VESTIBULAR EVOKED MYOGENIC POTENTIALS

IN INDIVIDUALS WITH

OTITIS MEDIA

Vinu (Francis)
Register Number: 08AUD032

A Dissertation Submitted in Part Fulfillment of

Final year Masters of Science (Audiology)

University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSORE – 570 006

MAY 2010

To

Beloved

Parents,

Sister

&

Divine brother

CERTIFICATE

This is to certify that this dissertation entitled '***VEMP findings in individuals with otitis media***' is a bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student Registration No.: 08AUD032. This has been carried out the under guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

V. Basavaraj

Dr. Vijayalakshmi Basavaraj

Mysore

DIRECTOR

May, 2010

All India **Institute of Speech and Hearing,**

Manasagangothri,

Mysore – 570 006.

CERTIFICATE

This is to certify that this dissertation entitled '***VEMP findings in individuals with otitis media***' has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Dr. Animesh Barman

Guide

Reader in Audiology,

Department of Audiology,

All India Institute of Speech and Hearing,

Manasagangothri,

Mysore – 570 006.

Mysore

May, 2010

DECLARATION

This is to certify that this master's dissertation entitled '*VEMP findings in individuals with otitis media*' is the result of my own study under the guidance of Dr. Animesh Barman, *Reader* in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore **Register No. 08AUD032**

May, 2010

Acknowledgements

I offer my sincere thanks to God almighty for countless graces He pours on me every day, especially for the completion of this dissertation.

I thank Dr. Vijayalakshmi Basavaraj, Director of AIISH, for permitting me to carry out this study.

I thank Prof. P.Manjula, H.O.D Audiology department, for permitting me to use the department.

I thank my guide, Dr.Animesh Barman for his constant support and encouragement. Sir, I learned a lot from you during past two years and especially during dissertation work. Sir, you never hesitate to appreciate good work and encourage students to widen their horizons with creative thinking. Thank you so much for being a wonderful teacher.

Special thanks to Mr.Sujeet kumar Sinha for his timely help. I thank all my friends who were subjects for this study.

The most precious asset for me is my parents, who are everything to me. I take this opportunity to thank them wholeheartedly for being so wonderful to me. Thanks, trillion times for your constant support, love and encouragement and prayers.

The chatterbox of my family, my sister, thanks for all your support and care and also for being a good model for me. From you I learned the value of relationships and family bond.

I sincerely acknowledge Fr.Jose, my elder brother and mentor for his kind love and intercession.

I thank Mr. Sobin Sebastian (brother in law) for his support and also for being a model for me, hats off to you, for your determination and commitment.

I thank Sagini, for being with me in all my ways. U helped me a lot to become a follower of Christ and taught me the value of relationships. Thank you so much.

I thank all my teachers especially Mrs.Reshmi Bhat for your appreciation and support.

Sincere thanks to all members of Jesus Youth Mysore especially Victor, Vivian and Joby chettan for their support.

Sincere thanks to all my friends at Calicut, Bangalore, AIISH mysore, Tamil Nadu. Special thanks to Albin, George, Praveen, Alex, Robin and Vivek.

I honor AIISH, for helping me to bud out as a professional and also creating opportunities to empower my talents.

Table of contents

List of Tables

List of Figures

Chapter 1

INTRODUCTION

Otitis media is one of the major diseases that cause conductive hearing loss with a high prevalence. Adverse effects of otitis media include sensori neural hearing loss, tinnitus, dizziness and disequilibrium with hearing loss being the major focus and vestibular function being overlooked in research (Paparella, Brady & Hoel 1970). Takahashi , Nakamura , Yui and Mori (1985) reported 50 cases of facial palsy due to otitis media. In humans, chronic otitis media seems to lead inner ear involvement in addition to the sequels caused in the middle ear (Paparella, Oda, Hiraide & Brady, 1972). The mechanism is believed to be that middle ear inflammatory mediators damage the inner ear through the round window and the oval window (Paparella, Oda, Hiraide & Brady, 1972). The saccule is anatomically nearer to the oval window than the cochlea and the semicircular canal; therefore, saccule is influenced to a greater extent in advanced chronic otitis media (Seo et al, 2008).

Vestibular evoked myogenic potentials (VEMPs) were first described by Bickford, Jacobson, and Cody (1964) can be used to assess saccular and inferior vestibular nerve function. Vestibular evoked myogenic potential (VEMP) is a myogenic potential of neck muscles elicited by stimulating the vestibular system with click or tone burst sound stimuli. The reflex is believed to be sacculocolic conducted through the inferior vestibular nerve (Murofushi, Matsuzaki & Wu, 1999).

Vestibular-evoked myogenic potentials (VEMPs) have been applied as a clinical test to explore the integrity of the sacculo-collic reflexes (Colebatch et al 1994). VEMP is a short latency evoked potential. It is recorded from the contracted sternocleido mastoid muscle. Recording of VEMP require high intensity acoustic stimulation, usually 95 dBnHL for Air Conduction and 60 – 70 dBnHL for Bone Conduction stimulus (Miyamoto, Seo, Node, Hashimoto & Sakagami, 2006; Yang & Young, 2003). The responses consist of positive and negative successive waves (pI-nII), with latency values in adults about 13 and 23 ms respectively (Wu, Young & Murofushi 1999).

Hart et al, (1998) showed that otitis media with effusion significantly affected balance and motor skills in children. The earliest publication related to this, belongs to Merica (1942) who found that Eustachian tube obstruction caused dizziness in children. Golz et al, (1991) found abnormal Elecronystagmography in 71% of the children with otitis media with effusion compared to 4% in children without otitis media. Casselbrant et al, (1995) evaluated vestibular functions in children with otitis media using moving posture platform test with velocity as the measurement parameter and their results suggested that middle ear effusion affects vestibular system in children.

Sheykholeslami, Murofush, Kermany, and Kaga, (2000) reported that bone conducted VEMP (B-VEMP) may be used in patients with bilateral external auditory canal atresia, with or without the middle ear anomalies. Seo et al, (2008) reported that Bone-conducted vestibular evoked myogenic potentials (B-VEMPs) showed high specificity to detect the presence of vertigo in patients with unilateral chronic otitis media (COM).

Need for the study

- Researches and observations in recent years suggest that otitis media with effusion causes dizziness in children (Golz et al, 1991); Koyuncu et al, 1999; Jones et al, 1990 and Casselbrant et al, 1995). There is dearth of information on otitis media and VEMP and also it has not been correlated with the duration of otitis media and VEMP findings. Thus, it is necessary to carry studies in this area.
- It is difficult to record VEMP using air conducted acoustic stimulus because a typical sound-evoked VEMP response is dependent upon a good energy transfer of sound from middle ear to inner ear. The air conducted VEMP responses are typically absent in the existence of conductive hearing loss (CHL) in which the air- bone gap (ABG) is> 20 dB (Halmagyi, Curthoys & Colebatch, 1994). So it is essential to use Bone conduction as an alternate mode of stimulation to record VEMP.
- It is also essential to have some norms for bone conducted VEMP in order to use it as a clinical tool.

- A comparison of air conducted and bone conducted VEMP recorded from normal hearing individuals would provide information regarding the efficacy of using bone conduction as stimulation mode.

Objectives of the study

The study aims to:

- Develop database for Bone Conducted VEMP.
- Assess reliability of bone conducted VEMP result by comparing with air conducted VEMP findings.
- Determine occurrence of bone conducted VEMP in individuals with normal hearing and
- Determine relationship between duration of Otitis media and VEMP results.

Chapter2

REVIEW OF LITERATURE

Infections of the middle ear space and their sequelae have plagued mankind from the beginning of time. Otitis media is an inflammatory condition of the middle ear cleft and may be associated with or without intact tympanic membrane. It was first described by Hippocrates as early as in 450 BC, and it continues to present itself even today as one of the most perplexing universally observed medical problems of childhood and a leading cause of hearing loss. It is estimated that 70% of children would have had one or more episodes of otitis media (OM) by three years of age. For children less than 15 years old, the most frequent diagnosis made in the clinical practice is otitis media. (Teele, Klein& Rosner, 1984; Healy, 1996; Bluestone & Klein, 2001). Streptococcus pneumoniae is the most frequently recognized pathogen, followed by Haemophilus influenzae (Klein & Bluestone, 1982).

Complications of chronic otitis media

Otitis media leads to many complications in middle ear such as acute mastoiditis and ossicular erosion. Apart from this, otitis media may also affect the otic capsule including cochlea and vestibular system. When infections from middle ear, mastoid air cells or both spreads into cochlear and vetibular apparatus, the complication is termed labryrinthitis.

Sensorineural hearing loss associated with otitis media

In humans, chronic otitis media seems to lead inner ear involvement in addition to the sequels caused in the middle ear (Paparella et al, 1972). In contrast, the situation regarding acute or secretory otitis media in man seems to be rather obscure. It is evident that no major inner ear lesions after secretory or acute otitis media are to be expected (Rahko, Karma & Sipila, 1989). Still, there are reports with more high tone losses in children with a history of otitis media (Avid & Ostfeld, 1982; Sorri & Rantakallio, 1988; Harada, Yamasoba & Yagi, 1992).

Kirtane, Merchant, Raje , Zantye and Shah (1985) evaluated prevalence of sensorineural hearing loss in chronic otitis media in 100 patients. The results of this study indicate that there is a definite sensori neural component to the hearing loss in cases of chronic otitis media. Bone conduction in diseased ears is depressed to a statistically significant degree when compared to that in normal control ears. They observed that this trend is equally evident in both unsafe and safe varieties of chronic otitis media. In other words, 'safe' type of chronic otitis media is not safe with respect to hearing.

Pathophysiology of chronic otitis media

Paparella et al, (1970) hypothesized that the round window membrane permits toxic materials to enter the inner ear and biochemically alter the inner ear fluids, resulting in gradual end-organ dysfunction. Various animal studies have conclusively demonstrated the ability of this membrane to serve as a portal (Paparella. 1981).

Radioactive isotopes, labelled proteins, antibiotics, toxins and tracers have been placed on the middle ear surface of the round window membrane and later collected from perilymphatic fluids. Temporal bone sections from patients with otitis media (Paparella, Oda, Hiraide, & Brady, 1972) have shown serofibrinous precipitate and inflammatory cells mainly localised in the scala tympani near the round window.

Vestibular damage in otitis media

A fistula arises when the endosteal layer has been a complication of chronic otitis media. The latral semicircular canal is more involved than the superior or posterior semicircular canals; the cochlea is rarely involved. The incidence of otic capsule fistula in the setting of chronic otitis media is 3.6 to 12.9 % (Lee, Jung, Park & Hong. 2008).

Suppurative labyrinthitis

Suppurative labyrinthitis is an uncommon complication of chronic otitis media that results from bacterial invasion of the inner ear via either the round or oval window or through a labyrinthine fistula created by cholesteatoma. The onset of suppurative labyrinthitis is characterized by sudden profound sensori neural hearing loss and severe vertigo (Kitsko, D. J. & Dohar, J. E. 2008).

Balance problems associated with otitis media

Cohen, Friedman, Lai, Pellicer, Duncan and Sulek (1997) evaluated balance function in 25 children with otitis media with effusion. Their results showed that unilateral disease did not differ significantly from normals. Subjects with bilateral disease, however, were significantly impaired compared to normals on balance, locomotion and total score and they were significantly impaired compared to unilateral subjects on all scores. Parental perceptions of their children's balance correlated poorly with the test results. Their data suggest that young children with bilateral otitis media with effusion are delayed in developing motor skills that require dynamic balance.

Casselbrant, Villardo, and Mandel, (2008) concluded that not only the adverse effect on hearing should be considered in the management of a child with otitis media, but also the child's balance. History of recurrent or persistent middle ear effusion affects the vestibular and/or balance function of four-year old children when tested in the absence of a concurrent episode of middle ear effusion, which may have developmental consequences (Casselbrant et al, 2000).

The mechanism by which OME causes balance dysfunction is unclear. Currently, three theories are presented in the literature: (1) Ionic transfer through the semi-permeable round window membrane indirectly alters the composition of the endolymph via the perilymph, with subsequent changes in ionic channels of the kinocilia and stereocilia which affect balance (Goycoolea et al, 1987); (2) Serous or toxic labyrinthitis occurs secondary to infection in a fluid-filled middle ear (Goycoolea 1988); and (3) Negative pressure changes in the middle ear are transmitted through the labyrinthine windows, leading to secondary movement of the inner-ear fluids (Kobrak 1935). Regardless of the ultimate underlying etiology, OME is now considered one of the most common causes of balance disturbance in children (Balkany 1986; Gates, 1980).

Is saccule affected in otitis media?

Since literature clearly shows that sensori neural hearing loss could occur as a result of chronic otitis media, involvement of saccular function is also important, because saccule is anatomically nearer to the oval window than the cochlea and the semicircular canal (Seo et al, 2008). Distance from middle ear is also shorter for saccule (0.4mm) compared to 0.65mm for utricle (Nobukazu, Tetsuo & Terufumi, 1990). Hence saccule is more prone to get affected by middle ear infection.

Some patients with chronic otitis media complain of balance problems (Komatsuzaki A, 1988). However, vestibular functions in these patients are poorly understood. Accurate evaluation of vestibular function in patients with chronic otitis media by means of the caloric test, which is the most commonly used test, is difficult. Results are obtained by comparing reactions between the two sides; thus, equal stimuli must be applied to both ears. Accurate evaluation is difficult in patients with a perforated ear drum because the bony wall of the promontrium is directly stimulated by cold or hot water. Hyper-reaction may be seen in the affected ear (Spector 1967).

Recently, vestibular evoked myogenic potential (VEMP) testing has been established as another means of examining vestibular function (Colebatch & Halmagyi, 1992; Colebatch, Halmagyi & Skuse, 1994; Welganpola & Colebatch, 2005). Unlike ENG testing, in which 1–2 hours may be needed for a complete evaluation, VEMP testing takes less than an hour. Moreover, the testing does not produce discomfort, and most people can tolerate the procedure with minimal cooperation. Hence VEMP can be used to assess saccule functioning in individuals with otitis media.

Origin of VEMP

Sound-evoked vestibular responses in humans were first described by Von Békésy (1935) who, using intense sounds of 128 to 134 dB, evoked head movement toward the stimulated ear. Displacement of the stapes footplate, which lies in close proximity to the sacculus, was thought to lead to eddy current formation within the endolymph, hair cell displacement, and activation of primary afferents.

At present, the most favored approach to test unilateral saccular function is by recording Vestibular Evoked Myogenic Potentials (VEMPs) first demonstrated by Cloebatch et al, in 1994. VEMP is a short latency evoked potential, recorded from the contracted sternocleidomastoid (SCM) muscle to intense auditory stimuli. The response consists of an initial positivity or inhibition (p13) followed by a negativity or excitation (n23) peak (Welgampola & Colebatch, 2005).

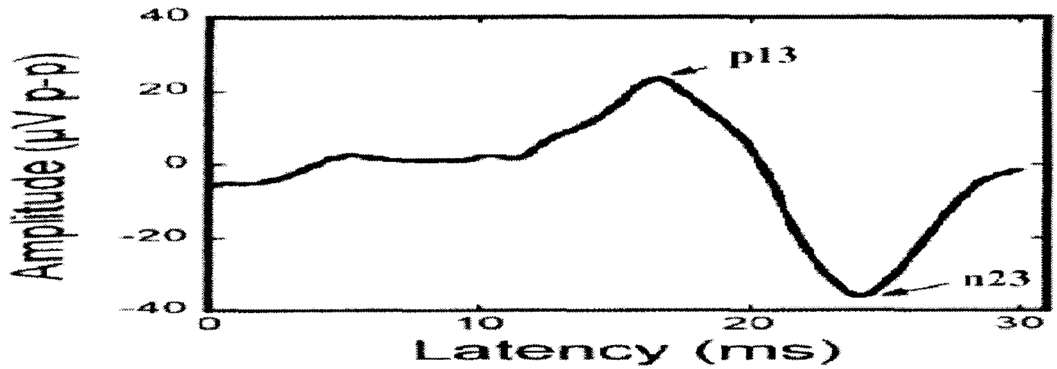

Figure 2.1: VEMP response having p13 and n23 peaks.

Later components (n34 & p44), have a lower stimulus threshold and are nonvestibular (probably cochlear) in origin. Recordings from patients with unilateral and bilateral inner ear deficits showed that the p13–n23 peaks can be elicited in patients with bilateral sensori neural hearing loss, while the n34–p44 peaks were absent. On the other hand, p13–n23 peaks were not present in individuals with ipsilateral vestibular loss. Thus the p13–n23 peaks are generated by activation of the ipsilateral saccular afferents (Waele, 2001; Todd & Cody, 2000).

The acoustically evoked VEMP is thought to reflect activation of the saccule, inferior vestibular nerve, and the descending vestibular spinal pathways. Recording of VEMP will be done using three electrode placements. Non-inverting electrode (+) is placed at the midpoint of the sternocleidomastoid muscle of the side being stimulated, inverting electrode at the sternoclavicular junction and ground electrode at the forehead (Zhou & Cox, 2004; Welgampola & Colebatch, 2005). The VEMP p13-n23 response waveform can be obtained in nearly all normal individuals younger than 65 years old without significant conductive hearing loss (Colebatch, 2001).

Factors affecting VEMP

There are several factors that can affect VEMP results. They can be put under subject factors, recording factors and stimulus factors.

Subject factors

- Eye position

It is recommended to fix the gaze in the straight ahead position to minimize variability arising from eye position (Sandhu & Bell, 2009).

- Head position

VEMP is hardly affected by head position. However, the gravitational axis in the upright position may have some special effect on tonic excitation of the saccule (Ito, Karino & Murofushi2007).

- Age Effects

Several studies show a decrease in VEMP amplitude in individuals older than 60years, indicating that aging affects human saccular and/or inferior vestibular nerve function (Welgampola & Colebatch, 2001; Akin & Murnane, 2008). Sheykholeslami et al. (2007) reported that reproducible biphasic VEMPs could be recorded from the sternocliedomastoid muscle of the infants.

Recording factors

- Recording sites

VEMP can be recorded from sternocleidomastoid muscle, trapezius muscle, gastrocnemius of the leg and extra ocular muscles. The optimal site for electrode placement for recording of clavicular VEMP is the middle third of the SCM. (Sheykholeslami, Murofushi & Kaga, 2001).

- Amplification, filter setting and number of sweeps

It is recommended to average 256 repetitions in order to record a VEMP response. Low pass filter cut off of 1500 Hz and high pass filter cut off of 30Hz is recommended for an ideal VEMP recording. Atypical amplifier setting for VEMP uses a gain of 5,000 (Welgompala & Colebatch, 2005).

- Laterality and Influence of voluntary tonic EMG level

VEMPs are ipsilateral-dominant, i.e. stimulation side and recording side and should be same for VEMP. This information is indicative of saccular origin of VEMP (Murofushi, Ochiai, Ozeki & Iwasaki, 2004). EMG target levels ranging from 30 μV to 50 μV are suggested for the VEMP (Welgompala & Colebatch, 2005).

Stimulus factors

- Mode and type of stimulation

Air conduction, bone conduction and galvanic modes of stimulation may be used to elicit a VEMP response. Intense clicks of about 95 to 100 dB above normal hearing level (NHL) (equivalent to 140 to 145 dB sound pressure level [SPL]) are required to evoke VEMPs and are at the limit of what is considered safe but are generally well tolerated. Stimuli of 95 dB NHL and 0.1-millisecond duration are used in routine clinical tests performed on subjects below age 60 (Welgampola & Colebatch, 2005). An intact middle ear conductive apparatus is needed to convey the click to the end organ. The response is abolished or attenuated in conductive hearing loss with air–bone gaps as small as 8.75 dB. (Bath, Harris & McEwan, 1999). Short tone bursts of 250- to 2,000-Hz frequencies, 2- to 10-millisecond duration, and intensities of 120 dB SPL evoke VEMPs similar to clicks. Their optimum stimulus frequencies lie between 500 and 1,000 Hz (Murofushi, Matsuzaki & Wu, 1999; Welgampola & Colebatch, 2001).

A short-duration (2-millisecond) pulsed current delivered via electrodes attached to the mastoid processes evokes a p13n23 response on the side ipsilateral to cathodal stimulation similar to that evoked by sound (Watson, & Colebatch.1998).

Skull taps and bone-conducted tones are stimuli that bypass the middle ear conductive apparatus and can evoke VEMPs despite conductive hearing loss. A forehead tap, delivered at Fpz (International 10–20 System) via a tendon hammer, evokes a vestibulardependent short-latency p1n1 response in both SCMs (Halmagyi, Yavor & Colebatch (1995). Tap-evoked VEMPs, owing to the magnitude of the stimulus, are 1.5 to 3 times as large as those evoked by clicks.

A bone-conducted tone burst delivered over the mastoid process, via a Radio ear B71 clinical bone vibrator, routinely used in audiometric testing, evokes VEMPs despite conductive hearing loss. Optimum stimulation is delivered with the bone conductor placed 3 ×2 cm posterosuperior to the external acoustic meatus, using frequencies of 200 to 250 Hz (Welgampola, Rosengren , Halmagyi & Colebatch 2003). VEMPs are often bilateral, as the stimulus is transmitted via bone and activates end organs on both sides. The ipsilateral VEMP is about 1.5 times larger and occurs approximately 1 millisecond earlier (Welgampola & Colebatch, 2005).

Welgampola, Rosengren, Halmagyi and Colebatch (2003) examined the properties and potential clinical uses of myogenic potentials to bone conducted sound. Myogenic potentials were recorded from normal volunteers, using bone conducted tone bursts of 7 ms duration and 250–2000 Hz frequencies delivered over the mastoid processes by a B-71 clinical bone vibrator. The best location for stimulus delivery, optimum stimulus frequency, stimulus thresholds, and the effect of aging on evoked response amplitudes and thresholds were systematically examined. Subjects with specific lesions were studied. Vestibular evoked myogenic potentials (VEMP) to air conducted 0.1 ms clicks, 7 ms/250–2000 Hz tones, and forehead taps were measured for comparison. Bone conducted sound evoked short latency p1n1 responses in both SCM muscles. Ipsilateral responses occurred earlier and were usually larger. Mean and standard deviation for p1 and n1 latencies were 13.6 and 22.3 ms with a standard deviation of 1.8 and 1.2 ms respectively ipsilaterally and 14.9 and 23.7 ms with a standard deviation of 2.1 and 2.7 ms respectively for contralateral recording. Stimuli of 250 Hz delivered over the mastoid process, posterosuperior to the external acoustic meatus, yielded the largest amplitude responses. Like VEMP in response to air conducted clicks and tones, p1n1 responses were absent ipsilaterally in subjects with selective vestibular neurectomy and preserved in those with severe sensorineural hearing loss. However, p1n1 responses were preserved in conductive hearing loss, whereas VEMP to air conducted sound were abolished or attenuated. Bone conducted response thresholds were 97.5 dB SPL/30.5 dB HL, significantly lower than thresholds to air conducted clicks (131.7 dB SPL/86.7 dB HL) and tones (114.0 dB SPL/106 dB HL). They concluded that bone conducted sound evokes p1n1 responses (bone conducted VEMP) which are a useful measure of vestibular function, especially in the presence of conductive hearing loss. For a given perceptual intensity, bone conducted sound activates the vestibular apparatus more effectively than air conducted sound. Curthoys, 2004 reported that irregular otolith afferents from both saccular and utricular macula exhibited a strong response to bone-conducted sound in guinea pig. These findings suggest that B-VEMP can originate from both the saccule and utricle.

Miyamoto, Seo, Node, Hashimoto and Sakagami(2006) studied relationship between vestibular-evoked myogenic potential evoked by air-conducted stimuli (A-VEMP) and those evoked by bone-conducted stimuli (B-VEMP). To determine the optimum stimulus conditions for B-VEMP, 40 ears of 20 healthy volunteers were used. To compare results of A-VEMP and B-VEMP, 60 ears of 30 healthy volunteers and 70 ears of 35 patients with unilateral vestibular disorder without conductive hearing loss were used. The results of B-VEMP were almost the same as those for A-VEMP, at least, for patients without conductive hearing loss

Applications of VEMP

Complete assessment of vestibular function is an important measurement in neurology, otology, and audiology. Typical tests used in the electronystagmography (ENG) battery only assess the integrity of lateral semicircular canals and the superior vestibular nerve. By adding VEMP measurements, the clinician may have the capability of revealing disorders in the saccule and/or inferior vestibular nerve (Zhou & Cox, 2004).

Since Colebatch, Halmagyi, and Skuse (1994) revised the recording procedure, VEMP testing has become attractive for clinical use, especially for the diagnosis of peripheral vestibular pathologies. The VEMPs are suitable for clinical application for the following reasons:

1. The response, specifically the first wave (p13–n13), is repeatable and consistent. Despite variations in amplitude, the latency is relatively stable.
2. Compared to other tests, VEMP testing may be more specific in locating lesions. It may reveal abnormal function of the saccule and/or the inferior vestibular nerve.
3. Potentially, VEMP testing could be sensitive and able to detect minor changes in the function of the vestibular system.

4. VEMP testing is relatively easy to perform. Most current equipment that is capable of recording the auditory brainstem responses (ABR) can be used to record VEMP.

VEMP may be used as a clinical tool in detecting following disorders.

- *Menieres disease*

Robertson and Ireland (1995) reported that VEMPs were absent in all 3 of their patients with Menieres disease.Ohki, Matsuzaki, Sugasawa and Murofushi(2002) reported that Seventy-five percent (9/12) of the patients showed decreased or absent VEMPs in the ears with endolumphatic hydrops.

- *Vestibular schwannoma*

Murofushi et al. (1998) reported that 15 out of the 17 had no VEMPs, while the remaining 2 had significantly decreased amplitude. It is supported by others also (Matsuzaki, Murofushi, &Mizuno 1999).

- *Vestibular hypersensitivity disorders*

Brantberg et al. (2001) studied 8 patients with superior canal dehiscence. In all patients, VEMPs were present with extremely low thresholds and abnormally large amplitudes on the affected side. Watson, Halmagyi, and Colebatch (2000) reported that the thresholds of click-evoked VEMPs were low for ears with superior canal dehiscence (four at 65 dB, one at 55 dB nHL) and normal (70–90 dB nHL) for the three unaffected ears.

- *Vestibular neuritis*

Heide et al. (1999) reported that VEMPs are not affected by vestibular neuritis as vestibular neuritis is associated with lesion in superior vestibular nerve.

It has been reported that the lesion sometimes affects the inferior vestibular nerve system (Murofushi , Halmagyi, Yavor, Colebatch.1996). Ochi, Ohashi and Watanabe (2003) found reduced VEMP amplitude in two of the eight patients with unilateral vestibular neuritis. Those two patients were diagnosed as having lesion in inferior vestibular nerve.

- *Benign paroxysmal positional vertigo*

Heide et al. (1999) recorded VEMP response in three BPPV patients, in which all BPPV patients had normal recorded VEMP response. However, more recent study on BPPV patients indicated that 30% of the patients showed abnormal VEMP responses. Akkuzu , Akkuzu and Ozluoglu (2006) found that VEMP for the 30 affected ears in the 25 BPPV patients revealed prolonged latencies in eight ears and decreased amplitude in one ear (nine abnormal ears; 30% of total).

- *Otitis media*

A typical sound-evoked VEMP response is dependent upon a good energy transfer of sound from middle ear to inner ear. The VEMP responses are typically absent in the existence of conductive hearing loss in which the air bone gap (ABG) is greater than 20 dB (Halmagyi , Curthoys & Colebatch, 1994).

Sheykholeslami , Murofushi , Kermany and Kaga (2000) studied utility of bone conduction stimulus in VEMP. Both clicks and sort tone bursts were used as stimuli. Subjects consisited of 20 normal volunteers and 12 patients with well-defined lesions of the middle or inner ear or the eighth cranial nerve. The bone-conducted clicks evoked short-latency vestibular-evoked myogenic potential (VEMP) responses only in young subjects or in subjects with conductive hearing loss. Short tone bursts evoked VEMPs with higher amplitude and better waveform morphology than clicks with the same acoustic intensity. They concluded that loud auditory stimuli delivered by bone as well as air conduction can evoke myogenic potentials from the sternocleidomastoid muscle.

Wang, Liu, Yu, Wu and Lee (2009) evaluated the VEMP in patients with chronic otitis media before and after surgery. Twenty-four subjects with unilateral COM were enrolled. A pure tone audiogram and VEMP using 500 Hz unilateral short tone-burst stimulations were recorded before and 3 months after surgery. The postoperative VEMP responses were compared with the responses before surgery and the healthy controls. Results showed that, after surgery, the 500 Hz air bone gap (ABG) decreased significantly and the VEMP response rate increased significantly from 41.7% to 66.7%. However, both the preoperative and postoperative p13 latencies were significantly longer than those of the healthy controls. So these authors concluded as, the pathology of chronic otitis media (COM) could delay and reduce the energy transfer of sound to the inner ear.

Seo et al, (2008) investigated the VEMPs induced by bone-conducted stimuli (B-VEMPs) in patients with conductive hearing loss due to chronic otitis media. Their study consisted of two subject groups, one group of individuals having unilateral otitis media with disequilibrium and the other group having otitis media without disequilibrium. They were divided into two groups on the basis of the presence or absence of balance problems for 6 months. In this study, balance problem means both vertigo and dizziness. Isolated, recurrent or persistent symptoms were included in this study. The disequilibrium group consisted of 25 patients and non-disequilibrium group consisted of 23 patients. And the mean duration of otitis media was 23.09 ± 20.9 years for non disequilibrium group and 29.09 ± 23.3 years for disequilibrium group. The control group comprised 35 healthy volunteers. Bone conducted VEMPs were stimulated with tone burst sound of 60 dB nHL at 250 Hz delivered from a bone vibrator and were recorded for each subject. The results of B-VEMP were compared between disequilibrium and non-disequilibrium groups. Results showed that mean interaural ratio was 16.59% with a standard deviation of 12.1% in the control group, thus the normal range was less than 40.7%. Abnormal results were not found in any subject in the non-disequilibrium group but were found in 13 patients (54.0%) in the disequilibrium group. The ear with COM showed lower responses than the intact ear in all subjects with abnormal results. So they concluded that bone-conducted vestibular evoked myogenic potentials (B-VEMPs) showed high specificity for the presence of vertigo in patients with unilateral chronic otitis media.

These results suggest that vestibular function can be evaluated with B-VEMPs, even in patients with conductive hearing loss.

The literature clearly shows that otitis media may lead to complications in the inner ear apart from the complication in the middle ear. There are several studies conducted to rule out the involvement of cochlea which is typically evident from the pure tone audiometry. Very few studies are done to evaluate the need to assess saccular function in individuals with otitis media. The current study aimed to assess the saccular function in individuals with otitis media using air conducted and bone conducted VEMP in Indian scenario.

Chapter 3

METHOD

The present study was taken up with the aim of evaluating the functioning of vestibular system (saccule and/ inferior vestibular nerve) in individuals with otitis media using VEMP. Study also aimed at assessing utility of the air conducted VEMP in varying degrees of conductive hearing loss. Attempt was also made to find out the prevalence of bone conducted VEMP in normal hearing and in individuals having otitis media.

Subjects

To accomplish the aim, two groups of subjects were taken for the study. They were, control group having normal hearing and clinical group having otitis media. Control group consisted of 30 normal hearing adults (15 males and 15 females) with an age range of 18 to 55 years having mean age of 23 years. Clinical group also consisted of 30 individuals having otitis media with an age range of 15 to 55 years having a mean age of 30.5 years.

Subject selection criteria for control group

- All of them had air conduction hearing sensitivity within 15 dB HL at octave frequencies from 250 to 8000 Hz.

- All the subjects had 'A' type tympanogram with presence of acoustic reflexes at normal level in both ears.
- They did not have any history or presence of any otological problem (like ear discharge, ear ache)
- No history or presence of any neurological symptoms was reported.
- All of them had speech identification score (SIS) 100% obtained at 40 dB SL.
- Uncomfortable levels (UCL) for speech in all the subjects was greater than 105 dB HL.

Subject selection criteria for clinical group

- All of them had presence of bilateral otitis media with duration of more than five years. Duration of five years was taken because; prevalence of inner ear damage due to otitis media is more if the duration is more than 3 years (Kaur, Sounkhya & Bapna, 2003).
- Presence of otits media was diagnosed by an experienced Otologist.
- Severity of hearing loss ranged up to moderately severe degree.
- Threshold for bone conduction was within normal limits (15 dB HL).
- They did not have any history or presence of any neurological symptoms.
- All of them had speech identification score (SIS) 100% obtained at 40 dB SL.

- Uncomfortable levels (UCL) for speech in all the subjects was greater than 105 dB HL.

Research design

The current study followed a specific research design. The research design used in this study was non experimental group comparison.

Instrumentation

- A Calibrated diagnostic audiometer GSI-61 was used to estimate the pure-tone threshold for air conduction and bone conduction threshold, speech identification scores and UCL for speech for all the subjects.
- A Calibrated immittance meter GSI Tympstar was used for tympanometry and reflexometry.
- IHS Smart EP version: 3140 (Intelligent hearing systems) was used to record and analyze VEMP. Eartone 3- A insert earphone was used to deliver the air conducted stimulus. Radio ear B-71 was used to deliver stimulus through bone conduction.

Test environment

All the tests were carried out in a sound treated room. The ambient noise level was as per the recommendation of ANSI (S - 3.1-1991.).

Procedure

Prior to the Audiological evaluation, a detailed case history was taken from the clinical group in order to gather information regarding the age of onset of otitis media, thus estimating the duration of the same. Information regarding age of onset of the problem, ear pain, ear discharge, itching and blocking sensation gave primary data regarding the presence of otitis media which was later confirmed by an experienced Otologist.

Pure tone threshold: was obtained using modified version of Hughson and Westlake procedure (Carhart & Jerger, 1959). Thresholds across octave frequencies from 250 to 8000Hz for air conduction and from 250 to 4000Hz for bone conduction were obtained.

Uncomfortable levels (UCL): Speech was presented through the headphone (TDH-39) at different intensities using ascending method to determine the uncomfortable loudness level (UCL) of the subjects. The hearing level at which the subjects considered speech material to be uncomfortably loud was considered as UCL for speech.

Tympanometry and Reflexometry: was carried out with GSI Tympstar using 226Hz probe tone to analyze the middle ear status of all the subjects. Acoustic reflexes were measured at 500Hz, 1 KHz, 2 kHz and 4 kHz. Control group showed

‘A’ type tympanogram with acoustic reflexes at normal levels whereas it was ‘B’ type with absent acoustic reflexes for clinical group.

VEMP recording: Those subjects, who fulfilled the selection criteria based on case history and Audiological assessment, underwent VEMP recording. Subjects were seated upright on a reclining chair. They were instructed to turn their head to opposite side of the test ear to activate the sternocleidomastoid muscle (SCM) unilaterally. Subjects were instructed not to move their head and neck while VEMP recording and also to fix their gaze in front to control eye movement. Recording of VEMP was done using three electrode placements.

Electrode montage used to record VEMP

Non-inverting electrode (+) was placed at midpoint of the sternocleidomastoid muscle of the side being stimulated. Sternoclavicular junction was the location for placement of inverting electrode (-) and forehead for ground electrode.

Before placing the electrodes, the sites were cleaned using skin preparation paste and silver chloride electrodes were placed with the ten-20 conduction paste to increase the conductivity. The electrode impedance was checked and it was ensured that the absolute impedance at each electrode site was within 5 Kohm and inter electrode impedance was within 3 Kohm. The parameters recommended by Damen(2007) was used to record VEMP.

Table3.1: *Parameters used to record VEMP*

Type of stimulus	500Hz tone burst
duration	5000 micro secs
Stimulus intensity for : air conduction Stimulus intensity for : bone conduction	105 dBnHL 66 dBnHL
Rate	5.1/sec
Polarity	Rarefaction
Total number of stimulus	200
Analysis time	70 msec
Filter settings	High pass: 30Hz Low pass: 1500Hz
Amplification	5000
Notch filter	Off
Electrode	Disc type

While recording VEMP, the tonic EMG level was monitored and maintained for each of the subjects between 50- 150 microvolts. A visual feedback available in the instrument was provided to each of the subjects to monitor the tonic EMG level of sternocleidomastoid muscle activation. VEMPs were recorded in normal hearing subjects and subjects having otitis media.

Analysis

Two recording at each level was carried out. Identification of p13 and n23 peaks was done by an experienced Audiologist. The mean latencies and peak to peak amplitude of p13 and n23 peaks for both air conducted and bone conducted VEMP in both control and clinical group were noted. Comparison between VEMP obtained using air conduction and bone conduction modes in both control and clinical group were carried out to find the significant difference. Air conducted VEMP was compared across control and the clinical group to find out the effect of otitis media on VEMP. Similarly, bone conducted VEMP obtained in the control group was compared with that obtained in the clinical group. Effects of the degree of hearing loss and duration of otitis media on air conducted and bone conducted VEMP were also found using appropriate statistical analyses.

Chapter 4

RESULTS

The present study was taken up with the aim of evaluating the functioning of vestibular system (saccule and/ inferior vestibular nerve) in individuals with otitis media using VEMP. Study also aimed at assessing utility of the air conducted VEMP in varying degrees of conductive hearing loss. Attempt was also made to find out the prevalence of bone conducted VEMP in normal hearing and in individuals having otitis media.

In order to accomplish the objectives of the study, latencies of p13 and n23 and their peak to peak amplitude were noted in both control and clinical group. Comparison of latencies of p13 and n23, and their peak to peak amplitude was carried out between air conduction and bone conduction VEMP in control group. Comparison of latency and amplitude across the control and clinical groups was also carried out. Statistical analysis of the latencies and amplitude were carried out using Statistical Package for Social Sciences (SPSS) software, version 16.

The following statistical analyses were carried out for the data obtained from within and across the groups of subjects.

- Descriptive statistics was carried out to find the mean latencies and standard deviation of p13, n23 and mean peak to peak amplitude in both control and clinical groups for both air and bone conduction modes of stimulation
- Paired t- test was administered to check whether any significant difference between air conduction and bone conduction exists within the control group
- Wilcoxon signed ranks test was carried out to check for any significant difference between air conducted and bone conducted VEMP parameters within the clinical group
- Mann – Whitney test was carried out to look for any significant difference between mean latencies and peak to peak amplitudes of air conducted and bone conducted VEMP across groups
- Spearman's correlation test was carried out to evaluate the relationship between duration of otitis media and bone conducted VEMP results and also the degree of hearing loss on bone conducted VEMP.

Air conduction VEMP response obtained in control group

Air conduction VEMP was recorded from 70 ears and all of them had VEMP responses. So the percentage of occurrence of air conducted VEMP was 100%. Out of

70 ears, 8 ears had poor wave morphology. VEMP response obtained from an individual with normal auditory and vestibular function is shown in figure 4.1.

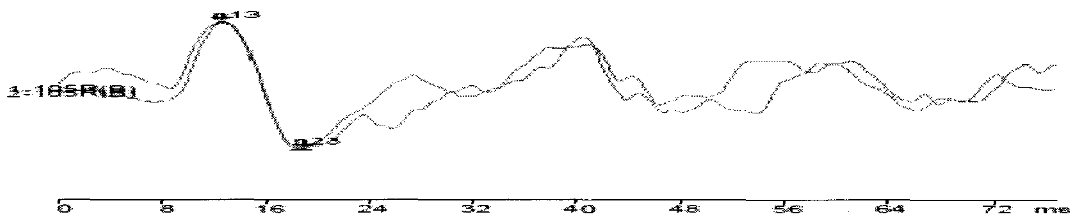

Figure 4.1: *VEMP response obtained for 500 Hz air conducted tone burst presented at 105 dBnHL in an individual with normal hearing.*

Bone conduction VEMP response obtained in control group

Bone conduction VEMP was recorded from 70 ears. Out of 70 ears, 61 ears had bone conduction VEMP. So the percentage of occurrence of bone conducted VEMP was 87.14%. Out of 61 ears, 29 ears had poor waveform morphology. VEMP response obtained from an individual with normal auditory and vestibular function is shown in figure 4.2.

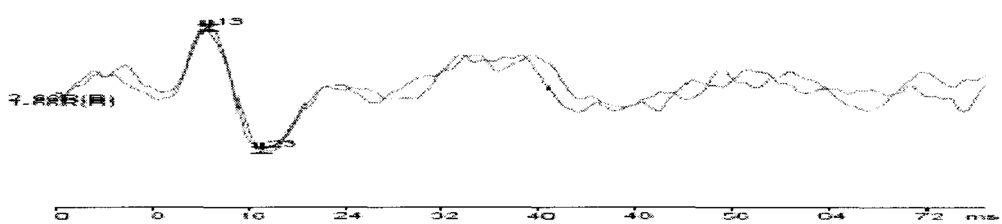

Figure 4.2: *VEMP response obtained for bone conducted 500 Hz tone burst presented at 66 dBnHL in an individual with normal hearing.*

Air conduction VEMP response obtained in clinical group

Air conducted VEMP was recorded from 38 ears having otitis media, out of which only 4 ears had air conducted VEMP response. Hence, the occurrence of air conduction VEMP in this group was 10.52%. Out of 4 subjects in whom air conducted VEMP could be recorded, 3 of them had poor wave morphology. VEMP response obtained from an individual with otitis media is shown in figure 4.3 and 4.4.

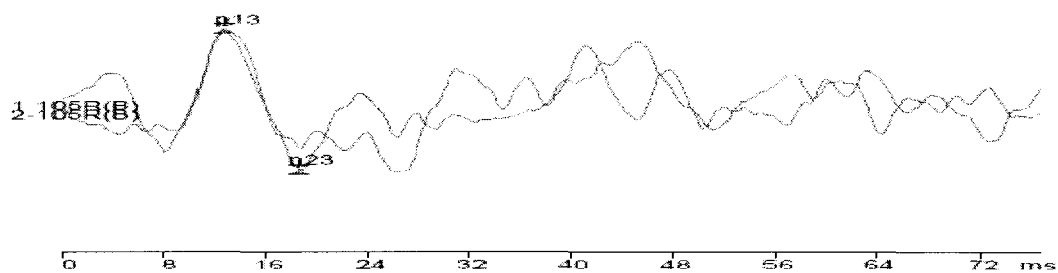

Figure 4.3: *VEMP response obtained for 500 Hz air conducted tone burst presented at 105 dBnHL in an individual with otitis media.*

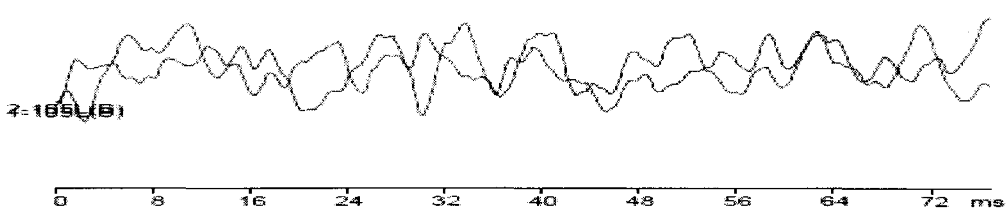

Figure 4.4: *Absent VEMP response obtained in an individual with otitis media for air conducted 500 Hz tone burst presented at 105dBnHL.*

Bone conducted VEMP response obtained in the clinical group

Bone conduction VEMP was recorded from 38 ears having otitis media, out of which 27 ears had bone conducted VEMP. Only 4, out of 27 ears showed good morphology. Hence, the occurrence of bone conduction VEMP in this group was 71.05 %. As found in the data, 11ears in the clinical group did not have bone conducted VEMP response. VEMP response obtained from an individual with otitis media is shown in figure 4.5 and 4.6.

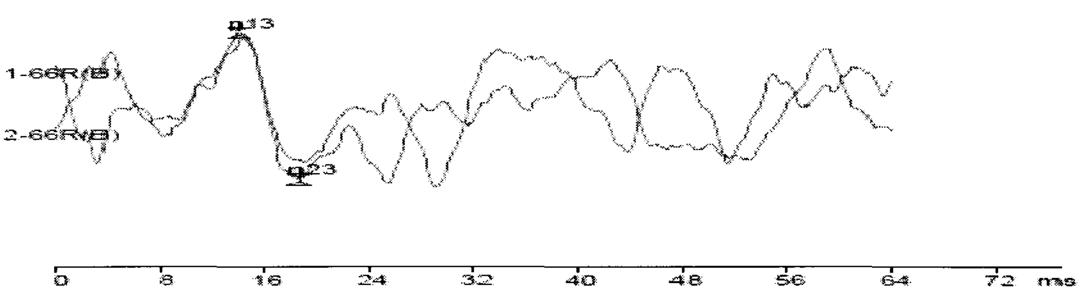

Figure 4.5: *VEMP response obtained in an individual with otitis media for 500 Hz tone burst presented at 66 dBnHL through bone conduction.*

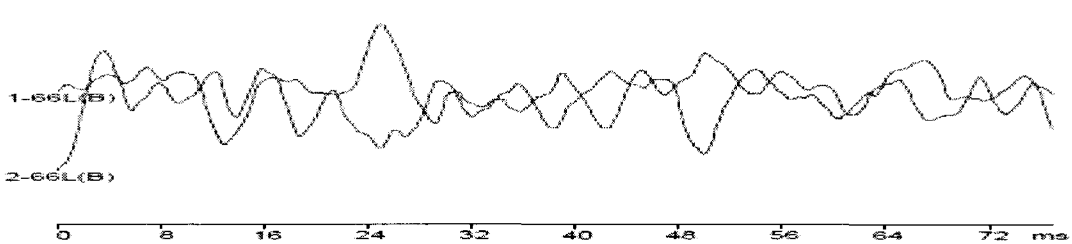

Figure 4.6: *Absent VEMP response obtained in an individual with otitis media for 500 Hz tone burst presented at 66 dBnHL through bone conduction.*

Comparison of air conducted and bone conducted VEMP in control group

The p13 and n23 latency, and peak to peak amplitude obtained using air conducted and bone conducted acoustic stimulus were compared within the control group. Initially, mean latency and peak to peak amplitude were calculated using descriptive statistics and the results are given in the table 4.1.

Table4.1: *Mean, standard deviation and range of latencies of p13, n23 latencies and peak to peak amplitude obtained for both air conduction and bone conduction VEMP in the control group*

Mode of stimulation		**AC**	**BC**
p13 latency	Mean(msec)	13.54	14.43
	Standard	1.21	2.61
	Range	11.60 – 18.70	9.80 – 22.90
n23 latency	Mean(msec)	20.06	20.45
	Standard	1.62	2.52
	Range	15.75 - 24	14.80 – 27.40
Peak to peak amplitude	Mean(μV)	90.5	34.13
	Standard	37.2	18.25
	range	15.52 – 179.86	4.73 – 84.56

It can be observed that p13 latency was significantly shorter for air conduction mode compared to bone conduction. The mean peak to peak amplitude was significantly higher for air conduction mode. However, n23 latency did not differ significantly between air conduction and bone conduction.

Paired t – test was carried out later, to find the significant difference between air conducted and bone conducted VEMP in control group. The results showed significant difference in p13 latency between air conducted and bone conducted VEMP. The details of the t- test results are shown in the table 4.2.

Table 4.2: *t- values, significant level and degrees of freedom between VEMP parameters obtained through air and bone conduction mode*

VEMP results	t- value	Degree of freedom	Significant level
p13 latency	4.11	60	0.000
n23 latency	1.331	60	.188
Peak to peak amplitude	12.24	60	0.000

It can be observed that the p13 latency and peak to peak amplitude for air conducted VEMP differ significantly from that of bone conducted VEMP.

Comparison of air conducted and bone conducted VEMP in clinical group

The mean latencies of p13, n23 and mean peak to peak amplitude of both air conducted and bone conducted VEMP were found out using descriptive statistics. The results are shown in the table 4.3.

Table 4.3: *Mean, standard deviation and range of p13, n23 latencies and peak to peak amplitude for both air conducted and bone conducted VEMP elicited in clinical group*

Mode of stimulation		**AC**	**BC**
p13 latency	Mean(msec)	15.42	16.03
	Standard	5.06	2.61
	Range	12.40 - 23	11.90 – 23.60
n23 latency	Mean(msec)	21.17	22.44
	Standard	6.30	2.91
	Range	17.30 – 30.60	17.00 – 28.40
Peak to peak amplitude	Mean(μV)	42.75	19.08
	Standard	38.50	9.70
	Range	10.40 – 97.40	9.56 – 58.40

It is observed that the mean latencies of p13 and n23 peaks were delayed for bone conducted VEMP. The mean peak to peak amplitude was reduced for bone conducted VEMP.

Wilcoxon signed rank test was administered to find out the significant difference between air conducted and bone conducted VEMP in clinical group. Table 4.4 shows the results obtained.

Table 4.4: *z - values and significant level obtained between air conducted and bone conducted VEMP in clinical group*

VEMP	Z - value	Significant level
p13 latency	.365	.715
n23 latency	.365	.715
Peak to peak amplitude	1.461	.144

It revealed no significant difference between air conducted and bone conducted VEMP for latencies and peak to peak amplitude.

Comparison across groups for air conducted VEMP

In order to fulfill the aim of the study, comparison across groups was also carried out, i.e. between control and clinical group. It is evident from the table 4.1 and 4.3 that there are differences in the mean values of latency and peak to peak amplitude obtained between control and clinical groups. The mean latencies of p13 and n23 were prolonged in clinical group compared to control group. The mean peak to peak amplitude was reduced for clinical group compared to that of control group. In order to statistically verify these findings, Mann – Whitney test was administered. The results are shown in table 4.5.

Table4.5: *showing/ z/ values and significance level*

VEMP	Z - values	Significant level
P13 latency	.036	0.971
N23 latency	1.125	0.261
Peak to peak amplitude	1.912	0.056

It can be observed that there is no statistically significant difference between mean latencies of p13, n13 and peak to peak amplitude elicited through air conduction mode between control and clinical groups.

Comparison across groups for bone conduction VEMP

Comparison of bone conducted VEMP between control group and clinical group would reveal the effect of otitis media on bone conducted VEMP which is one of the aims of the present study.

It is evident from the table 4.1 and 4.3 that the mean latencies of p13 and n23 are prolonged in the clinical group compared to that of control group. The mean peak to peak amplitude is reduced in clinical group in the clinical group. Mann – Whitney test was administered to find any significant difference between the groups. The results are shown in the table 4.6.

Table 4.6: *z- values and significant level of bone conducted VEMP parameters between the groups*

VEMP results	Z - value	Significance level
p13 latency	3.25	0.001
n23 latency	2.897	0.004
Peak to peak amplitude	4.044	0.000

Results of Mann – Whitney test suggest that latencies of p13 and n23 are significantly prolonged. Peak to peak amplitude obtained in clinical group was significantly reduced.

Relationship between VEMP results and duration of otitis media

One of the aims of the present study was to find out the effect of duration of otitis media on VEMP in the clinical group. Details about presence or absence of VEMP and duration of otitis media are listed in the table 4.7.

Table 4.7: *Presence or absence of VEMP and duration of otitis media*

No of subjects	AC		BC		Duration
	right	left	Right	left	
1	A	A	P	P	6.00
2	A	A	P	P	5.00
3	A	A	P	P	9.00
4	A	A	P	P	6.00
5	A	A	A	A	12.00
6	A	A	A	P	5.00
7	P	A	P	P	10.00
8	A	A	A	A	15.00
9	A	A	P	P	10.00
10	A	P	P	P	5.00
11	A	A	P	P	10.00
12	P	A	A	P	13.00
13	A	A	A	A	7.00
14	P	A	P	P	10.00
15	A	A	A	A	8.00
16	A	A	P	P	6.00
17	A	A	P	P	5.00
18	A	A	P	P	16.00
19	A	A	A	P	15.00

It is clear from the table that a specific trend could not be observed with regard to VEMP results and duration of otitis media. In order to find the relationship between duration of otitis media and VEMP findings, Spearman's rank correlation test was administered for bone conducted VEMP. this statistical analysis on air conducted VEMP could not be done as the number of subjects who had air conducted VEMP was vey less. The results obtained for bone conducted VEMP are summarized in table 4.8.

Table4.8: *r – values and significant level between bone conducted VEMP parameters and duration of otitis media*

Parameters	r - value	Significant Level
p13 latency	0.15	0.959
n23 latency	-0.314	0.270
Peak to peak amplitude	-0.413	0.127

It can be inferred from the table that there was a positive correlation between mean latency of p13 and duration of otitis media. The mean latency of n23 and mean peak to peak amplitude showed negative correlation with duration of otitis media. But these correlations were not statistically significant.

Relationship between degree of hearing loss and VEMP results

Another aim of the present study was to find out the correlation between VEMP findings and degree of hearing loss. Details regarding the presence or absence of VEMP and degree of hearing loss are given in the table 4.9.

Table 4.9: *Presence or absence of VEMP and degree of hearing loss*

No of Subjects	AC		BC		Pure tone average in dBHL	
	right	left	Right	left	Right	left
1	A	A	P	P	40.00	41.66
2	A	A	P	P	38.33	41.66
3	A	A	P	P	45.00	31.66
4	A	A	P	P	40.00	51.66
5	A	A	A	A	48.33	36.66
6	A	A	A	P	55.00	35.00
7	P	A	P	P	33.30	50.00
8	A	A	A	A	58.30	45.00
9	A	A	P	P	36.60	30.00
10	A	P	P	P	48.33	38.33
11	A	A	P	P	31.60	28.33
12	P	A	P	A	25.00	56.66
13	A	A	A	A	46.66	45.00
14	P	A	P	P	38.33	45.00
15	A	A	A	A	51.66	55.00
16	A	A	P	P	41.66	28.33
17	A	A	P	P	35.00	38.33
18	A	A	P	P	41.66	31.66
19	A	A	A	P	36.66	33.30

It is evident from the table that air conducted and bone conducted VEMP were present only when degree of hearing loss was less. Spearman's rank correlation test was carried out to find the correlation between degree of hearing loss and bone conducted VEMP. Air conducted VEMP was not compared with degree of hearing loss due to less number of data. The results obtained for bone conducted VEMP are shown in table 4.10.

Table 4.10: *r- values and significant level between VEMP results and degree of hearing loss*

Parameters	r - value	Significant level
p13 latency	0.345	0.205
n23 latency	0.310	0.261
Peak to peak amplitude	-0.03	0.914

As evident in the table 4.10, that there was a positive correlation between latencies of p13 and n23 and degree of hearing loss and a negative correlation between peak to peak amplitude and degree of hearing loss. But these correlations are not statistically significant.

Thus, it can be concluded from the results that

- The mean p13 latency is shorter and peak to peak amplitude was larger for air conducted VEMP in control group. This difference was statistically significant.

- There was no significant difference in n23 latency between air conducted and bone conducted VEMP in control group.
- There was no significant difference in terms of p13 latency, n23 latency and peak to peak amplitude between air conducted and bone conducted VEMP in clinical group.
- There was no significant difference in air conducted VEMP in terms of p13, n23 latency and peak to peak amplitude between control and clinical group.
- The mean p13 and n23 latencies were prolonged and peak to peak amplitude reduced for bone conducted VEMP in clinical group than the control group.
- There was a positive correlation between mean latency of p13 and duration of otitis media. The mean latency of n23 and mean peak to peak amplitude showed negative correlation with duration of otitis media, suggest that latency of p13 get prolonged and n23 latency become shorter with increase in duration of otitis media. The peak to peak amplitude gets diminished as the duration of otitis media increases. But these correlations were not statistically significant.
- There was no statistically significant correlation between degree of hearing loss and VEMP findings. The mean p13 and n23 latency was prolonged as the degree of hearing loss increased. The peak to peak amplitude diminished with greater degree of hearing loss.

Chapter 5

DISCUSSION

Air and bone conducted VEMP parameters were noted and studied for the following:

- Percentage of occurrence of air conducted and bone conducted VEMP in both control and clinical group.
- Air conducted and bone conducted VEMP obtained from control and clinical group were compared within and across the groups.
- Correlation analysis was carried out to find whether degree of hearing loss and duration of otitis media had any significant effect on bone conducted VEMP.

The results obtained are discussed below.

Air conduction

The result obtained from the present study reveal that the percentage of occurrence of air conducted VEMP in control group was 100% which is in par with the literature. Sheykholeslami et al. (2000) also studied air conduction VEMP in normal individuals and reported 100% occurrence of VEMP in normal individuals.

The occurrence of air conduction VEMP in clinical group was 10.52%. The relatively less percentage of occurrence of air conducted VEMP in clinical group could be attributed to the degree of conductive hearing loss. As the degree of conductive hearing loss increased, the attenuation to acoustic signal also increased hence limited amount of sound reached the inner ear which might not be sufficient to evoke a VEMP in the stimulated ear. A study conducted by Wang, Liu, Yu, Wu and Lee (2009) on VEMP in individuals with chronic otitis media revealed that as the air bone gap decreased the percentage of occurrence of air conducted VEMP also increased from 41.7% to 66.7%. So it can be concluded that the middle ear pathology due to chronic otitis media (COM) could delay and reduce the energy transfer of sound to the inner ear, resulting in absent or abnormal VEMP.

In the control group, the mean latency of p13 and n13 were 13.54 ± 1.62 and 20.06 ± 1.21 respectively. The results of Sheykholeslami et al. (2000) also showed similar results. The mean latencies for p13 and n23 were 14.74 ± 2.6 and 23.41 ± 4.00 respectively.

The mean latency of p13 was 15.42 msec with a standard deviation of 6.30 and 21.17 msec with a standard deviation of 5.06 for n23 in the clinical group. The variations among individuals were very high as evident from the values of standard deviation. Wang and Lee(2007) studied air conducted VEMP in ears with middle ear effusion and found the mean latency of p13 was 16.59 msec with a standard deviation of /5.2 msec, mean latency for n23 was 23.89 msec with a standard deviation of /5.2 msec. Hence, it is clear that both the studies have similar findings.

The mean peak to peak amplitude in the control group was 90.5μV. Welgampola (2001) also found similar results in normal individuals. The mean peak to peak amplitude was 72.5 ± 46.8μV with a range of 25 to 297 μV.

The mean peak to peak amplitude for air conducted VEMP in the clinical group was 42.75 μV with a standard deviation of 38.50μV which is similar to findings obtained by Wang and Lee (2007). The mean peak to peak amplitude obtained in their study was 65.39μV with a standard deviation of 28.2μV in individuals with middle ear effusion. This increased up to 85.49μV with a standard deviation of/ 47.5μV after surgery for middle ear effusion. The relative reduction in peak to peak amplitude, compared to normal ears could be due to the attenuation and delay of sound energy caused by otitis media.

The clinical group had prolonged mean latencies and reduced peak to peak amplitude. This finding is similar to that obtained by Wang and Lee (2007). They compared normal ears and ears with middle ear effusion. Their results indicated that there exists a significant difference between the two groups. The mean latencies of p13 and n23 get prolonged and the mean peak to peak amplitude reduces in ears with middle ear effusion.

In the present study, statistical analysis could not find a significant difference between the groups and this may be attributed to the less number of ears that were considered for statistical analysis. Only four ears had air conducted VEMP responses, and this data was compared with 70 normal ears.

Bone conduction

The percentage of occurrence of bone conducted VEMP was 87.14% in the control group. The percentage of occurrence of bone conducted VEMP was less in the present study compared to a 100% occurrence obtained by Miyamoto, Seo, Node, Hashimoto, and Sakagami (2006). The possible reason could be the difference in transducer used in both the studies. Radio ear B71 bone vibrator was used in the current study where as it was BR- 41; Rion, Japan used in study by Miyamoto, Seo, Node, Hashimoto, and Sakagami (2006), which could be a better transducer to elicit bone conducted VEMP.

This data suggest that vestibular evaluation may be carried out using bone conducted VEMP in individuals having conductive hearing loss. Seo et al, (2008) investigated the VEMPs induced by bone-conducted stimuli in patients with conductive hearing loss due to chronic otitis media. Their results suggest that vestibular function can be evaluated with B-VEMPs, even in patients with conductive hearing loss.

The percentage of occurrence of bone conducted VEMP in the clinical group was 71.05 %. This is similar to the findings of Seo et al. (2008). They had also reported that percentage of occurrence of bone conducted VEMP was less in ears with chronic otitis media which was 40 % compared to 100 % in normal ears. The reason for low percentage of occurrence of bone conducted VEMP in individuals with otitis media could be the saccular dysfunction due to chronic otitis media. The current study had higher percentage of occurrence than Seo et al. (2008). This could be due to a difference in subject selection criteria. All individuals in the present study had normal bone conduction thresholds where as in study by Seo et al. (2008) involved individuals having abnormal bone conduction thresholds also. Murofushi, Kermany and Kaga (2000) reported in their study that bone conducted VEMP had poor wave morphology compared to air conducted VEMP which is *observed even in the present study for both control and clinical group.*

The mean latencies for p13 and n23 for bone conducted stimuli were 14.43msec and 20.45msec respectively for the control group. This is in consonance with the results obtained by Sheykholeslami , Murofushi , Kermany and Kaga (2000) for bone conducted VEMP in normal individuals. They observed 12.98 msec as the mean latency for p13 with a standard deviation of 1.34 ms and 20.00 msec mean latency with a standard deviation of 2.36 ms for n23.

The mean latencies for bone conducted p13 and n23 in the clinical group were 16.03mses and 22.44 msec respectively in the present study. Seo et al (2008) also studied bone conducted VEMP in ears having chronic otitis media and the mean latencies obtained were 14.39 msec and 24.49 msec for p13 and n23 respectively.

The mean peak to peak amplitude obtained from control group was 34.13µV with a standard deviation of 18.25µV. The peak to peak amplitude obtained was relatively less in the current study compared to results obtained by Murofushi , Kermany and Kaga(2000), which was 158.48µV.

The variation in the results could be due to the higher intensity (77 dBnHL) used by Murofushi , Kermany and Kaga(2000), compared to 66 dBnHL used in the current study. Another reason could be the difference in transducer used in both the studies.

The mean peak to peak amplitude for bone conducted VEMP in the clinical group was 19.08 µV with a standard deviation of 9.70 µV which is significantly less than that of control group. This finding is in support with the findings of Seo et al (2008). They found that the mean peak to peak amplitude in individuals with chronic otitis media was lower than that was obtained in normal ears. The possible reason for reduced peak to peak amplitude in ears with otitis media could be the damage to the saccule due to chronic otitis media. Seo et al.(2008) also discussed the saccular dysfunction in ears with chronic otitis media which would result in reduced peak to peak amplitude in bone conducted VEMP.

Degree of conductive hearing loss and VEMP

Air conduction

A general trend which could be observed in the mean latencies and peak to peak amplitude was that occurrence of air conducted VEMP reduced as the degree of hearing loss increased. This finding is in agreement with that of Wang, Liu, Yu, Wu and Lee (2009). They also reported a similar trend, as the degree of conductive hearing loss increased occurrence of air conducted VEMP diminished. The possible reason could be attenuation and delay of the sound energy reaching to the inner ear due to the conductive hearing loss.

Bone conduction

The results of the present study reveal that there exists a correlation between them which are not significant statistically. The mean latencies of p13 and n23 was prolonged with increasing degree of hearing loss whereas the mean peak to peak amplitude decreased with increasing degree of hearing loss. Seo et al (2008) found that the occurrence of bone conducted VEMP was reduced in ears with otitis media. Occurrence of bone conducted VEMP was 40% in ears with otitis media compared to 100% in normal ears. Their study did not attempt to find a correlation between degree of hearing loss and bone conducted VEMP parameters.

Duration of otitis media and bone conducted VEMP

The results suggest that the peak to peak amplitude has a negative correlation with duration of otitis media. This indicates that the mean peak to peak amplitude reduced as the duration of otitis media increased. But this correlation is not statistically significant. These results are similar to that obtained by Seo et al (2008). Their findings indicated that complaints of disequilibrium were more in individuals who had chronic otitis media for a mean duration of 29.09 years with a standard deviation of 23.3 years. As the literature clearly shows that chronic otitis media can cause damage to otic capsule (Paperella et al, 1970), involvement of saccular dysfunction may be suspected in such cases (Seo et al, 2008). The results of the present study, in agreement with previous studies (Seo et al, 2008; Murofushi, Kermany & Kaga, 2000) suggest that bone conducted VEMP may be used as a clinical tool to evaluate the functioning of vestibular system (saccule/ inferior vestibular nerve) in individuals with otitis media, and the degree of hearing loss and duration of otitis media may be factors affecting the VEMP findings.

Chapter 6

SUMMARY AND CONCLUSION

Otitis media is an inflammation of the middle ear cleft, with or without intact tympanic membrane. Presence of otits media was first identified by Hippocrates as early as in 450 BC and it is highly prevelant in children and in adults (Teele, Klein & Rosner, 1984; Healy, 1996; Bluestone & Klein, 2001). Otitis media may lead to inner ear complications apart from that in the middle ear due to the permeability of round window (Paperalla et al, 1970). These complications may include sensori neural hearing loss, otic capsule fistula and suppurative labyrinthitis (Avid & Ostfeld, 1982; Dornelles, Costa & Rosito, 2008; Harada, Yamasoba & Yagi, 1992; Kirtane, Merchant, Raje, Zantye & Shah 1985; Paparella, Oda, Hiraide, & Brady, 1972; Schachern, Paparella, Duvall & Choo, 1984).

Balance problems are also associated with chronic otitis media. Cohen et al. (1997) found that bilateral chronic otitis media was associated with balance problems than unilateral otitis media, in children. Casselbrant, Villardo and Mandel (2008) also found that chronic otitis media causes vestibular dysfunction in children.

Since literature clearly shows that there is a relationship between otitis media and vestibular dysfunction, functioning of saccule should be assessed in individuals with otitis media as saccule is in close proximity with middle ear (Seo et al, 2008; Tetsuo, Nobukazu & Terufumi, 1990).

Accurate evaluation of vestibular system using caloric test is difficult in patients with a perforated ear drum because the bony wall of the promontrium is directly stimulated by cold or hot water and Hyper-reaction may be seen in the affected ear (Spector 1967).

Recently, vestibular evoked myogenic potential (VEMP) testing has been established as another means of examining vestibular function (Colebatch & Halmagyi, 1992; Colebatch, Halmagyi & Skuse, 1994; Welganpola & Colebatch, 2005). The clinical utility of VEMP has been described in the light of many studies and it is found that VEMP is sensitive to various clinical entities.

Vestibular evoked Myogenic potential may be the choice of interest, to assess the functioning of saccule and inferior vestibular nerve in individuals having otitis media as it is time efficient and cause less discomfort to the subject. The air conducted VEMP responses are typically absent in the existence of conductive hearing loss in which the air bone gap (ABG) is greater than 20 dB (Halmagyi , Curthoys & Colebatch, 1994). Since the occurrence of air conducted VEMP is less in cases of conductive hearing loss, bone conducted VEMP is used an alternate mode of stimulation. Utility of bone conducted VEMP was verified by various authors and it was found that use of 250 or 500 Hz tone bursts evokes better myogenic potentials of saccular origin. (Sheykholeslami, Murofushi, Kermany & Kaga, 2000; Welgampola, Rosengren, Halmagyi & Colebatch 2003; Miyamoto, Seo, Node, Hashimoto & Sakagami2006).

The present study was taken up with the aim of evaluating the functioning of vestibular system (saccule and/ inferior vestibular nerve) in individuals with otitis media using VEMP. Study also aimed at assessing utility of the air conducted VEMP in varying degrees of conductive hearing loss. Attempt was also made to find out the prevalence of bone conducted VEMP in normal hearing and in individuals having otitis media.

A total of 108 ears were evaluated in the study. They were divided into two groups i.e. control (70 ears) and clinical (38 ears) group with otitis media for more than 5 years. Audiological evaluation involving pure tone audiogram, speech audiometry, tympanometry and reflexometry were done, which were the basis on which the participants for the present study were selected. Air conducted (at 105 dBnHL) and bone conducted (at 66 dBnHL) VEMP were recorded for all the subjects in both control and the clinical group for 500Hz toneburst. Analysis of VEMP waveform was carried out by an experienced Audiologist. Latencies of p13 and n23 and peak to peak amplitude were noted. Comparisons were done within and across groups for both air conducted and bone conducted VEMP using statistical package for social sciences (SPSS) software version 16.

The following ststistical analyses were carried out within and across groups for all subjects:

- Descriptive statistics was carried out to find the mean latencies and standard deviation of p13, n23 and mean peak to peak amplitude in both control and clinical groups for both air conduction and bone counduction mode of stimulation
- Paired t- test was administered to check whether any significant difference between air conduction and bone conduction exists within the control group
- Wilcoxon signed ranks test was carried out to check for any significant difference between air conducted and bone conducted VEMP parameters within the clinical group
- Mann – Whitney test was carried out to look for any significant difference between mean latencies and peak to peak amplitudes of air conducted and bone conducted VEMP across groups
- Spearman's correlation test was carried out to evaluate the relationship between duration of otitis media and bone conducted VEMP results and also the degree of hearing loss and bone conducted VEMP.

The results of the statistical analysis revealed the following:

Table 6.1: *Mean and standard deviation of VEMP parameters for both control and clinical groups*

Group	Mode of stimulaation	P13 latency		N23 latency		Peak to peak amplitude	
		mean	SD	mean	SD	mean	SD
control	Air conduction	13.54	1.21	20.06	1.62	90.5	37.2
	Bone conduction	14.43	2.61	20.45	2.52	34.13	18.25
clinical	Air conduction	15.42	5.06	21.17	6.30	42.75	38.50
	Bone conduction	16.03	2.61	22.44	2.91	19.08	9.70

- The mean p13 latency is shorter and peak to peak amplitude was larger for air conducted VEMP in control group. This difference was statistically significant.
- There was no significant difference in n23 latency between air conducted and bone conducted VEMP in control group.
- There was no significant difference in terms of p13 latency, n23 latency and peak to peak amplitude between air conducted and bone conducted VEMP in clinical group.

- There was no significant difference in air conducted VEMP in terms of p13, n23 latency and peak to peak amplitude between control and clinical group.
- The mean p13 and n23 latencies were prolonged and peak to peak amplitude reduced for bone conducted VEMP in clinical group than the control group.
- There was a positive correlation between mean latency of p13 and duration of otitis media. The mean latency of n23 and mean peak to peak amplitude showed negative correlation with duration of otitis media, suggest that latency of p13 get prolonged and n23 latency become shorter with increase in duration of otitis media. The peak to peak amplitude gets diminished as the duration of otitis media increases. But these correlations were not statistically significant.
- There was no statistically significant correlation between degree of hearing loss and VEMP findings. The mean p13 and n23 latency was prolonged as the degree of hearing loss increased. The peak to peak amplitude diminished with greater degree of hearing loss.

The results of the present study are in agreement with previous studies (Seo et al, 2008; Murofushi, Kermany & Kaga, 2000). The present study suggest that bone conducted VEMP may be used as a clinical tool to evaluate the functioning of vestibular system (saccule/ inferior vestibular nerve) in individuals with otitis media, and the degree of conductive hearing loss and duration of otitis media may be factors affecting the VEMP findings.

Clinical implications

- This study helps to understand that bone conduction mode can be used to record VEMP effectively.
- The bone conduction VEMP is useful to assess the saccular function in subjects with conductive hearing loss.
- Saccular function needs to be evaluated in individuals with chronic otitis media.
- Provides information regarding the effect of duration of middle ear effusion on vestibular system.
- Adds information, to the literature related to effects of chronic otitis media.

Core of future research

- Further studies could aim to involve more number of subjects and find, if there is any statistical significant relationship between duration of otitis media and VEMP findings.
- The present study involved subjects who had normal bone conduction thresholds in the clinical group. A future research could be aimed to record bone conducted VEMP in subjects with otitis media having poor bone conduction threshold in pure tone audiometry.

Chapter 7

REFERENCES

Akin, F. W., Murnane, O. D., & Proffitt, T. M. (2003). The effects of click and tone-burst stimulus parameters on the vestibular evoked myogenic potential (VEMP). *Journal of the American Academy of Audiology, 14*, 500–509.

Akkuzu, G., Akkuzu, B., & Ozluoglu, L., N. (2006). Vestibular evoked myogenic potentials in benign paroxysmal positional vertigo and Meniere's disease. *European journal of otorhinolaryngology*,; 263(6):510-517.

Avid, A., & Ostfeld E. (1982). Acquired irreversible sensori neural hearing loss associated with otitis media with effusion. *American Journal of Otolaryngology*, 3: 217- 22.

Balkany, T.J., & Finkel, R.S. (1986). The dizzy child. *Ear and Hearing*, 7, 138 - 142.

Bath, A.,P., Harris. N., McEwan J., & Yardley., M.,P. (1999). Effect of conductive hearing loss on the vestibulo-collic reflex. *Clin Otolaryngol Allied Sci*, 24(3), 181-183.

Bluestone, C.B., & Klein, J.O. (2001). *Epidemiology, otitis media in Infants and Children,* Philadelphia: W. B. Saunders.

Brantberg, K., Bergenius, J., & Tribukait, A. (1999). Vestibular- evoked myogenic potentials in patients with dehiscence of the superior semicircular canal. *Acta Otolaryngologica, 119,* 633–640.

Casselbrant, M. L., Furman, J. M., Rubenstein, E. & Mandel, E. M. (1995). Effects of otitis media on the vestibular system in children. *Annals of Otol Rhinol Laryngol*, 104, 620-624.

Casselbrant, M. L., Villardo, R. J. M., & Mandel, E. M. (2008). Balance and otitis media with effusion', *International Journal of Audiology*, 47, 9, 584 -589.

Casselbrant, M. L., Furman, J. M., Mandel, E. M., Fall, P. A., Kurs-Lasky, M., & Rockette, H. E. (2000). Past history of otitis media and balance in four-year old children. *Laryngoscope*, 110, 773 – 778.

Cody, D. T. R., Jacobson,J. L., Wailker,J. C. & Bickford,R. G.(1964). Averaged evoked Myogenic and cortical potentials to sound in man. *Annals of otorhinolaryngology*, 73, 763 – 777.

Cohen, H., Friedman, E. M., Lai1, D. Pellicer, M. Duncan, N. & Sulek, M. (1997). Balance in children with otitis media with effusion. *International Journal of Pediatric Otorhinolaryngology*, 42. 107 – 115.

Colebatch, J. G., Halmagyi, G. M., & Skuse, N. F. (1994). Myogenic potentials generated by a click-evoked vestibulocolic reflex. *Journal of Neurology, Neurosurgery, and Psychiatry, 57*, 190–197.

Colebatch, J. G., Day, B. L., Bronstein, A. M., Davies, R. A., Gresty, M. A., Luxon, L. M., (1998). Vestibular hypersensitivity to clicks is characteristic of the tullio Phenomenon. *Journal of Neurology, Neurosurgery, and Psychiatry,* 65(5), 670-678.

Curthoys, I.S. (2004). The physiological basis of VEMPVThe response of guinea pig primary vestibular neurons to air-counducted and bone conducted sound. *Journal of Vestibular Research,* 14:138- 139.

Gates, G.A. (1980). Vertigo in children. *Ear Nose Throat Journal*, 59, 358 – 360.

Golz, A., Westerman, S.T., Gilbert, L.M., Joachims, H.Z. & Netzer, A. (1991). Effect of middle-ear effusion on the vestibular labyrinth. *Journal of Laryngology and Otology*, 105, 987 - 989.

Goycoolea, M.V., Muchow, D. & Schachern, P. (1988). Experimental studies on round window structure: Function and permeability. *Laryngoscope,* 98 (6, Pt 2 Suppl 44), 1 - 20.

Halmagyi, G. M., Yavor, R. A., & Colebatch, J. G. (1995). Tapping the head activates the vestibular system: A new use for the clinic reflex hammer. *Neurology, 45,* 1927–1929.

Halmagyi, G. M., Colebatch, J. G., & Curthoys, I. S. (1994). New tests of vestibular function. *Baillieres Clinical Neurology*, 3, 485-500.

Harada, T., Yamasoba, T., & Yagi, M. (1992). Sensorineural hearing loss assciated with otitis media with effusion. O*torhinolaryngology*; 54: 61-5.

Hart, M. C., Nichols, D. S., Butler, E. M., & Barin, K. (1998). Childhood imbalance and chronic otitis media with effusion: Effect of tympanostomy tube insertion on standardized tests of balance and locomotion. *Laryngoscope*, 108, 665 - 670.

Healy, G. B. (1996). Otitis media and middle ear effusions. In: John J. Ballenger(Eds) *The Ear* (1003-1009), Baltimore: Williams & Williams.

Heide, G., Freitag, S., Wollenberg, I., Iro, H., Schimrigk, K., & Dillmann, U (1999). Click evoked myogenic potentials in the differential diagnosis of acute vertigo. *Journal of Neurol Neurosurg Psychiatry,* 66:787–790.

Ito, K., Ishimoto, S. I., & Murofushi. T. (2001). Narrow Internal Auditory Meatus: An Idiopathic Case Confirming the Origin and Pathway of Vestibular Evoked Myogenic Potentials in Humans. *Archives of Otolaryngol Head Neck Surgery*, 127, 275-278.

Kirtane, M. V., Merchant, S. N., Raje, A. R., Zantye, S. P., & Shah, K. L., (1985). Sensorineural hearing loss in chronic otitis media--a statistical evaluation. *Journal of Post Graduate Medicine*, 31,183.

Kitsko, D. J., & Dohar, J. E. (2008). Inner ear and facial nerve complications of acute otitis media, including vertigo. *Current Allergy and Asthma Reports*, 7,444-450.

Klein, J. O. & Bluestone, C. D. (1982). Acute otitis media. *Pediatric Infectious Diseases,* 1, 66-73

Kobrak, H. (1935). Influence of the middle ear on labyrinthine pressure. *Archives of Otolaryngology Head and Neck Surgery*, 21, 547-60.

Komatsuzaki, A., Futaki, T., Harada, Y., Hozawa, J., Ishii, T., Kamei, T., (1988). Inner ear disorders for chronic otitis media. Guideline for diagnosis of vertigo. Reply to the committee for diagnostic guidelines of vertigo in. *Equilibrium Research*, 47: 246.

Lee, J. H., Jung, S., H. Park, C., H. & Hong, S.,M. (2008). Bilateral promontory fistula due to noncholesteatomatous chronic otitis media. *Otorhiniolaryngology,* 226, 933-936.

Matsuzaki, M., Murofushi, T., & Mizuno, M. (1999). Vestibular evoked myogenic potentials in acoustic tumor patients with normal auditory brainstem responses. *European Archives of Otorhinolaryngology, 256*, 1–4.

Merica, F.W. (1942). Vertigo due to obstructionof the eustachian tubes. *JAMA*, 118, 1282 - 1284.

Miyamoto., A., Seo, T., Node, M., Hashimoto, M., & Sakagami, M. (2006). Preliminary study on vestibular-evoked Myogenic potential induced by bone-conducted Stimuli. *Otology & Neurotology,* 27, 1110-1114.

Murofushi, T., Halmagi, M. G., Yavor, R. A., & Colebatch, J. G. (1996). Absent vestibular evoked myogenic potentials in vestibular neurolabyrinthitis: An indicator of inferior vestibular nerve involvement. *Archives of Otolaryngology-Head & Neck Surgery, 122,* 845–848.

Murofushi, T., Matsuzaki, M., & Mizuno, M. (1998). Vestibular evoked myogenic potentials in patients with acoustic neuromas. *Archives of Otolaryngology-Head & Neck Surgery, 124,* 509–512.

Murofushi, T., Matsuzaki, M., & Mizuno, M. (1999). "Short tone burst-evoked myogenic potentials on the sternocleidomastoid muscle: are these potentials also of vestibular origin?" *Archives of Otolaryngology-Head & Neck Surgery,* 125(6), 660-4.

Murofushi, T., Ochiai, A., Ozeki, H., & Iwasaki, S. (2004). Laterality of vestibular evoked myogenic potentials. *International Journal of Audiology*, 43, 66–68.

Nobukazu, Y., Tetsuo, I., & Terufumi, M. (1990). Measurement of the Mechanical Properties of the Tympanic Membrane with a Microtension Tester. *Acta oto laryngologica*, 110 (1 & 2), 85 – 91.

Ohki, M., Matsuzaki, M., Sugasawa, K., & Murofushi, T. (2002). Vestibular Evoked Myogenic Potentials in Ipsilateral Delayed Endolymphatic Hydrops. *Journal of oto rhino laryngology, head & neck surgey*, 64, 424-428.

Ochi, K., Ohashi. T., & Watanabe, S. (2003). Vestibular-evoked myogenic potential in patients with unilateral vestibular neuritis: abnormal VEMP and its recovery. *Journal of Laryngology and Otology,* 117: 104–108.

Paparella, M. M., Brady. D. R., & Hoel. R. (1970). Sensorineural hearing loss in chronic otitis media and mastoiditis. *Trans AAOO,* 74, 108.

Paparella. M. M., Oda. M., Hiraide. F. & Brady. D. R. (1972). The pathology of sensorineural hearing loss in otitis media. *Annals of Otorhinoilaryngology, 86,* 632.

Paparella, M. (1981). 'Insidious Labyrinthine Changes in Otitis Media'. *Acta Oto-Laryngologica*, 92:1,513 — 520.

Rahko, T., Karma, P., & Sipila, M. (1989).Sensorineural hearing loss and acute otitis media in children. *Acta Otolaryngologica(Stoch),* 108, 107-12.

Robertson, D. D., & Ireland, D. J. (1995). Vestibular evoked myogenic potentials. *The Journal of Otolaryngology,* 24, 3–8.

Seo, T., Miyamoto, A., Saka, N., Shimano, K., Nishida, T., Hashimoto, M. (2008). Vestibular evoked myogenic potential induced by bone-conducted stimuli in patients with conductive hearing loss. *Acta Oto-Laryngologica,*128, 6, 639 - 643.

Sheykholeslami, K., Murofushi, T., Kermany, M. H., & Kaga, K. (2000). Bone-conducted evoked myogenic potentials from the sternocleidomastoid muscle. *Acta Otolaryngologica*, 120(6), 731-4.

Sheykholeslami, K., Megerian, C. A., Arnold, J. E., & Kaga, K. (2005). Vestibular-evoked myogenic potentials in infancy and early childhood. *Laryngoscope, 115(8):* 1440-1444.

Sorri, M. & Rantakallio, P. (1988). Secretory otitis media and hearing loss. *Acta Otolaryngol (Stockh)*; Suppl 457: 94 - 9.

Spector, M. (1967). Caloric testing of semicircular canal function. *Dizziness and vertigo*, 56 - 66.

Takahashi, H., Nakamura, H., Yui, M., & Mori H(1985) Analysis of fifty cases of facial palsy due to otitis media. *Archives of otorhinolaryngology*, 241(2):163-168.

Teele, D. W., Klein, J. O., & Rosner, B. A. (1984). Otitis media with effusion during the first three years of life and the development of speech and language. *Pediatrics,* 74, 282 - 287.

Todd, N. P., Cody, F. W. J., & Banks, J. R. (2000). A saccular origin of frequency tuning in myogenic vestibular evoked potentials? Implications for human responses to loud sounds. *Hearing Research, 141*, 180–188.

Wang, M., C., Liu, C., Y., Yu, E., C., Wu, H., J. & Lee, G., S. (2009). Vestibular evoked myogenic potentials in chronic otitis media before and after surgery. *Acta oto laryngologica*, 129(11):1206-11.

Watson, S. R. &. Colebatch, J. G. (1998). Vestibulocollic reflexes evoked by short-duration galvanic stimulation in man. *Journal of Physiology*, 513, 587-97.

Watson, S. R. D., Halmagyi, G. M., & Colebatch, J. G. (2000). Vestibular hypersensitivity to sound (Tullio phenomenon) structural and functional assessment. *Neurology, 54,* 722–728.

Welgampola, M. S., Rosengren, S. M., Halmagyi, G. M., & Colebatch, J. G. (2003). Vestibular activation by bone conducted sound. *Journal of Neurology Neurosurgery Psychiatry*, 74, 771-778.

Welgampola, M. S., & Colebatch, J. G. (2005). Characteristics and clinical applications of vestibular evoked myogenic potentials. *Neurology*. 64. 1682-1688.

Wu, C. H., Young, Y. H., & Murofushi, T. (1999). Tone burst evoked myogenic potentials in human neck flexor and extensor. *Acta Otolaryngologica, 119,* 741–744.

Yang, Tsung-Lin., & Young, Yi-Ho. (2003). Comparison of Tone Burst and Tapping Evocation of Myogenic Potentials in Patients with Chronic Otitis Media. *Ear and Hearing*, 24(3), 191-194.

Zhou, G., & Cox, C. L. (2004). Vestibular Evoked Myogenic Potentials: History and Overview. *American Journal of Audiology,* 13, 135–143.