.

The Ambient processing is the most important for vestibular function. Think of a Gymnast on a Balance Beam, looking peripherally and not at her feet.

Unfortunately, it is the Ambient visual processing that is suppressed by patients with vestibular dysfunction as the Brain attempts to maintain balance by looking straight ahead. This is logical as the person does not want to fall on his face, but it is disastrous if the suppression of the peripheral awareness rises to the point of disorientation of the surroundings such as is seen in those with this clinical disturbance.

This distortion of vision occurs centrally, and is another effect of a Vestibular Dysfunction on Brain Function.

Treatment revolves around restoring normal vestibular function and normal gravity perception and inducing the return of peripheral awareness to the visual system.

I have noted and described abnormalities in Brain Function that I have seen in patients with Vestibular disorders. I have described anatomical and functional links between the vestibular system and Brain areas associated with cognition, vision and anxiety.

I have reviewed the history of a patient with a vestibular disorder, who displayed abnormalities in all of the area of Brain Dysfunction discussed, even the area devoted to arithmetic. I have produced her testimony as to the improvements she experienced after treatment of her vestibular disorder.

I can tell you that I see this clinical picture frequently in my present practice, in which I see many patients with inner ear injuries.

My aim was to provide input to you on the relationship of vestibular dysfunction to Brain dysfunction. I hope that this information will have some value to you as you pursue your work and passions in the understanding of Brain Disorders.

Thank you for your attention.