EFFECT OF CONTRALATERAL NOISE ON COCHLEAR MICROPHONICS IN INDIVIDUALS WITH NORMAL HEARING SENSTIVITY AND MENIERE'S DISEASE

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CERTIFICATE

This is to certify that this dissertation entitled **"Effect of Contralateral Noise on Cochlear microphonics in the Individuals with Normal hearing sensitivity and Meniere's Disease**" is a bonafide work in part fulfilment of Masters of Science (Audiology) of the student registration no: 11AUD028. This has been carried under the 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**.**

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CERTIFICATE

This is to certify that this independent project entitled **"Effect of Contralateral Noise on Cochlear microphonics in the Individuals with Normal hearing sensitivity and Meniere's Disease**" 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.

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DECLARATION

This dissertation entitled ' **Effect of Contralateral Noise on Cochlear microphonics in the Individuals with Normal hearing sensitivity and Meniere's Disease**" is the result of my own study and has not been submitted earlier at any university for any other diploma or degree.

Mysore	**Register No.**
May, 2013	**11AUD028**

This is dedicated to my

Guide, Family,

God

and

My LOVE

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CHAPTER 1

Introduction

Auditory evoked potentials refer to any attempt to measure or observe the electrophysiological or Neuro-eclectic events that occur as a result of auditory activation. Most of these potentials focus on the evaluation of central pathways i.e. brain stem and cortical structures. To measure the information related to the peripheral part of the auditory system, electrocochleography is used. Electrocochleography (ECochG) refers to the method which measures the stimulus-related electrophysiologic potentials from the cochlea and auditory nerve. The stimulus-related electrical potentials associated with this part of the auditory pathway include the cochlear microphonics, the summating potential, and the compound action potential of the auditory nerve (Dallos, 1985 ; Coats, 1987).

The summating potential (SP) is a DC potential that follows the waveform envelope of an acoustic stimulus. It is most evident as a baseline shift in the cochlear microphonics. Intracellular recordings from cochlear hair cells show DC components in response to acoustic stimuli. The action potential (AP) is the most popular stimulus-related potential measured in humans. The AP reflects the summed response of synchronous discharges from several thousand individual nerve fibers primarily located in the basal or high-frequency region of the cochlea (Staller , 1986).

The cochlear microphonic (CM) is a gross result of the vector sum of the extra-cellular components of receptor potentials arising in inner (IHCs) and outer hair cells (OHCs) that can be recorded in humans and experimental animals at several recording sites. It is an alternating current (AC) voltage that mirrors the waveform of the acoustic stimulus at low-moderate levels of stimulation. CM reflects predominantly the basal-end cochlear activity when recorded from the round window and more remote sites. However it is often difficult to separate CM from stimulus artifact in non-invasive recordings (Ruth, 1993).

ECochG has been used in the diagnosis of a variety of disorders such as; in patients with suspected endolymphatic hydrops (Steller, 1986) in the differential diagnosis of inner ear/auditory nerve disorders and has received recent attention in the diagnosis of auditory neuropathy.

ECochG has emerged as one of the more powerful tools in the diagnosis, assessment and monitoring of Meniere's disease (MD), primarily through the measurement of the SP and AP. It has been reported that the incidence of an enlarged SP and SP/AP amplitude ratio in the general Meniere's population is approximately 60%-65% (Coats, 1981; Gibson, Moffat & Ramsden, 1977, Kumagami, Nishida & Baba, 1982) and elevated SP/AP ratio has been reported to be important in diagnosing MD (Eaton, 2003; Gibson, 1983). Mori, (1987) reported in his study that extratympanic ECochG is useful in diagnosing MD patients and an increased SP/AP amplitude ratio to be much more common among MD patients than among those with hearing loss of other origin such as sudden hearing loss and Lymez syndrome.

In hydropic ears, the CM amplitude tends to be lower, AP thresholds are quite variable and SP tends to be increased. As with humans, the results of ECochG measurements in hydropic cochlea tend to fluctuate with the stage of the disease. In a study by Fetterman (2001), he studied the correlation between distortion product otoacoustic emmsions (DPOAEs) and CM in hydropic and non hydropic individuals and found that there was no significant correlation between DPOAE and CM , but CM amplitude was lower in hydropic ears compared to non hydropic ears. However, ECochG investigations related to CM in MD are somewhat limited because of the fluctuant and variable nature of the disease.

Need for the study

ECochG has been used extensively in the assessment of MD, however most of the studies are related to the AP / SP ratio, and studies related to CM is very limited. Studies in the past have documented that CM amplitude is reduced in individuals with MD (Fetterman , 2001). Studies have also shown that around 10-27 % of the contralateral ear of an individual with Meniere's disease show endolympathic hydrops in EcochG evaluation (Conlon & Gibson 1999; Friedrichs & Thornton 2001). Thus it would be ideal to test efferent stimulation in MD to assess contralateral ear. As it is known fact that CM is originated from OHCs thus it would be ideal to study CM in MD as OHCs are affected in MD.

Contralateral suppression of CM is explored by stimulating medial olivocochlear bundle (MOCB). According to Liberman (1989) the medial olivery cochlear bundle can be stimulated by presenting acoustic stimulus in the contralateral ear , and which can lead to suppressive effect on cochlear potentials. It is also known that the auditory nerve potentials as well as cochlear potentials will have an inhibitory effect when contralateral MOCB is stimulated. (Fex, 1962; Guinan, 1996; Guinan & Gifford, 1988). Collet (1994) considered OAEs as the best measure to study contralateral acoustic stimulation. This is because ipsilateral MOCB will be activated through contralateral acoustic stimulation and its direct synapse on the OHCs and thus will affect the generation of OAEs .

Subsequent to the rationale of Collet (1994), one would assume that CM should also be an effective means to measure the influence of the contralateral auditory stimulation. This is because OHCs are involved in the generation of CM as well. Even though measuring the cochlear neural responses is considered a more precise way than OAE measurements to evaluate the strengths of the MOCB reflexes (Guinan, 2006), the existing literature describing the suppressive effect of the MOCB on the CM in humans is still very limited.

However, the CAP suppression has been reported in animal research (Kawase & Liberman, 1993; Liberman, 1989; Wiederhold & Kiang, 1970) and humans (Folsom & Owsley, 1987). But CM suppression has been studied minimally in animal research only (Bonfils et al., 1986). This lack of research in humans should be fulfilled.

Endolymphatic hydrops results in a decrease in the resting endocochlear potential (EP), increases in CM and AP thresholds, and an increase in the negative summating potential amplitude. It is difficult to separate the direct effects of hydrops from secondary effects of hair cell and nerve fiber loss, but the changes in EP and SP are probably direct effects of hydrops and are present early in the progression of the disease while changes in CM and AP occur later. Studies in the past have also reported that even if an individual is having unilateral MD the other ear is also affected. Around 10-27 % of the contralateral ear of an individual with Meniere’s disease show endolympathic hydrops in EcochG evaluation (Conlon & Gibson, 1999; Friedrichs & Thornton, 2001). Having this information at hand, it seems logical to examine the CM suppression in individuals with normal hearing sensitivity and in individuals with Meniere’s disease.

Thus the present study intended to study the feasibility of assessing the CM suppression clinically in humans using a tympanic recording approach. The main purpose of this study was to study the effect of the auditory efferent system on the OHCs activity by measuring the effect of contralateral noise on CM.

Aim of the study

To evaluate the effect of contralateral noise on cochlear microphonics in individuals with normal hearing sensitivity and in individuals with Meniere's disease.

CHAPTER 2

Review of Literature

Electrocochleography (ECochG) is a measure that has been applied to a group of electrophysiologic techniques intended towards the recording of stimulus related potentials generated from the cochlea and eighth nerve. The most widely used clinical applications of electrocochlegraphy is the assessment of patient with Meniere's disease.

The documentation of the potentials recorded via ECochG is called the electrocochleogram (ECochGm). Even though the ECochGm consists of more than one electrical potential the most evident and most easily recorded component is the whole nerve action potential (AP) of the eighth nerve. The AP component consists of one to three primary negative waves among which N1 is the largest wave.The AP N1 component is the most salient feature of the ECochG (Coats, 1974).

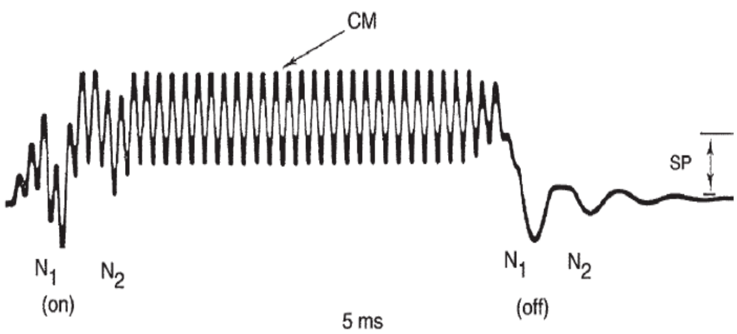

*Figure.1.*An electrocochleogram recorded from the ear canal in response to an 8000-Hz tone (Durrant, 1986).

Factor affecting ECochG/ECochGm

Electrocochleography is affected by a variety of stimulus and subject related factors. These factors could influence the latency and / or amplitude of the waveforms. Thus, it is important to understand these factors and apply them during the recording and interpretation of Electrocochleograph.

Stimulus related Factors.

Transducer. Insert earphones have a lot of clinical advantages compared to other transducers. Three advantages of insert earphones in the recording of ECochG are 1) EcochG potentials occur early in the waveform (within 2-3 milliseconds), 2) Stimulus artifact can be eliminated and waveform analysis can be enhanced when the transducer box is separated from electrode site, 3) Insert earphones is a better option during intra operating monitoring during surgery (Picton 1974).

Type of Stimuli. Use of clicks and tone bursts can change the morphology of ECochG. Clicks are most widely used stimulus because it excites the synchronous discharges from a large number of neurons and thus produces well-defined neural components. Click is produced with a 0.1 ms (100 µs) electrical pulse. However, the transient nature of the click makes it a less ideal stimulus for studying cochlear potentials such as the CM and SP, whose durations are stimulus dependent. Mostly in clinical ECochG measurement high-intensity acoustic clicks are used , but a tone-burst with sudden onset can also be used (where the plateau is prolonged to 10ms). Tone-burst stimulus is useful in the diagnosis of MD (Campbell, Harker, & Abbas, 1992; Orchik, Shea, & Ge, 1993). Toneburst of a 1000Hz signal frequency has been used widely in the past for the diagnosis of MD. (Conlon & Gibson, 1999, 1998; Sass, Densert, Magnusson,

& Whitaker, 1998). The detection of ECochG components of low frequency tone burst signals, are significantly greater for TM and TT electrode recordings than with ECochG recorded from the ear canal.

Effects of Intensity. At a higher intensity wave N1 of the compound action potential is greater in amplitude and shorter in latency whereas N2 is evident at high intensities only. The slope of amplitude-intensity functions of the CAP increases for the subjects with recruitment (Eggermont & Odenthal, 1974). Thus, a larger slope of the amplitude - intensity function of CAP is associated with an elevated threshold with cochlear hearing impairment. However, in MD, the SP amplitude is higher whereas in cochlear hearing losses the SP is reduced mainly due to hair cell damage. CM and SP have very short latencies and there is no significant dependence of latency on the intensity of stimulation. If CM magnitude is represented in logarithmic units, it grows in direct proportion to dB SPL, usually with a slope of unity (Dallos 1973).

Rate Effects. The CAP amplitude reduces and latency increases at rapid stimulus rates. Thus CAP can be easily distinguished from SP when rates are more than 150/s. However, in contrast to the AP, SP and CM do not display temporal interactions of any significance and their amplitude does not change with change in repetition rate. One technique to emphasize the SP is to increase the repetition rate until the AP is maximally depressed (Coats, 1981; Gibson, Moffat, & Ramsden, 1977). However this technique needs repetition rates of 100/second, but at higher repeatition rate, AP will not be totally eliminated because of adaptation (Durrant, 1986; Harris & Dallos, 1979).

Polarity of Stimulus. EcochG components are phase dependent where, CM and AP are phase sensitive, whereas SP is not phase sensitive. (Coats, 1981). Also, when tone bursts are used for ECochG measurement particular care should be taken because of contamination of electromagnetic radiation from the earphone. Usually a monophasic polarity is used to elicit CM instead of alternating polarity which will also produce differences in the latencies of SP and AP components (Coats1981).

Masking. For two reasons Masking is not necessary during the recording of ECochG :1) The ECochGm potentials are obtained in a quasi near-field mode (Davis, 1976) therefore, there is a strong response of ECochG in the surrounding areas of electrodes adjacent to the generators of the eighth nerve potentials. Thus recording of the potentials on the head opposite side of to the ear stimulated will yield a significantly attenuated response. 2) Due to the considerable transcranial attenuation of sound, crossover stimulation will yield reduced amplitude of the response, with a simultaneous latency shift, compared to that seen with direct stimulation of that ear.

Bonfils, Remond, and Pujol (1986) investigated the impact of efferent pathway sectioning in guinea pig on the CM and CAP. Results revealed that it reduced the CAP masking and the CM suppression with no impact on the absolute CM amplitude. Therefore, it is evident that crossed medial efferent tracts is involved in the masking function itself, rather than one of the mechanisms responsible for high frequency cochlear selectivity. However studies related to effect of masking noise on cochlear microphonics are limited. Salt and Konishi (1978) studied the impact of noise exposure on cochlear potentials and K+ ion activity in guinea pigs. It was found that exposure to 115 dBA noise, which was sufficient to reduce considerably the sensitivity of the CM and AP responses, resulted in an increase in the Endolympatic potential whilst no change in the endolymph potassium activity was observed.

Frequency Effects. ECochG morphology is altered noticeably for low- versus high frequency tone-burst stimuli. The latency of the CAP response is longer for lower frequency stimuli (Eggermont, 1976). However the effect of frequency is not very evident at high intensities, as high intensity low-frequency tones trigger the high-frequency regions of the cochlea and thus lead to an earlier latency than that is predicted by frequency.

Monaural versus Binaural Stimulation. Studies have reported that AP is reduced during binaural stimulation. In a study by Prasher and Gibson, (1984) they recorded ECochG on 30 individuals with normal hearing sensitivity. Clicks were presented through TDH-39 earphones and they reported that for 87% of the participants, AP amplitude was significantly reduced for binaural versus monaural stimulation. This reduction in AP could be attributed to the impact of the reduction in stimulus intensity by 20 dB. In spite of these amplitude changes for monaural versus binaural stimulation AP latency remained equivalent.This could presumably be due to the reason that efferent auditory system activation by electrical stimulation causes both an inhibitory effect on the VIII-nerve AP (Galambos, 1956) and will also cause an improvement in CM.

Type and Location of Electrode. The morphology of ECochG waveform depends on electrode placement relative to the cochlea, and middle-ear cavity (on the medial wall). AP amplitude is found to be improved relative to SP amplitude when the recording electrode is nearer to the promontory. Most researchers have done ECochG recording in participants with Meniere's disease using the TM technique (Hall, 1992; Margolis, Levine, Fournier, Hunter, Smith, & Lilly , 1992; Ruth & Lambert, 1989). In spite of the invasive nature the application of the TT, ECochG measurement in Meniere's disease has been strongly recommended in the literature (Schwaber& Hall, 1990). This is for the reason that it produces robust ECochG components practically in all subjects, despite of their degree of hearing loss.

Analysis time. ECochG recording typically involves an analysis time in the range of 5 to 10 ms. But a 5 ms analysis time may also be used for ECochG recording , as higher amplitude potentials and later latency brainstem components (eg., ABR wave V) can be removed from the analysis. However an analysis time of 10ms or even 15 ms can be used if the clinical purpose is the collective recording of ECochG and ABR. An analysis time of greater than 5 ms can be used as the latency of AP component is delayed for low frequency stimuli (e.g., a 500 Hz tone-burst) when presented at reduced intensity levels (Ferrero & Ruth 1986).

Filter setting. Cochlear microphonics mainly reflect stimulus polarity and frequency of energy in the region of the stimulus. Thus wide filter settings are required to include these frequencies and to circumvent any phase distortion. However the SP, being a DC potential, presents a distinctive difficulty in filtering. In fact, band-pass filter settings of 3 or 10 or 10 to 1500 or 3000 Hz are normally used in test protocols. The SP component can be distinctly recorded with high-pass filter settings in 10 to 30 Hz range, and even 100 Hz (Ferrao & Durrant,2006), without altering the SP / AP ratio. For ECochG measurements for SP component widening the high-pass filter setting to less than 100 Hz and low pass 3000 Hz is preferable.

Number of Sweeps The number of sweeps required for a reliable ECochG measurement and satisfactory SNR depends upon the noise level during recording and the size of the response signal. Thus, electrode type is a significant factor when ECochG is recorded. A true near-field recording will produce a robust ECochG with higher amplitude (2 to over 10 μV), as compared to an extra-tympanic (ear-canal) electrode site recording (less than 1 μV) (Coats 1986).

Subject related variables.

Normal Variability. ECochGm shows a lot of variability both within and between subjects. Transtympanic recordings have shown variation in AP amplitudes by as high as 20:1 (Eggermont, 1976). Although the recording of ECochGm through extratympanic procedure would be dependent upon electrode placement but its variance in fact does not appear to be more than that seen with transtympanic method. It is also comparable to that obtained with surface recordings from the mastoid (Durrant, 1986). However the main problem with extratympanic recording is that it will have poor SNR. This is the result of a decline in signal amplitude with no changes in noise amplitude. Also the variability is more visible in amplitude compared to that of latency and is not much dependent on the recording technique. Studies have reported less than 0.2 ms of standard deviations for the AP when recorded from individuals with normal hearing (Durrant, 1986).

Santarelli and Arsal (2006) studied cochlear microphonics in individuals with normal hearing sensitivity, sensory neural hearing loss and auditory neuropathy. Results revealed that CM recorded in normal hearing and with various degrees of hearing loss showed that the amplitude of cochlear microphonic was reduced and there was an elevation of compound action potential and also individuals with positive central nervous disorder had enhanced cochlear microphonics in the terms of amplitude and latency.

Gender. The gender effect on ECochG have not been studied extensively. However, gender differences are more evident for the potentials which arise at levels beyond the eighth nerve (McClelland & McCrae, 1979). Females have a significantly larger CAP amplitude (mean 1.6µV) and SP amplitude than males (mean 1.1 µV) in the ear-canal recordings (Chatrain, Wirch, Edwards, Lettich, & Snyder, 1985). However there was not much variability seen in the SP / AP ratio between sexes (Chatria et al, 1985). In one study when CM was recorded by transtympanic electrocochleography in 502 individuals with normal hearing sensitivity and hearing loss. Results revealed that based on gender there there was no significant difference in amplitude and latency of CM (Santarelli, Scimemi, Monte, & Arslan, 2006).

Ear effects. The amplitude of CAP is found to be slightly higher for right ear (mean 1.5 µV) compared to left ear (mean 1.2 µV) when elicited through clicks (Chatrain et al , 1985), however there is no significant difference between the ear in terms of latency and amplitude of cochlear microphonics (Snatarelli, 2006).

Age effects. The impact of age on ECochG is studied only during early development (Fria & Doyle, 1984; Starr, Amlie, Martin & Sanders, 1977). An apparent ECochG N1 component can be recorded and seen as early as 27 weeks of conceptual age. In infants latency of N1 is delayed and amplitude is reduced compared to adults (Coen, & Stockard, 1983). In premature infants, there is a slight delay in the AP which reaches normality with maturity. This could be due to the maturation of the peripheral system.

Also in neonates there is a presence of fluid leading to conductive hearing loss which would resolve with age. With age, however, the CAP amplitude gets smaller which could be attributed to increased thresholds for 4 kHz and 8 kHz tones (Chatrain et al , 1985).

SP amplitude is found to decrease as a function of age (only in the left ear) however AP amplitude reduces relatively more than that of the SP. A strong negative correlation between AP amplitude and age is reported in literature and, thus a positive correlation between the SP/AP ratio was seen with age. Santarelli, Scimemi, Dal Monte and Arslan (2006) found that there is no significant effect of age on the amplitude of CM but latency is slightly delayed as age increases.

Body Temperature. Effect of Hypothermia on ECochG recording has been studied in a variety of animal models. In vitro, membrane potential depolarization has been recorded in the Hensen's cells of the organ of Corti (Santos-Sacchi, 1986). Studies have shown that CM amplitude reduces reversibly but CM latency showed slight or no change at all (Butler, Konishi, & Fernandez, 1960; Coats, 1965; DeBrey & Eggermont, 1978; Kahana, Rosenblith, & Galambos, 1950). Studies related to SP have shown that there are variable changes with hypothermia (Butler, Konishi, & Fernandez, 1960; Manley & Johnstone, 1974) which is related to increased travel time of the basilar membrane (DeBrey & Eggermont, 1978) and also produces a reversible decline in cochlear nerve compound action potential amplitude and a reversible enhancement of latency of N1 (Kahana et al, 1950). A selective loss of auditory sensation is the primary effect of hypothermia mainly seen in the high frequency stimulus which is assessed electrophysiologically (Manley & Johnstone, 1974).

Arousal and attention. Many studies have shown that sleep and stimulus level has no effect on ECochG waveforms (Amadeo & Shagass, 1973; Jewett & Williston, 1971), however, sleep condition is best demonstrated in EEG recordings. Studies have also reported that reduced states of arousal, such as narcolepsy and metabolic coma (Hall, 1988; Hall, Hargadine, & Kim, 1985; Hall, Huangfu, & Gennarelli, 1982) do not effect ECochG latency or amplitude .

Muscle/Movement Artifact. Muscular activities during testing, affect ECochG interpretation, especially identification of the SP component (Ruben1987). But if the ECochG component occurs within 2 or 3 ms time it has a minimal effect on muscular activity. However, a patient in quiet condition will lead to less muscle activity and thus facilitates identification of even a lesser amplitude.

EcochG in Meniere's disease

Meniere's disease is a situation which arises from the irregular fluid and ion homeostasis in the labyrinth leading to episodic vertigo in combination with fluctuating loss of hearing sensitivity (Gates, 2006). According to AAOO.,(1972) it is a condition of the membranous labyrinth which is characterized by hearing loss, vertigo and tinnitus, and also associated with hydropic distension of the endolymphatic system.

Assessment of MD starts with detailed case history which requires information regarding hearing loss, tinnitus and form of vertigo. Formal assessment starts with pure tone audiometry for assessing the degree and type of hearing loss. Immittance should be done to know the middle ear status. Speech Audiometry is done to assess the speech perception abilities. It is evident that ability to discriminate speech is poor in Meniere's disease but not as severe as in retrocochlear pathology. This could be because of the distortions which are produced in the cochlea which in turn lead to poor perception of loudness, pitch, and clarity of speech. The discrimination scores become poorer when the stimulus is presented at higher intensity.

Assessment of Meniere's disease involves an interdisciplinary approach which includes audiologist and ENT professional. Electrocochleography, Vestibular Evoked Myogenic Potential, Glycerol Test are used to diagnose an individual having Meniere's disease. Among these tests EcochG has been studied extensively in the assessment of individuals with MD.

As mentioned earlier ECochG involves three potential ie, AP, SP and CM and in the diagnosis of MD studies have reported that elevated SP/AP ratio is the most useful tool (Eaton, 2003; Gibson & Prasher ,1983). SP enlargement is the sign of endolymphatic hydrops and is highly sensitive in the diagnosis of Meniere's disease (Conlon & Gibson, 2000; Gibson et al, 1983). Increase labyrinthine pressure would create mechanical biasing of vibration of the organ of Corti. This would amplify the SP since at least some of its components represent nonlinearities in the transduction process. However it is not clear that whether the characters of this enhanced distortions are mechanical (Gibson et al, 1977), electrical (Durrant & Dallos, 1972; Durrant & Gans, 1975) biochemical or vascular (Eggermont, 1976; Staller, 1986). An SP/AP ratio of 0.45 or more is taken as abnormal which suggests an increase in labyrinthine pressure (Ferraro, 1994). It has been reported that the sensitivity of SP/AP ratio in the diagnosis of MD is only between 55 and 65% or less (Gibson , 1977) and the specificity is 90% or higher (Ferraro et al, 1983). So the diagnostic value of ECochG is doubtful, mainly for the individuals who do not show classic symptoms of MD and whose clinical profile is not clear.

Studies related to CM in the diagnosis of MD are very limited. Kumagami and Miyazaki (1983) studied changes in cochlear microphonics in artificially created endolympatic hydrops in guinea pig from a period of 1 week to 13 months after the endolymphatic sac obliteration. The results showed that the threshold of CM increased with the lapse of time and the CM output potential was highest around 3rd week when endolymphatic hydrops was slightly formed, and it decreased thereafter.

In another study by Ge and Shea (1997), they studied CM in 119 ears of Meniere's disease using 1 kHz tone burst. It was noted that the cochlear microphonics was increased in individuals with endolymphatic hydrops, and higher SP/AP ratio was seen. Fetterman, (2001) studied correlation between DPOAEs and cochlear microphonics in hydropics and non hydropics individual and found that there was no significant correlation between DPOAE and CM. However, CM amplitude was reduced in hydropic ears compared to non hydropic ears.

From these findings it can be inferred that individuals with hearing loss who had higher CM could be the outcome of change in cochlear mechanics and the individuals with hearing loss who had small CM is a result of hair cell loss. The CM measurement, to evaluate the hair cell status, may be helpful in identifying patients whose hearing may be recoverable if the underlying hydrops can be corrected (Campbell, 1992).

Zheng, McFadden, Henderson, Ding, & Burkard (1999) studied the effect of removal of olivocochlear bundle (OCB) on the amplitude of cochlear microphonics and DPOAEs. Results showed a significant reduction in CM input/output function by 40-50 % for the stimuli of 1 to 8 kHz for all input levels. He suggested that the olivocochlear bundle plays a major role in altering electrical characteristics of the OHC and in lessening the extent of cochlear distortion due to high intensity signal.

Medial Olivococochlear Bundle Activity

Contralateral stimulation of MOCB leads to a suppressive effect of OHCs and can be measured through otoacoustic emissions and CM. Liberman (1989) verified in his study that in cats, on contralateral stimulation, the CAP measured at the round window in response to tone pips was significantly suppressed. This he attributed to the function of the MOCB as there was a loss of the contralateral suppression upon MOCB sectioning. In another study Salt and Konishi (1978) studied impact of noise exposure on cochlear potentials and potassium ion activity in guinea pigs. It was found that exposure to 115 dBA noise, which was sufficient to reduce considerably the sensitivity of the CM and AP responses, resulted in an increase in the EP whilst no change in the endolymph potassium activity was observed. Thus the study concluded that the reduction of cochlear sensitivity resulting from acute noise exposure is due to changes in hair cells rather than stria vascularis.

CHAPTER 3

Method

The present study was conducted with the aim of studying the cochlear receptor cochlear microphonics (CM) and the effect of efferent stimulation in participants with normal hearing sensitivity and Meniere's disease.

Participants

The present study consisted of two groups:

A. The individuals with normal hearing sensitivity (control group)
B. The individuals diagnosed with Meniere's disease (experimental group)

Participant selection criteria.

A. **Experimental group**. Eight individuals in the age range of 18 to 55 years (mean age of 35 years) diagnosed as Meniere's disease were selected for the study. All the subjects fulfilled the following criteria:

- Individuals diagnosed as unilateral definite Meniere's disorder as per AAOO 1995.
- No history of middle ear infection, tympanic membrane perforation, head trauma, and ear discharge.
- Individual with sensorineural hearing loss with PTA less than 40 dB in poorer ear and an air bone gap of less than 10 dB at octave frequencies from 250 Hz to 8000 Hz.
- Recruitment
- Tinnitus

- No complaint of BBVP or other neurological problem.
- No current illness at the time of testing.
- No retrocochlear pathology as confirmed by auditory brainstem response.

B. **Control group**: 10 individuals with normal hearing sensitivity in the age range of 18 to 45 years (mean age range 25 years) were included in the control group and they fulfilled the following criteria:

- No history of middle ear infection, tympanic membrane perforation, head trauma, and ear discharge.
- Subjects with pure-tone thresholds less than 15 dB HL for octave frequencies between 250 Hz to 8000 Hz for air conduction and 250 Hz to 4000 Hz for bone conduction. Speech recognition scores ± 12 dB with reference to pure tone average (PTA).
- Speech identification scores greater than 90% in both the ears.
- Bilateral 'A' type tympanograms with ipsilateral and contralateral reflexes present in both the ears.
- No current illness at the time of testing.
- No retrocochlear pathology as confirmed by auditory brainstem response.

Instrumentation

- Otoscope was used to inspect the ear canal.
- Calibrated two channel GSI-61 diagnostic audiometer with an acoustically matched headphone (TDH-39) and bone vibrator (B-71) was used for pure tone audiometry and for providing contralateral broadband noise.

- Calibrated GSI TYMPSTAR Immitance meter (version 2) was used for assessing middle ear function.
- IHS (Intelligent Hearing System) Smart EP (3.94 USBez) system with ER-3A Insert ear phones was used for Auditory Brainstem Response and ECochG recording.

Testing Enviroment

All the audiological tests were conducted in an acoustically treated room with permissible noise level as per ANSI S 3.1 (1999) standards.

Procedure

The testing was done in following steps:

Case History. A detailed Case History was taken to make sure that clients fulfill the inclusion/ exclusion criterion.

Otoscopic Examination. Otoscopy was done to inspect the ear canal for wax or any kind of ear discharge. Only those subjects who had a clean ear canal were selected for the study.

Pure-tone audiometry. To ensure that the subjects had normal hearing, pure tone testing was carried out for all the participants. Pure tone thresholds for air conduction and bone conduction were obtained for the frequencies from 250 Hz to 8000 Hz and 250 Hz to 4000 Hz respectively, using a modified version of Hughson and Westlake procedure (Carhart & Jerger, 1959).

Immittance evaluation. During this testing subjects were made to sit comfortably and asked not to swallow. Tympanometry was done at a probe tone frequency of 226 Hz.

Ipsilateral and contralateral acoustic reflex thresholds were obtained for frequencies 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz.

Auditory Brainstem Response (ABR). While recording ABR, the participants were made to sit on a reclining chair and were instructed to relax. The ABR was recorded from two channels. The site of electrode placement was prepared with skin preparation gel and this was carried out to rule out any retrocochlear pathology. Test protocol used for ABR recording is mentioned in Table 1.

Table 1.

Test protocol for ABR recording

Transducer type	ER-3A Insert earphones
Type of stimulus	Clicks
Intensity	90 dB nHL
Stimulus Polarity	Rarefaction
Stimulus Rate	11.1/sec and 90.1/sec
Filter setting	100 Hz to 3000 Hz
No of Sweeps	1500
No. of recording	2
Electrode montage	Inverting (-) –test ear mastoid Non inverting (+) –vertex Ground – non test ear mastoid
Inter-electrode impedance	Less than 5 k Ω.
Gain	1 lakh

ElecrococleoGraphy. ECochG was done using a single channel. The site of electrode placement was prepared by skin preparation gel and Tip Trode was used for recording ECochG. The subjects were made to relax on a reclining chair. Inverting electrode was placed on contralateral mastoid and the non inverting electrode was placed in the ear canal and the ground electrode on forehead. Test protocol used for ECochG recording is mentioned in Table 2.

Table2.*Test protocol for ECochG measurements*

Transducer type	ER-3A Insert earphones
Type of stimulus	Clicks
Intensity	80 dB nHL
Stimulus Polarity	Rarefaction, Condensation
Stimulus Rate	7.1/sec
Filter setting	10 Hz to 3000 Hz
No of Sweeps	1500
No. of recording	2
Electrode montage	Inverting (-) — non test ear mastoid Non inverting (+) –ear canal Ground – forehead
Inter-electrode impedance	Less than 5 k Ώ.
Gain	10,000

Latency and amplitude of CM were recorded in two conditions. In first condition it was recorded without any contralateral noise and in the second condition CM was recorded by presenting contralateral Broad Band Noise of the 50 dB SL. Latency and amplitude of CM were estimated from the average of condensation and rarefaction stimuli. Two audiologist independently identified the waveforms.

Statistical analysis

The data were subjected to statistical analysis using SPSS software (version 17). Descriptive statistics were used to estimate the mean and standard deviation of amplitude and latency of cochlear microphonics. To analyze the data across conditions and between groups Wilcoxon signed rank test and Mann Whitney U test was done.

CHAPTER 4

Results and Discussion

The present study aimed to compare the latency and amplitude of cochlear microphonics in individuals with normal hearing sensitivity and Meniere's disease. To investigate the aim of the study EcochG was obtained for clicks in quiet and in the presence of contralateral broadband noise and cochlear microphonics were analyzed for latency and amplitude. It was noted that CM was present in all individuals with normal hearing sensitivity, however in individuals with MD, CM was present in 8 individuals out of 12 individuals tested. Auditory brainstem responses for site of lesion testing in all the individuals in the experimental group showed indication of no retrocochlear pathology in both the ears.

The obtained data for latency and amplitude was tabulated and subjected to statistical analysis using spss (statistical packages for the social science) software version 17.0. To achieve the aim of the study the following analysis was carried out.

1) Descriptive statistics (To estimate the Mean and Standard Deviation)

2) Wilcoxon signed rank test

3) Mann Whitney U test

The mean and SD of latency and amplitude of CM for both the groups in both the conditions was estimated (Table 1). From Table 1 it is evident that there is a difference between the latency and amplitude of CM with and without noise for both the groups.

Table 3.

Mean and SD of amplitude and latency of CM in control and experimental group.

	Control Group		Experimental Group	
	Mean	SD	Mean	SD
CM amplitude without noise (µv)	.12	.069	.08	.05
CM amplitude with noise (µv)	.20	.01	.12	.07
CM latency without noise (ms)	.51	.06	.62	.17
CM latency with noise (ms)	.52	.05	.64	.07

Although the mean latency of CM was higher in the experimental group, there was an overlap in the range obtained in the two groups. In the control group the latency ranged from .40 ms to .62 ms whereas it ranged from .14 ms to .88 ms for the experimental group in without noise condition. The amplitude ranged from 0.02µv to 0.38µv for the experimental group and it ranged from 0.04µv to 0.27µv for the control group in without noise condition.

Comparison of amplitude and latency of CM between the conditions

To analyze whether there was a significant difference in amplitude and latency of CM in without noise and with a noise condition for both the groups non parametric analysis (Wilcoxon signed rank test) was done. Non parametric analysis was performed as the number of subjects in both the groups were less. Results revealed that in the control group there was a significant difference between the amplitude of cochlear microphonics with and without noise ($p< .05$) but there was no significant difference between the latency of cochlear microphonics (Table 4) in both the conditions in the control group. However in experimental group there was no significant difference in both amplitude and latency in both the conditions as evident in the Table 4.

Table 4

Z values for amplitude and latency of CM in both the conditions for the control and experimental group.

	AWN vs AN	LWN vs LN
Control Group	-2.040*	-1.889.05
Experimental Group	-1.400	. -1.825

*=p<0.05

AWN - Amplitude without noise, AN - Amplitude with noise, LWN - Latency without noise, LN - Latency with noise.

Comparison of amplitude and latency of CM between the groups

The mean amplitude of CM was higher in the control group compared to the experimental group and the mean latency of CM in the experimental group was greater than the control group in both the conditions. To estimate the significant difference in amplitude and latency of CM between the groups, Mann Whitney U test was performed. The results of the Mann Witney U test showed there was no significant difference in amplitude and latency of CM between two groups (Table 5).

Table 5

Z values for amplitude and latency of CM in control vs experimental group in both the conditions.

	ACWN vs AEWN	LCWN vs LEWN	ACN vs AEN	LCN vs LEN
Z value	-2.040	-1.889	-1.400	-1.825

ACWN-Amplitude of control group without noise, AEWN-Amplitude of experimental group without noise, LCWN=Latency of control group without noise , LEWN= Latency of experimental group without noise, ACN= Amplitude of control group with noise, AEN=Amplitude of experimental group with noise, LCN=Latency of control group with noise, LEN= Latency of Experimental group with noise.

In the present study the mean latency of CM seen in individuals with normal hearing sensitivity is similar to as reported in the literature (Flex, 1959; Shea, 2001). However the mean amplitude of CM seen in both experimental and control groups was lower than that reported in the literature. This could be due to the methodological difference in the data analysis. In the present study CM was analyzed by taking the average of condensation and rarefaction polarity.

Starr et al., (2001) measured the mean amplitude of CM from the subtracted averages of condensation and rarefaction polarity and measured the amplitude at the peak where it had maximum amplitude, which results in greater amplitude. However due to technical limitations, this could not be done in the present study.

In the present study it can be noted that though there was no significant difference in the amplitude and latency of CM across both the groups however the amplitude of CM was higher in the control group than the experimental group. Similar results have been reported in the past where some authors report that the amplitude of CM is reduced in the patient of Meniere's disease and they contribute these results due to increased accumulation of Ca^{2+} ion in endolymph (Ohash, Nishin, Arai & Koizuk, 2013). In another study by Fetterman (2001) where he studied the correlation between DPOAEs and cochlear microphonics in hydropic and non hydropic individuals and found that there was no significant correlation between CM and DPOAE but CM amplitude tended to be lower in hydropic individuals.

However, the results of the study by Ge , Shea & , Orchik (1997) is in contrast with the present study. They studied cochlear microphonics in individuals with normal hearing sensitivity and Meniere's disease and found significant enhanced cochlear microphonics in individuals with Meniere's disease and suggested that this could be due to the alteration in cochlear mechanics. However in the present study there was no significant difference in amplitude and latency of CM between both the groups, this could be due to less number of subjects participated in the study. This also might reflect that efferent pathway or due to excessive pressure the OHC of basal region is affected and not contributing to the enhancement of cochlear microphonics.

This study is the initial attempt to study the effect of contralateral noise on individuals with MD and thus there are no supporting studies related to this on humans. However studies have been done in the past on animals. Drexl and Kossl (2003) studied DPOAEs and CM in bats. Contralateral stimulation was given to the efferent system using 3 different stimuli i.e. sinusoids, broadband noise , and bat echolocation call. Results revealed that the sinusoidal stimulation did not have any significant effect. However, the bat echolocation calls and the BBN caused an intensity dependent reduction in both DPOAEs and CMs. In another study by Naijam and Spring field (2011), they compared contralateral suppression of CM and DPOAEs in individuals with normal hearing sensitivity. Results revealed that contralateral BBN showed suppression as well enhancement of cochlear microphonics for clicks and for tone burst. Similar results have also been reported in various animal studies (Fex, 1959; Patuzzi and Rajan, 1990; Wiederhold and Peake, 1966) .

Overall present study shows that there is a difference between CM of individuals with normal hearing sensitivity and Meniere's disease when noise is presented contralaterally. However there is no significant change in amplitude in the individual with Meniere's disease but there is a change in amplitude of the control group. This might be because of the normal efferent system in the control group but in the individual with Meniere's disease there is disruption in efferent system or possibly there is loss of OHC in the basal region or the stiffness created by excessive pressure by endolymph which could have led to less enhancement of cochlear microphonics..

CHAPTER 5

Summary and Conclusion

Electrocochleography is a technique used to record the electrical potentials of the cochlea and the auditory nerve which is elicited by an acoustic stimulus (Hirsch, 1996). Cochlear microphonics is one of the component of electrocohleography which is a electrical response that mimics the stimulus acoustic waveform and is generated by the cochlear hair cells. ECochG has been widely used in the diagnosis of Meniere's disease. However studies related to Cochlear microphonics in the diagnosis of MD is limited and whether presentation of contralateral noise in individuals with Meniere's disease has any effect on CM is not studied in humans till date.

The aim of the present study was to see the effect of contralateral noise in the individuals with normal hearing sensitivity and Meniere's disease.To fulfil the aim of the present study data was collected on 2 groups of participants where first group consisted of 10 individuals with normal hearing sensitivity (control group) and second group consisted of eight individuals diagnosed with Meniere's disease (experimental group).Their routine extratympanic ECcohG was done using tiptrode in quiet condition and in presence of contralateral broad band noise. The responses were recorded in terms of amplitude and latency of CM for both the groups. The data were analyzed by using a descriptive statistics, Wilcoxson signed rank test and Mann Whitney U test.

The analysis of the data for between condition revealed that there was an enhancement of cochlear microphonics amplitude in the presence of contralateral noise in individual with normal hearing sensitivity which signify normal functioning of efferent system but there was no effect of contralateral noise on individuals with Meniere's disease. This could possibly be due to the disruption in the efferent pathway of experimental group indicating that though the threshold of the contralateral ear is normal but the initial signs of MD are visible through ECochG.

The results of between group comparison showed that there was no significant difference in amplitude and latency of CM in both the conditions between control and experimental group. However the results of the present study should be taken cautiously and cannot be generalized as it was done on a limited number of subjects.

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