Vestibular Evoked Myogenic Potentials (VEMPs) in Normal Subjects: Inter – and Intrasubject variability

THESIS

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LIST OF ABBREVIATIONS

CNS	Central nervous system
VOR	Vestibulo – ocular reflex
VSR	Vestibulo-spinal reflexes
BPPV	Benign paroxysmal positional vertigo
VsEPs	Vestibular evoked neurogenic potentials
CW	Clockwise
CCW	Counterclockwise
SCC	Semicircular canal
msec	milisecond
ABR	Auditory brainstem response
EMG	Electromyography
DPOAEs	Distortion product otoacoustic emissions.
SRT	Speech reception threslold
WD%	Word discrimination scores

AIMS OF THE WORK

The objectives of this study are:

1- To define the results of VEMPs in normal subjects.

2- To report the inter- and intra- subject variability of VEMPs.

INTRODUCTION

Vestibular evoked myogenic potentials (VEMPs) are muscle reflexes recorded by surface electrodes following repeated high intensity sound stimulation using averaging technique similar to that used to record auditory evoked potentials. It was first described by ***Bickford et al. (1964).*** These responses are named either “Click-evoked vestibulo-collic response” or “Vestibular evoked myogenic potential” to differentiate them from the usual evoked potentials of neurogenic origin. The potential was preserved in patients with profound sensorineural hearing loss who were unable to hear the clicks indicating that it was not of cochlear origin ***(Halmagyi & Colebatch, 1995).*** The receptor of these responses is thought to be the saccule, afferent pathways being the vestibular nerve and efferent pathways the vestibulo-spinal tract ***(Ferber- Viart et al, 1997).***

As stated by ***Morawec Bajda (1997),*** VEMPs are considered and objective, secure, simple and comfortable method to evaluate vestibular pathology. Its recording provides both a straightforward non-invasive exploration of each vestibule independently and an attractive method to explore the saccule and vestibulospinal tracts ***(Ferber – Viart et al, 1999).***

Ferber-Viart et al. (1998) stated that in total unilateral cochleovestibular damage, VEMPs were absent either ipsilaterally or contralaterally. ***Halmagyi and colebatch (1995***) found that ipsilateral vestibular evoked myogenic potentials were absent in unilateral vestibular neuritis. VEMPs were absent on the affected side in 15 patients (71%) out of 21 patients with acoustic neuroma with decreased amplitude in two patients (9%) out of the 21 patients ***(Murofushi et al. 1998).***

At the present time, there is no general agreement on the stimulating & recording parameters of VEMPs. Whereas ***Halmagyi and Colebatch (1995) and Murofushi et al. (1996)*** recorded responses using repititon rate of 5 Hz, ***Ferber-Viart et al. (1997)*** mentioned that the responses are better with a rate of 3 Hz. The bandpass filter used by Murofushi et al (1996) was 20-1000 Hz while ***Ferber-Viart et al (1997)*** used 5-1000 Hz filter. ***Halmagyi and Colebatch (1995)*** and ***Murofushi et al. (1996)*** agreed that the sweeps suitable for averaging the response were 128. Inspite of this, ***Ferber-Viart et al. (1997)*** used 200 sweeps to average the response. As regards the recording sites**, *Ferber-Viart et al (1997)*** mentioned that latencies and amplitudes of trapezius muscle responses were higher than those of sternomastoid muscle.

Taking into consideration the defective information about inter-and intrasubject variability of VEMPs and the controversy reported in reference to the stimulating and recording parameters of VEMPs, there exists a need for standardization of such measurement on normal subjects. Accordingly, this study is designed to define clearly the VEMPs parameters in normal subjects before its application on patients with balance disorders.

FUNCTIONAL ANATOMY

The function of the vestibular system is to generate information about head movement and head position in space and to distribute this information to appropriate sites located throughout the CNS that subserve the bodily functions of equilibrium. The centrifugal flow of information begins at the hair cells located within the vestibular labyrinth. These hair cells synapse chemically with vestibular primary afferents causing them to fire with a frequency that encodes the parameters of head movement and head position ***(Baloh and Halmagi, 1996).***

The vestibular system is divided into peripheral and central systems. The peripheral system comprises the semicircular canals, the otolith organs, the hair cells and the vestibular nerve up to the root entry zone in the brainstem. The central vestibular system is composed of vestibular nuclei, the vestibulo-ocular reflex tract (VOR), the vestibulo-spinal reflex tract (VSR) and the cerebellum. The brainstem reticular formation and area postrema are also parts of the system ***(Hamid, 1993).***

I- Peripheral Vestibular System:

Bony and membranous labyrinth

The bony labyrinth lies within petrous portion of the temporal bone. It consists of anterior cochlear part and posterior vestibular part. The superior and posterolateral walls of the vestibular part contain openings for the three semicircular canals ***(Anson and Donaldson, 1973).*** The membranous labyrinth is enclosed within the channels of the bony labyrinth. The space between the periostium of the bony labyrinth and the membranous labyrinth contains perilymphatic fluid and supportive network of connective tissue and blood vessels. The space within the membranous labyrinth contains endolymphatic fluid ***(Anson, 1973)***.

Semicircular ducts

The three semicircular ducts are thin curved tubes attached to the utricle and open into it. Each duct forms about two thirds of a circle and each lies at right angles to the other two. The three semicircular canals are named according to their relative position in the upright head; superior (or anterior vertical), posterior (or inferior vertical), and lateral (or horizontal). The superior and posterior ducts are oriented vertically, whereas the lateral duct lies in an approximately horizontal plane (the lateral duct is actually tilted upwards by about 30 degrees from the horizontal plane). Each of the semicircular ducts has a bulbous dilatation at one end called the ampulla, which houses the sensory receptor organ. The non-ampullated ends of the superior and posterior canals unit to form the crus commune, which joins the posterior aspect of the utricle ***(Anson and Donaldson, 1973)***. (Fig.1).

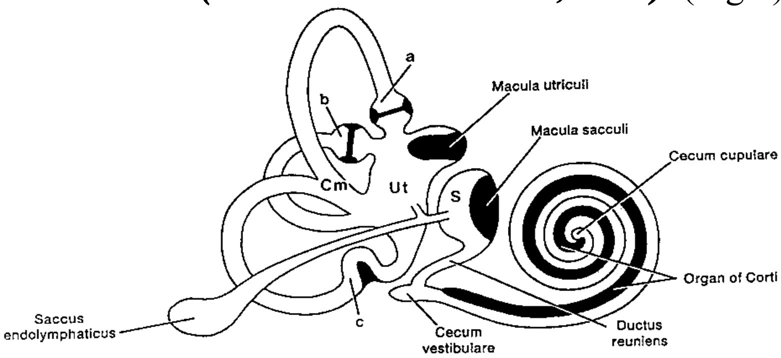

Fig.1: Diagram showing relationships between structures of the membranous labyrinth [Quoted from *Shepared and Telian (1996)*].

The Otolith

The saccule is an ovoid membranous sac situated in a depression of the wall of the vestibule known as the spherical recess. It is located immediately adjacent to the basal portion of the cochlea and connected with the cochlear duct by a narrow tube, the ductus reuniens. The saccule gives rise to the saccular duct that joins a smaller duct from the utricle to form the endolymphatic duct which leads to the endolymphatic sac ***(Watanuki and Schuknecht, 1976).***

The utricle is an irregular-shaped membranous tube that is considerably larger than the saccule. It has a superior to inferior orientation in the vestibule and lies behind the saccule ***(Igarashi et al., 1983).***

The saccular macula is composed of sensory and supporting cells. The sensory cells are arranged in a single layer and are separated from one another by supporting cells. The sensory cells have clusters of hair like cilia at their apical ends and, because of this feature, are often referred to as “hair cells”. All vestibular hair cells have cilia of two types: sterocilia and kinocilia. The sterocilia are arranged in several rows that increase in height across the top of the cell. Situated near the tallest row of sterocilia is a single longer process known as the kinocilium. The sterocilia and kinocilia of the macular hair cells project into a sheet of gelatinous material that blankets the surface of the neuroepithelium. Resting on the gelatinous layer is mass of tiny crystals called otoconia. The otoconia together with the gelatinous layer makes up the structure known as the otoconial membrane, which is responsible for stimulation of the macular hair cells in response to linear acceleration. ***(Lim, 1984).***

Under the influence of gravitational force of linear head movement, the otoconial membrane undergoes minute shifts in position on the macular surface, thereby deflecting the cilia on the underlying sensory cells. This alters the electrical polarization of the hair cells, which controls the release of neurotransmitter on to the nerve endings making contact with the sensory cells ***(Goldberg and Fernandez, 1984).***

The utricular macula is oriented in the horizontal plane while the saccular macula is oriented in the vertical plane. Accordingly, the otolith organs are sensitive not only to gravity but also to other linear acceleration forces, such as forward motion and bobbing movements of the head during walking ***(Lysakowski et al., 1998).***

The sensory organs of the vestibular labyrinth are innervated by the vestibular component of the vestibulocochlear nerve, which carries both afferent and efferent fibers to the vestibular apparatus. The vestibular nerve is divided into superior and inferior divisions. The two divisions contain between 18.000 and 20.000 nerve fibers ***(Schuknecht, 1993).***

The peripheral portion of the superior division of the nerve innervates the utricular macula, the superior and lateral cristae, and the anterosuperior region of the saccular macula. Peripheral fibers of the inferior division supply the major of the saccular macula and the posterior crista. The vestibular nerve projects to the brainstem where most of its fibers enter the vestibular nuclei, however, a small contingent of fibers bypasses the vestibular nuclear complex and projects directly to the cerebellum ***(Brugge, 1991).***

II- Central Vestibular System:

Vestibular nuclei

The vestibular nuclei are located in the dorsolateral portion of the brainstem near the junction of the medulla and pons. They consist of four major nuclei (lateral, medial, superior, and inferior) together with several closely associated minor nuclear groups. As the vestibular nerve enters the brainstem, it bifurcates into ascending and descending branches that distribute to the various nuclei in a highly organized fashion ***(Gacek, 1980).*** In addition to the vestibular nerve fibers, the vestibular nuclei receive inputs from other sources, including the visual system, the cerebellum, the brainstem reticular formation, and the spinal cord. They, therefore, serve as much more than simple relay station for peripheral input; these nuclei play a significant role in the complex interaction between the vestibular system and other major centers of the CNS ***(Brugge, 1991).***

Carleton and Carpenter (1983) reported that the lateral nucleus sends most of its efferent fibers to the spinal cord as the vestibulospinal tract. The lateral nucleus is an important station for the control of vestibulospinal reflexes, particularly those involving the forelimbs. They mentioned also that the medial nucleus appears to be an important center for coordinating eye, head and neck movements. The superior nucleus is connected to the thalamus and higher vestibular centers. ***Brodal (1972)*** mentioned that the inferior nucleus integrates vestibular signal from the two sides with signals from the cerebellum and reticular formation. (Fig. 2).

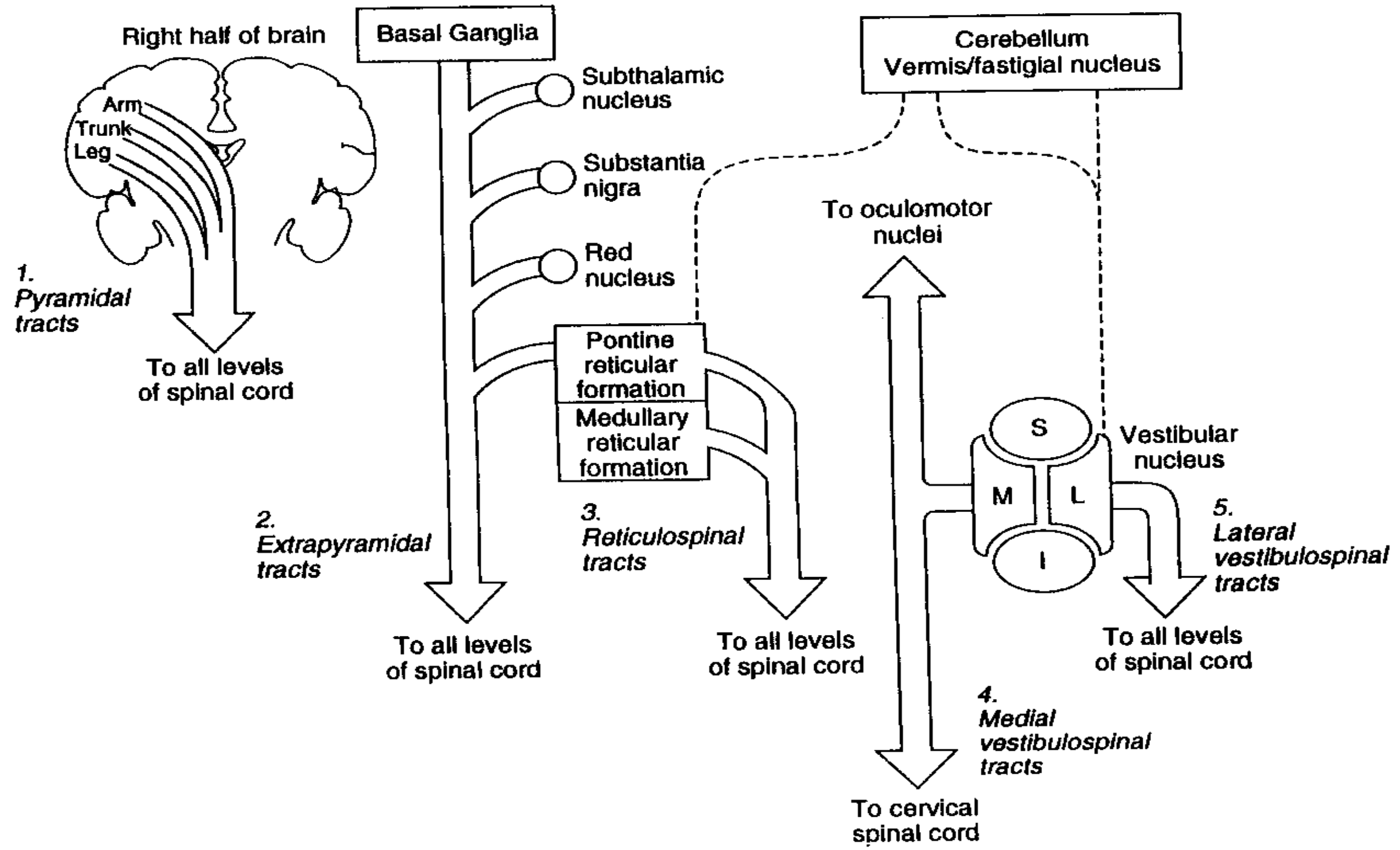

Fig. 2: The neural connections of vestibular nuclei S, superior vestibular nucleus; M, medial vestibular nucleus; L, lateral vestibular nucleus; I, inferior vestiibular nucleus *[Quoted from shepared and Telian (1996)]*.