Audio-Vestibular Assessment and Rehabilitation of patients with Spondylo-degenerative Disorders of the Cervical Spines

Thesis submitted in partial fulfillment of

M.D. Degree in Audiology

By

Fathy Naeem Fatouh
(M. Sc. Audiology)

Under supervision of

Prof. Dr. Nadia M. Kamal
Professor of Audiology
ENT department
Ain Shams University

Prof. Dr. Fatma K. Abdel Metaal
Professor and head of Physical Medicine department
Ain Shams University

Prof. Dr. Iman M. Sadek
Professor of Audiology
ENT department
Ain Shams University

Prof. Dr. Adel I. Abdel Maksoud
Professor of Audiology
ENT department
Ain Shams University

Faculty of Medicine
Ain Shams University
(2009)

Aims of the work

1- To assess the effect of cervical spine degenerative disorders on the cochlear functions, if any.

2- To assess the effect of cervical spine degenerative disorders on the vestibular functions, if any.

3- To assess the efficiency of combined physiotherapy-balance and vestibular rehabilitation therapy (BVRT) approach in management of cervical related dizziness patients.

Introduction and Rationale

Degenerative diseases of the spines which commonly known as spondylosis characterized by the presence of degenerative changes throughout the spine. In the cervical region, most of these changes occur around the two facet joints, the intervertebral disks and the two uncovertebral joints leading to dysfunction of the cervical spine and generalized degenerative type of neck pain **(Rndall, 1993)**.

Dysfunction of the cervical spine can be the cause of vertigo, impaired hearing as well the cause of localized or pseudoradicular pain via disturbance of the proprioception from the neck **(Galm et al., 1998).**

Hüsle (1994) mentioned the term vertebrogenic hearing loss and reported that it may be accompanied by tinnitus, a feeling of ear pressure and otalgia as symptoms of a functional deficit of the upper cervical spines.

Recently, there is growing evidences that, proprioceptive input from the neck participates in the coordination of eye, head, and body posture as well as spatial orientation. **(Peterson et al., 1985; Kanaya et al., 1995; Brandt and Bronstein, 2001).** Central connections to the thalamic and cortical levels had also reported by **Oosterveld et al., (1991).** This implies that stimulation of, or lesion in, cervical structures can produce dizziness **(Brandt, 1996).**

The term cervical vertigo was introduced in **1955** by **Ryan and Cope** and has become, after cupulolithiasis, the most commonly diagnosed cause of vertigo **(Brandt, 1996).** Dizziness in the form of non-rotatory vertigo and unsteadiness are frequent complaints in degenerative diseases of the cervical spine **(De Jong and Bles, 1986).**

Three mechanisms are usually suggested to explain the pathophysiology of cochleo-vestibular symptoms in cervical spodylo-degenerative disorders:

altered cervical proproceptive input, vaso-motor changes caused by irritation of the cervical sympathetic chain and lastly vascular compression **(Filtz-Ritson, 1991; Hain, 2001).** Accordingly, cervical spine degenerative disorders could affect balance and postural control by means of temporary alteration of labyrinth microcirculation and/or vestibular dysfunction at the level of brainstem vestibular nuclei through abnormal afferent firing from cervical proprioceptors **(Gacek, 1994).**

Diagnosis of cervical vertigo is suggested when there is a history of dizziness associated with cervical rotation, extension and cervical pain. The presence of cervical nystagmus is considered more diagnostic, however, it is not very sensitive **(Stenger, 1969; Ojala and Palo, 1991; Wrisley et al., 2000).** Otorhinolaryngologic and otoneurologic examination do not provide specific data for the diagnosis of cervical vertigo but are especially important to rule out the presence of other pathologies associated with vertigo **(Eduardo et al., 2000).**

Although the term cervical vertigo became prevalent in the clinical diagnosis nowadays, however, true cervical vertigo is a controversial clinical entity and patients with suspected disease often have alternative basis for their symptoms. Further clinical studies seeking to define cervical vertigo should focus on establishing reliable measures for it **(Brandt and Bronstein, 2001).**

This study was conducted in attempt to assess and search for more effective and diagnostic profile for patients with cervical spine degenerative disorders and dizziness, also, to study the value of different rehabilitation programs (physiotherapy and BVRT) on the symptomatology of those patients.

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List of Abbreviations

ADT: Adaptation test
A-ROM: Active range of motion
BVRT: Balance and vestibular rehabilitation therapy
CCN: Central cervical nucleus
CCR: Cervico-colic reflex
COR: Cervico-ocular reflex
CDP: Computerized Dynamic Posturography
CNS: Central nervous system
COG: Center of gravity
CSM: Cervical spondylotic myelopathy
CSR: Cervico-spinal reflex
CT: Computerized Tomography scan
DHI: Dizziness Handicap Inventory
DVA: Dynamic Visual Acuity
EMG: Electromyography
ENG: Electronystagmography
©-cells: Gamma cell system
ICHD: International Classification of Headache Disorders
MCID: Minimal clinically important difference
MCT: Motor control test
MRI: Magnetic Resonance Imaging
MSQ: Motion Sensitivity Quotient
MST: Medial superior temporal sulcus
NDI: Neck Disability Index
NPRS: Numeric Pain Rating Scale
NT: Neck torsion maneuvers
NTNT: Neck Torsion Nystagmus test
ODI: Oswestry Disability Index
OKAN: Optokinetic after nystagmus
OPK: Optokinetic system
OKR: Optokinetic reflex
PTA: Pure tone audiometry
ROM: Range of motion
PPRF: Para-Pontine reticular formation
SCC: Semicircular canals
SM: Spinal manipulation
SNHL: Sensorineural hearing loss
SOT: Sensory Organization test
SP: smooth pursuit system
SPNT: Smooth pursuit neck torsion test
SPNT diff: Smooth pursuit neck torsion test difference
SSEPs: Somato-sensory evoked potentials
TEOAE: Transient evoked otoacoustic emission
TIA: Transient ischemic attacks
VCR: Vestibulo-collic reflex
VEMPs: Vestibular Evoked Myogenic potentials
VN: Vestibular nuclei
VNG: Videonystagmography
VOR: vestibule-ocular reflex
VRP: Vestibulo-reticular projections
VSR: Vestibulo-spinal reflex

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Balance and postural control system

Human postural control is governed by vestibular, visual and proprioceptive inputs and their central processing **(Basta et al., 2005).** The vestibular system gives information to the brain about the movements and positions of the head in space, the visual systems brings information of the surroundings, the proprioceptors of the neck transmit statements of the position of the head in relation to the rest of the body, finally the proprioceptors of the rest of the body give information concerning its position and velocity. This sensory input, ***"sensory pictures"***, are integrated and stored in a ***"bank of memory pictures"*** which is supposed to be located in the parapontine reticular formation of the brainstem **(Roberts, 1967; Jeffrey and Vrabec, 1996).**

Every moment ***"sensory pictures"*** concerning the position and movement of the body are presented for the ***"bank of memory pictures"***, if the incoming ***"sensory pictures"*** are recognized, the signals pass through at a subconscious level. Efferent activity, from this balance control centers, is transmitted for adjustment of the muscles of the neck and the rest of the body. This creates a feedback system with a series of new ***"sensory pictures".***

In case of inexperienced ***"sensory pictures"*** due to over stimulation or disease in one of the balance controlling organs, these new ***"sensory pictures"*** will not be recognized by the ***"memory bank"***. This will lead to neural activity at a conscious level, subsequently, dizziness well be experienced as a result of abnormality of the ***"sensory picture"*** or from a disturbance in the complex perceptive system containing interacting and integrating signals of vestibular, visual and proprioceptive origin **(Tjell, 1999)**.

To maintain a constant posture in relation to static and dynamic external environment; the vestibular, visual and proprioceptive systems "through many postural reflexes" are working and interacting; these postural reflexes can be subcategorized as:

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visual righting reflexes, labyrinthine righting reflexes, neck righting reflexes, body on head righting reflexes, and body on body righting reflexes **(Baloh and Honrubia, 1989).**

Due to the fact that earth's gravitational field is a constant, the postural reflexes develop and react to this constant. From the moment an infant learns to first hold its head up through the time the child begins to walk upright, these postural reflexes are essentially supervising spinal structural and functional development in direct response to the constant force of gravity. To allow for a balance of strength and flexibility, the spine develops natural sagittal curves that provide functional lever arms for muscular attachment and efficient movement. All of this is achieved using the constant of gravity as the main reference point, and the postural reflexes serve as the neuromotor force for this adaptive response **(Morningstar et al., 2005).**

The contribution of and interaction between the three balance control systems and their postural reflexes will be discussed in details.

I- The vestibular system

The vestibular system constitutes one of the phylogenetically oldest CNS functions which in all species are to achieve stability. However, in higher animal forms, it is especially developed to maintain posture and locomotion in all situations **(Gacek, 1994; Schwarz and Tomlinson, 1994).**

The receptor organs of the vestibular system (three semicircular canals, utricle and saccule) are stimulated by angular and linear acceleration and deceleration respectively. The signals from the primary afferent neuron from labyrinthine receptors are conveyed through the vestibular nerve to the vestibular nuclei (VN) **(Brugge, 1991).**

The second-order vestibular neurons are the efferent projection pathways of the vestibular nuclei complex:

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1) to the oculomotor muscle system (III, IV, VI);
2) to the midcerebellum (cerebellar flocculus);
3) to the para-pontine reticular formation (PPRF);
4) to the opposite located vestibular nuclei;
5) to thalamus, superior colliculus;
6) to the neck via the medial vestibulo-spinal tract; and
~~1)~~7) to the trunk and neck via the lateral vestibulo-spinal tract. **(Gacek, 1994)**.

The vestibular system is an integral component in many of the postural reflexes, especially those that are responsible for upright human posture. These reflexes are protective fast mechanism in response to an external stimulus **(Goldberg and Hudspeth, 2000).**

There are three types of reflexes following peripheral stimulation:

1- Vestibulo-Ocular Reflex (VOR):

It is traditionally viewed as gaze stabilizing reflex that keep the gaze fixed on an object of interest while the head is moving thereby maintaining constant eye orientation in space and supporting clear vision during translational and rotational movements of the head and body (**Raphan and Cohen, 2002; Koizuka, 2003~~; Raphan and Cohen, 2002~~).**

It occurs by generating compensatory eye movements, in the opposite direction of the head, but at the same speed that hold the eye stationary in space during head movement (**Baloh, 1998; Redfern et al., 2001~~; Baloh, 1998~~).**

The vestibulo-ocular reflex may be subdivided into three major components: 1~~1~~) the rotational vestibulo-ocular reflex, which detects head rotation through the semicircular canals, 2) the translational vestibulo-ocular reflex, which detects linear acceleration of the head via the utricle and saccule, and 3) the ocular counter-rolling response, or optokinetic reflex, which adapts eye position during head tilting and rotation **(Goldberg and Hudspeth, 2000).**

2- Vestibulo-collic reflex (VCR):

The vestibulocollic reflex (VCR) acts on the neck musculature in order to stabilize the head in space. It does this by reflexively contracting cervical muscles opposite to the direction of cervical spine perturbation **(Bogduk, 2004).** VCR originates in the semicircular canals, utricle and saccule. VCR is distinct and largely dissociated from

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the vestipulospinal reflex, which orients the extremities to the position of the head and neck **(Wilson and Schor, 1999)**.

Welgampola and Colebatch (2001) found that the vestibulocolic reflex is not significantly affected by stimulation of lower extremity afferents, thus, its activation is mainly dependent upon stimulation of cervical afferents directly. The reflex head movement produced counters the body movement sensed by the otolithic or semicircular canal organs. The precise pathways mediating this reflex have yet to be detailed **(Abdel Razek, 2002).**

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3- Vestibulo-spinal reflex (VSR):

VSR is one of several specific vestibular reflexes that are thought to assist in the execution of the learned purposeful movements. The VSR permits stability of the body when the head moves and is important for the coordination of the trunk over the extremities in upright postures. VSR originated mainly in the maculae of otoliths and to a lesser extent in the vertical semicircular canal (SCC). Afferent information is carried to the medial and lateral vestibular nuclei, then modulated and integrated with visual and proprioceptive stimuli in midcerebellum **(Fetter and Dichgans, 1996; Ghez and Thach, 2000; Fetter and Dichgans, 1996).**

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The vestibulo-spinal reflex are mediated mainly through tThe medial and lateral vestibulospinal tracts. Both are modulating motor neuron activity regarding the axial and appendicular muscles respectively. Reflexive responses from the vestibulospinal tracts help correct sudden perturbations in static upright posture.

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While the visual input may be more important in constant postural adaptation, the vestibular apparatus, via the vestibulospinal tracts, is much quicker to respond to early or slight postural disruptions, allowing for a faster response from the skeletal postural muscles **(Goldberg and Hudspeth, 2000).**

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Another very important connection between the vestibular neuclei and central vestibular system which are: