Electrocochleography in individuals with Auditory dys-synchrony

Register no: A0490012

A dissertation submitted in part fulfillment for the degree of

Master of Science (Audiology)

University of Mysore, Mysore

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APRIL 2006.

My Dear Parents,

&

Vanaja Ma'm

Certificate

This is to certify that this dissertation entitled "Electrocochleography in individuals with auditory dys-synchrony" is a bonafide work in part fulfillment for the degree of Master of science (Audiology) of the student Registration no: A0490012.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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This is to certify that this master's dissertation entitled "Electrocochleography in individuals with auditory sys-synchrony" is the result of my own study and has not been submitted earlier to any other university for that award of any degree or diploma.

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Table of Contents

Chapters	Page No
1. INTRODUCTION	1- 4
2. REVIEW OF LITERATURE	5- 19
3. METHOD	20- 24
4. RESULTS AND DISCUSSION	25- 34
5. SUMMARY AND CONCLUSION	35- 38
6. REFERENCES	39- 47

LIST OF TABLES

TABLE NO	TITLE	PAGE NO
1.	Test protocol for the Electrocochleography	23
2.	Mean and Standard deviation of OAE in the control and experimental group	26
3.	Mean and SD of Latency and amplitude of cochlear microphonics in control and experimental group	27
4.	Mean and Standard deviation of the Summating potentials in the control group	30
5.	Mean and Standard deviation value of action potentials in the control group.	32

INTRODUCTION

Auditory neuropathy (AN) is a hearing disorder affecting auditory nerve function in the presence of preserved cochlear outer hair cell activity (Starr, Picton, Sininger, Hood, & Berlin, 1996). The hearing loss is characterized by disproportionate effects on auditory temporal processes, relative to pure tone thresholds with speech perception and binaural hearing being profoundly impaired (Starr et al. 1991; Zeng, Oba, Garde, Sininger, & Starr, 1999).

Physiological tests generally used in diagnosing auditory dys-synchrony are auditory brainstem response and otoacoustic emissions. By clinical definition, a subject with auditory neuropathy/dys-synchrony will have abnormal or absent auditory brainstem response with presence of otoacoustic emissions. Because normal auditory brainstem response can be recorded only when multiple neurons fire synchronously at onset, even minor variation in the timing of neural discharge after each stimulus can make the auditory brainstem responses unrecognizable (Kraus et al., 2000)

Another evoked potential which can be used to check the integrity of outer hair cells and auditory nerve is electrocochleography. Electrocochleography is a measurement of stimulus related electrical potentials, which include the cochlear microphonics, summating potentials, and the action potentials of the auditory nerve (Ruth, 1994). These three potentials can be recorded independently or in various combinations (Ferraro, 2000).

It has been reported that the cochlear microphonics recorded from subjects with auditory neuropathy / dys-synchrony is either of normal amplitude (Santarelli & Arslan, 2002) or they have higher amplitude and persist for several milliseconds after a click stimulus (Starr, Sinninger, Winter, Derbery, Oba, & Michalewski, 1998; Starr, Sinninger, Nguyen, Michalewski, Oba, & Abdala, 2001; Starr, Sininger, & Pratt, 2000; Santarelli & Arslan, 2002; Berlin, 1999). Very few studies have investigated summating potentials in subjects with auditory neuropathy / dys-synchrony and the results are equivocal. A few investigators have reported that in subjects with auditory neuropathy / dys-synchrony the amplitude of summating potentials is within normal limits (Santarelli & Arslan, 2002; Sheykholeslami, Kaga, & Kaga, 2001), whereas others have reported there is an absence of summating potentials (Starr, 2001). There are also reports that the amplitude of summating potentials is abnormal i.e. a large positive summating potentials is noted in some of the subjects with auditory neuropathy / dys-synchrony (O'Leary, Mitchell, Gibson, & Sanli, 2001).

The compound action potentials in auditory neuropathy / dys-synchrony subjects is generally absent (Liang, Liu, & Liu, 1999; Wang, Duan, Li, Huang, Chen, & Jin et al., 2002; Santarelli & Arslan, 2002) or is of very small amplitude (Wang et al., 2002) and present at only high sensation levels (Liang et al., 1999).

Studies have revealed that dys-synchronization doesnot affect only afferent functioning, but also have an effect on the functioning of the efferent system. One of the audiological test which has been used widely to assess the integrity of efferent system is

contralateral suppression of otoacoustic emissions. Subjects with auditory neuropathy / dys-synchrony demonstrate significantly reduced or no suppression of Otoacoustic emissions (Hood, Berlin, Bordelon, & Rose, 2003). Similar findings have been reported by other investigators also (Abdala, Starr, & Sininger, 2000; Hood & Berlin, 2001). However, the effect of contralateral suppression on cochlear microphonics has not been studied.

***Need of the Study*:**

There is equivocal findings in subjects with auditory neuropathy / dys-synchrony on summating potentials especially when extratympanic recording is used for recording EcochG.Hence there is a need for further investigations to study summating potentials using extratympanic methods in subjects with auditory neuropathy / dys-synchrony. It has been reported in literature that even though the auditory brainstem responses were absent, the N1 action potentials were present while recording ECochG in a few subjects with auditory neuropathy / dys-synchrony (Santarelli & Arslan, 2002). These investigators used trans--tympanic ECochG recording. There is a need to check if these findings can be replicated using extratympanic ECochG.

Studies have documented absence of contralateral suppression in subjects with auditory neuropathy / dys-synchrony (Hood, Berlin, Bordelon, & Rose, 2003). In individuals with normal hearing sensitivity, efferent stimulation reduces the amplitude of OAE (Collet, Kemp, Veuillet, Duclaux, Moulin, & Morgon, 1990; Moulin Collet & Duclaux, 1992), summating potentials (Fex, 1959) and N1 action potentials (Folsom & Owsley, 1987), but increases the amplitude of the cochlear microphonics (Gans, 1977). It can be hypothesized

from this that there will not be any change in amplitude of cochlear microphonics, summating potentials & action potentials, if present in subjects with auditory neuropathy / dys-synchrony. However in subjects with auditory neuropathy / dys-synchrony there is a dearth of information regarding effect of contralateral stimulation on amplitude of cochlear microphonics and action potentials. Hence there is a need to investigate the effect of contralateral suppression on cochlear microphonics, summating potentials and action potentials in subjects with auditory neuropathy / dys-synchrony.

Aim of the Study:

1. To study the cochlear receptors (cochlear microphonics, summating potentials) and N1 action potentials in subjects with auditory neuropathy / dys-synchrony.

2. To study the effect of efferent stimulation on cochlear receptors (cochlear microphonics, summating potentials) and action potentials in subjects with auditory neuropathy / dys-synchrony.

REVIEW OF LITERATURE

The term auditory neuropathy / dys-synchrony has been used to describe a form of hearing impairment in which outer hair cells function is normal, but afferent neural conduction in the auditory pathway is disordered (Starr, Picton, Sininger, Hood, & Berlin, 1996). The clinical findings that define auditory neuropathy / dys-synchrony are the demonstration of outer hair cell integrity in evoked otoacoustic emissions and / or cochlear microphonics recordings in conjunction with the inability to record evoked neural activity at the level of 8th nerve (Starr, et al., 1996).

Currently the specific risk factors for auditory neuropathy /dys-synchrony are not clearly understood. Some individuals have risk factors related to hearing loss in their history, however, a significant amount of patients have no risk factors (Hood, Berlin, Morlet, Brashears, Rose, & Tedesco, 2002). A number of infants diagnosed with auditory neuropathy/dys-synchrony have history of major neonatal illness including pre-maturity, low-birth weight, anoxia and hyperbilurubinemia (Sininger, 2002). Cochlear hypoxia has also been suggested as a possible cause for auditory neuropathy / dys-synchrony (Harrison, 1998). Genetics also play an important role in the etiology of auditory neuropathy/dys-synchrony. Families have been identified with siblings with auditory neuropathy/dys-synchrony. In addition, there are also parents with auditory dys-synchrony who have children with this disorder. Therefore, auditory dys-synchrony appears to follow both recessive and dominant inheritance patterns (Hood, et al., 2002).

The site of lesion for auditory neuropathy / dys-synchrony is not completely understood. Many subjects with this hearing disorder have concomitant peripheral neuropathy, which makes the auditory nerve a logical site of lesion (Abdala, Sininger, & Starr, 2000). However, there are a number of pathologies that could produce the auditory neuropathy / dys-synchrony profile. Some of these include insult specific to the cochlear inner hair cells, abnormality of inner hair cells / auditory nerve fibers synapse, spiral ganglion cells disorder (Rance et al., 1999; Doyle, Sininger, & Starr, 1998). However, currently there is no physiological or functional test to identify pathology restricted to the inner hair cells or the spiral ganglion cells (Rapin & Gravel, 2003).

Audiological findings in subjects with auditory neuropathy / dys-synchrony:

Pure tone thresholds: The behavioral pure tone audiograms of auditory neuropathy/dys-synchrony subjects are less predictive than those of patients with conductive or sensorineural hearing loss. The pure tone thresholds for individuals with auditory dys-synchrony may vary from normal hearing sensitivity to a profound hearing loss (Starr et al., 1996). Some subjects with auditory neuropathy / dys-synchrony show rising or unusual configurations and threshold responses may or may not be symmetric between ears. Sininger and Oba, (2001) reported 59 subjects with auditory neuropathy / dys-synchrony in whom degree of hearing loss varied from slight to profound, most losses were bilateral and symmetrical in configuration (82%) with a few patients having normal hearing in both ears

and a unilateral disorder. Audiogram configurations were usually flat; however, a smaller but notable percentage (28%) displayed a rising audiometric configuration.

It is not uncommon for hearing threshold to fluctuate dramatically from day-to-day or even during a test (Sininger, 2002). Some cases of fluctuating hearing loss associated with auditory neuropathy / dys-synchrony have been reported in literature. Starr, Sininger, Winter, Derebery, Oba, and Michalewski (1998) reported three children with temperature sensitive auditory neuropathy / dys-synchrony, who demonstrated elevated pure tone thresholds with absent or impaired speech comprehension and abnormal or absent ABR and symptoms worsened when their core body temperature was raised by as little as 1^{o} c. In general, subjects with auditory neuropathy/auditory dys-synchrony can have any degree of hearing loss and the day-to-day fluctuations in auditory capacity can be much more dramatic than are generally seen in patients with sensory loss (Sininger & Oba, 2001).

Middle ear muscle reflex. In subjects with auditory neuropathy / dys-synchrony the middle ear muscle reflex is typically absent or abnormal (Hood, 1998). Sininger and Oba, (2001) reported that a majority of the subjects (93%) had absent middle ear muscle reflex with about 6.5% having normal or elevated reflex ipsilaterally and contralaterally. Berlin, et al., (2005) reported 136 subjects with auditory neuropathy / dys-synchrony in whom none of the subject showed normal reflexes at all frequencies tested. Only three subjects showed any reflex at 95 dB HL or below, but never at both 1 kHz & 2 kHz in both ears, whether ipsilaterally or contralaterally elicited. All the other reflex measures in the remaining 133

subjects were either absent or observed above 100 dB HL, which was incongruous with their normal otoacoustic emissions throughout the frequency bands.

Subjects with unilateral auditory neuropathy/dys-synchrony however demonstrate a middle ear muscle reflex in the auditory neuropathy/dys-synchrony ear at normal levels when the normal ear is stimulated, but middle ear muscle reflex is absent when the ear with auditory neuropathy / dys-synchrony is stimulated (Berlin, et al., 2005). In general in subjects with auditory neuropathy / dys-synchrony the middle ear muscle reflex is absent, but in a few subjects with auditory neuropathy / dys-synchrony the presence of middle ear muscle reflex has also been reported.

Auditory Brainstem Responses: The auditory brainstem response is usually absent in subjects with auditory neuropathy / dys-synchrony. Kraus, Ozdamar, Stein, Reed, and Chicago (1984) reported four subjects with audiometric findings ranging from normal to moderate hearing loss with absent ABR. They showed ABR abnormalities, which were out of proportion to the pure tone hearing loss. As there was a lack of auditory test to find out the normal functioning of outer hair cells the diagnosis of auditory neuropathy was not established.

Starr et al. (1996) reported that in nine out of their 10 subjects with auditory neuropathy / dys-synchrony, auditory brainstem response was absent bilaterally. There was only one subject who showed wave V to be present. Also Starr, Sininger and Pratt (2000) reported that components I through V was absent in 73 % of the subjects with auditory

neuropathy / dys-synchrony, whereas in 21 % of the subjects had a wave V with prolonged latency and reduced amplitude and wave V with wave III of poor morphology was present in 6% of the subjects with auditory neuropathy / dys-synchrony. A common feature of subjects who did exhibit auditory brainstem response was an increased sensitivity of the response to increased stimulus rate.

Sininger and Oba, (2001) reported that 70% of the subjects with auditory neuropathy / dys-synchrony had a complete absence of any ABR waveform regardless of the level of the stimulus. Nineteen percent showed wave V only and in most of those the peak was poorly defined, the latency was abnormal and the amplitude was small. In 6% of the subjects ABR was absent but included at least two of the peaks, usually wave III and Wave V. Again the wave morphology including peak latency and amplitude was clearly abnormal in these subjects with auditory neuropathy / auditory dys-synchrony. Starr, Sininger, Nguyen, Michalewski, Oba, and Abdala (2001) reported that wave V without a preceding wave I was present in the ABR from 13 (21 %) of the 60 auditory neuropathy / dys-synchrony test ears. Seven of the auditory neuropathy / dys-synchrony subjects with preserved auditory brainstem responses had been tested bilaterally, four had a wave V from stimulating ear and three had a wave from stimulating only one of the ears. The mean amplitude of the wave V when present in auditory neuropathy / dys- synchrony subjects was 0.10 µv which was significantly less than the mean amplitude of wave V in normals (0.51 µv). Wave V latency in subjects with auditory neuropathy / dys-synchrony was delayed (6.0 msec to 8. 5 msec) in 10 out of the 16 recordings.

Sininger and Oba, (2001) reported that an apparent relationship exists between the degree of severity of the ABR result and the degree of hearing loss in subjects with auditory neuropathy / dys-synchrony. Those subjects with absent ABR show the poorest pure tone average thresholds and those with several peaks in the waveform have the best thresholds. Subjects with preserved components (wave V with or without wave III) have a hearing loss that is approximately 29 dB less than that found in subjects without ABR components (Starr et al., 2000). In all cases of auditory neuropathy/dys-synchrony however the threshold of the ABR is not related to the hearing threshold. Thus it is clear that, the ABR cannot be used to estimate hearing thresholds in subjects with auditory neuropathy / dys-synchrony.

Otoacoustic Emissions*:* Subjects with auditory neuropathy / dys-synchrony have normal outer hair cell function, therefore subjects with auditory neuropathy / dys-synchrony have preservation of Otoacoustic emissions (Madden, Rutter, Hilbert, Greinwald, & Daniel 2002; Hood, 2002; Sininger, & Oba, 2001). It has been reported that Otoacoustic emissions are robust in subject with auditory neuropathy / dys-synchrony. Kumar and Jayram, (2006) reported that in a retrospective analysis of 61 subjects with auditory neuropathy / dys-synchrony the amplitude of TEOAE was 16 dB SPL, whereas for the normal hearing adults the mean amplitude of TEOAE was 11.5 dB SPL.This phenomenon has been attributed to the lack of efferent suppression of Otoacoustic emissions.

In all subjects with auditory neuropathy / dys-synchrony however the amplitude of the otoacoustic emission (OAEs) is not always higher. In a few subjects even TEOAE with normal amplitude has been reported. Rance et al. (1999) reported 20 infants and children

with auditory neuropathy / dys-synchrony. TEOAE was done in 17 of the children. Overall response amplitudes were 11.04 ±1.66 dB and the average waveform reproducibility in the 1 to 4 KHz bands was approximately 85 %. The amplitude reported in Rance et al was similar to those reported for normal hearing infants & children by Widen (1997).

In a few subjects with auditory neuropathy / dys-synchrony however, absence of OAEs have also been reported and some of the studies have reported that the OAEs are present in subjects with auditory neuropathy / dys-synchrony but disappears over time. Sininger and Oba, (2001) reported that in 80% of the subjects with auditory neuropathy / dys-synchrony OAE's were present, absent in 9% of the subjects, and OAE disappeared over time in 11% of the subjects. Loss of OAEs in the subjects with auditory neuropathy / dys-synchrony was not likely due to progressive hair cell pathology because the cochlear microphonics was apparently recordable in these subjects. Deltenre, et al. (1999) reported two prelingual children, whose follow-up data demonstrated a selective loss of otoacoustic emissions. However, there are reports in the literature where follow-up of auditory neuropathy / auditory dys-synchrony subjects demonstrated no change in the amplitude of OAE. Shah, (2004) reported a case identified as having auditory dys-synchrony whose hearing was monitored over a period of 17 weeks, in which three consecutive audiological evaluations were carried out. In the first evaluation, the subject had minimal to mild low frequency hearing loss. During the subsequent audiological evaluation the behavioral thresholds worsened whereas OAE did not show any significant change.

Electrocochleography in auditory neuropathy / dys-synchrony

Cochlear microphonics: Cochlear microphonics have been recorded in subjects with auditory neuropathy / dys-synchrony while recording ABR by reversing the polarity of the stimulus (Starr et al., 1996; Starr et al., 2000, Berlin, et al., 1998) or using electro cochleography (Santarelli & Arslan, 2002; Kaga, Nakamura, Shinogami, Tsuzuku, Yamada, & Shindo, 1996). As the outer hair cell functioning is normal in subjects with auditory neuropathy / dys-synchrony the test results on cochlear microphonics is normal (Hood, 2002). Starr et al. (1996) reported 10 subjects with auditory neuropathy / dys-synchrony in whom cochlear microphonics was present in all the subjects. The polarity of cochlear microphonics was reversed with reversal of click phase from condensation to rarefaction with latency between 1 & 2 msec with very low amplitude.

There are also reports that the cochlear microphonics is of abnormally high amplitude in subjects with auditory neuropathy / auditory dys-synchrony. Starr, et al. (2001) reported thirty-three children under the age of 10 years with auditory neuropathy / dys-synchrony in whom abnormally increased cochlear microphonics were found in all the subjects. The mean amplitude of cochlear microphonics was 0.46µv if TEOAE was present; the ampltude was 0.38 µv when TEOAE was absent. Also when the puretone average was greater than 57 dB the mean amplitude was 0.50 µv and if the pure tone was less than 57 dB the amplitude was 0.40µv. Starr, et al. (2000) also reported 33 subjects with auditory neuropathy / dys-synchrony in whom cochlear microphonics was present in all subjects and was abnormally increased in amplitude in approximately 50 % of the subjects below the age

of ten years. The finding of increased cochlear microphonics in young subjects was attributed to the specific hair cell changes that are secondary to the alternations of auditory nerve inputs.

Some of the studies have reported prominent and long lasting cochlear microphonics in individuals with auditory neuropathy/dys-synchrony. Santarelli and Arslan, (2002) reported five subjects with auditory neuropathy / auditory dys-synchrony in whom cochlear microphonics was present with normal amplitude in all but one patient. In one subject the cochlear microphonics was long lasting. Also Starr, et al. (1998) reported three subjects with auditory neuropathy / dys-synchrony in whom cochlear microphonics were present in ABR recordings and the cochlear microphonics were of the large amplitude extending almost for 5 msec duration. Starr, et al. (1991) also reported a subject with auditory neuropathy / dys-synchrony in whom the cochlear microphonics extended up to 5 msec duration. The latency of these potentials did not change as signal intensity was reduced.

Summating potentials: The results of the studies investigating summating potentials in subjects with auditory neuropathy / dys-synchrony are equivocal. Some of the studies have reported presence of summating potentials with a normal amplitude (Sheykholeslami, Kaga, & Kaga, 2001; Santarelli & Arslan, 2002), whereas summating potentials with abnormal amplitude has also been reported (Santarelli & Arslan, 2002). Santarelli and Arslan, (2002) reported 5 subjects with auditory neuropathy / dys-synchrony in whom amplitude of summating potentials were within normal limits in all but one subject. In one of the subject the summating potentials were abnormally large. O'Leary, Mitchell, Gibson, and Sanli

(2001) reported a large positive summating potential in subjects with auditory neuropathy /dys- synchrony.

There are also reports that the summating potentials are present at abnormal levels in subjects with auditory neuropathy / dys-synchrony. Jutras, Russell, Husteau, and Chapdelaine (2003) reported a subject with auditory neuropathy / auditory dys-synchrony in whom the summating potentials were recorded even at 50 dB nHL in transtympanic recording. Using an extratympanic recording of ECochG, Kaga, et al. (1996) reported a large negative summating potentials at 100 dB HL, 80 dB HL, 75 dBHL, & 70 dBHL, in one of the subjects with auditory neuropathy whereas in another subject they reported a broad summating potentials at 100dBHL, 90 dBHL, 85 dBHL, & 80 dBHL. However, in far field recording summating potentials are not present in all normal subjects. Starr et al. (2001) reported summating potentials in approximately 50% of the auditory dys-synchrony subjects using an extra tympanic method of electrocochleography.

The measures of summating potentials are important, because the generators for summating potentials include both types of hair cells i.e. IHCs & OHCs, with IHCs the principle generator (Durrant, Wang, Ding, & Salvi, 1998). Further presence of summating potentials in auditory neuropathy / dys-synchrony subjects leads one to conclude that IHCs retains a normal function in these patients. However, additional studies of summating potentials are required to conclude that this cochlear event is normal in all the auditory dys-synchrony subjects (Starr et al., 2001).

Compound action potentials: In subjects with auditory neuropathy / dys-synchrony the compound action potentials is absent or shows a variable degree of desynchronization spanning from a broad response to a low amplitude delayed activity. Santarelli and Arslan, (2002) studied five subjects with auditory neuropathy / dys-synchrony. Compound action potential was absent in three of the subjects whereas in two other subjects a clear identifiable compound action potentials with the absence of N2 component and a broad morphology was present.

The compound action potentials are also present at abnormal levels in the subjects with auditory neuropathy / auditory dys-synchrony. Jutras et al. (2003) reported a subject in whom the compound action potentials were present at 50 dB nHL. These studies have used transtympanic method of recording electrocohleography; however, there is dearth of information on compound action potentials recorded using far field recording of electrocochleography in subjects with auditory neuropathy / dys-synchrony.

In summary, a review of literature suggests presence of cochlear microphonics in all the subjects with auditory neuropathy / dys-synchrony. But there are equivocal reports on summating potentials and compound action potentials in subject with auditory neuropathy / dys-synchrony.

Efferent activity in subjects with auditory neuropathy / dys-synchrony:

In humans the effect of efferent system has been studied by adding tones or noise to the opposite ear (Liberman, 1989; Folsom & Owsley, 1987). By addition of tone to the contralateral ear a significant reduction in the amplitude of N1 is observed but there is no significant change in the latency of the action potentials (Folsom & Owsley, 1987). In addition to the inhibiting N1 action potentials, medial efferent also affect non neural cochlear potentials, efferent stimulation increases the amplitude of the cochlear microphonics which is typically larger at high sound levels and can be as large as 4 dB (Fex, 1959; Gifford & Guinan, 1987). Medial efferent system stimulation also suppresses the summating potentials. Fex, (1959) reported a reduction in the summating potentials following medial efferent stimulation. They observed a reduction in amplitude coincided with the amplitude reduction of N1 and the amplitude facilitation of cochlear microphonics. However there is dearth of information on suppression of cochlear microphonics, summating potentials, and compound action potentials in subject with auditory neuropathy / dys-synchrony.

Otoacoustic emissions have been widely used to assess the functional integrity of the efferent system in the auditory neuropathy / dys-synchrony subjects. Subjects with auditory dys-synchrony consistently shows no or minimal suppression of TEOAEs (Hood & Berlin, 2001; Hood, Berlin, Bordelon, & Rose, 2003; Abdala, Sininger, & Starr, 2000) and DPOAEs (Abdala et al., 2000). The result for TEOAE suppression is consistent using ipsilateral, binaural and contralateral noise (Hood & Berlin, 2001; Hood, et al., 2003).

Hood et al. (2003) studied the efferent characteristics in 10 subjects with auditory neuropathy / dys-synchrony using ipsilateral, contralateral and binaural suppressor noise. They reported significantly lower suppression in the auditory neuropathy / dys-synchrony subjects compared to normal subjects for all three suppressor noise condition. These authors reported a mean suppression of TEOAE, which was less than 0.22 dB across all suppressor condition.

The absence of efferent suppression is also observed on DPOAE's. Abdala et al. (2000) studied contralateral suppression of DPOAE in four subjects with auditory neuropathy / dys-synchrony. They reported that reduction of DPOAE amplitude with presentation of contralateral noise was non-equivocally absent in the subjects with auditory dys-synchrony.

The lack of efferent suppression may be due to an afferent deficit rather than an efferent deficit. The afferent deficit in subjects with auditory dys-synchrony has been supported by findings in subjects with unilateral auditory dys-synchrony (Hood & Berlin, 2001; Hood, et al., 2003). Hood et al. (2003) reported a case of unilateral auditory dys-synchrony in whom TEOAE suppression for binaural, ipsilateral and contralateral suppression yielded a combination of presence and absence of responses. In their study when normal ear received the suppressor stimuli, the suppression was present. The only other condition where suppression was present in the abnormal ear binaural conditions, where both abnormal and normal ear received suppressor stimuli, when suppressor was presented to the abnormal ear, suppression was below normal. The similarity in amplitude

between the abnormal ear binaural and abnormal ear contralaterally suggested that only the normal ear was processing the suppressor stimuli effectively. They concluded that the absence of efferent suppression in patients with auditory dys-synchrony is most likely due to an afferent deficit rather than an efferent problem.

The deficit in afferent system rather than efferent system has also been supported by the presence or absence of middle ear muscle reflex in subjects with auditory dys-synchrony. Berlin, et al. (2005) reported 8 subjects with unilateral auditory dys-synchrony in whom there was a clear middle ear muscle reflex at normal level when the normal ear was stimulated but it was absent when the abnormal ear was stimulated. This supports the hypothesis of Starr, (2001) that in subjects with auditory dys-synchrony the auditory nerve may not achieve a sufficient high rate of discharge to activate crossed olivocochlear reflex.

To summarize in subjects with auditory neuropathy /dys-synchrony, the behavioral puretone thresholds varies from normal hearing sensitivity to profound hearing loss. Sometime the puretone thresholds may fluctuate dramatically from day to day or even during tests. In addition the middle ear muscle reflexes are absent in subjects with auditory neuropathy / dys-synchrony subjects. Otoacoustic emissions are typically present in all the subjects with auditory neuropathy / dys-synchrony, whereas auditory brainstem responses are typically absent. Cochlear microphonics is always present, but there are equivocal findings on summating potentials and action potentials in subjects with auditory neuropathy / dys-synchrony.

METHOD

The present study was conducted with the aim of studying the cochlear receptors (cochlear microphonics, summating potentials) and N1 action potential and also to study the effect of efferent stimulation on cochlear receptors and N1 action potential in normal hearing subjects and subjects with auditory dys-synchrony.

Subjects: Subjects were divided in to two groups; control group and experimental group.

Experimental group: Experimental group included eighteen ears of nine subjects, diagnosed as auditory dys-synchrony on the basis of audiological findings (i.e. normal outer hair cells functioning as revealed by presence of Otoacoustic emissions, absence of auditory brainstem responses. The subjects were in the age range of 10-22 years with a mean age of 17years.The subjects did not had any space occupying lesion as confirmed by the neurological report.

Control group: 31 ears of 24 normal hearing individuals were included in the control group. All the subjects in the control group had threshold no more than 15 dB HL at octave frequencies between 250Hz to 8000 Hz. All the subjects had normal middle ear functioning as revealed by a normal tympanogram and presence of middle ear muscle reflexes. Subjects with any history with otologic or neurologic history were excluded from the study. The age of the subjects ranged from 10-26 years with a mean age of 21 years.

Equipment: The following equipments were used for the study:

1. A calibrated two channel clinical audiometer OB922 with TDH-39 headphones housed in Mx-41/AR ear cushions with audio cups were used for puretone audiometry.
2. A calibrated immittance meter, GSI-TYMPSTAR was used to assess the middle ear functioning of the subjects.
3. ILO 292 Echoport Plus was used for measuring Otoacoustic emissions.GSI-16 audiometer was used for providing broadband noise while recording contralateral suppression of Otoacoustic emissions.
4. Interacoustic EP15 system with ER-3A insert receiver was used for recording ABR and ECochG.

Test environment: All the audiological tests were carried out in an acoustically treated room with adequate illumination.

Procedure:

1. Puretone thresholds were obtained at octave intervals between 250HZ to 8000 HZ for air conduction and between 250 HZ to 4000 HZ for bone conduction.
2. Immittance audiometry was carried out with a probe tone frequency of 226 HZ ipsilateral and contralateral. Acoustic reflexes thresholds were measured for 500 HZ, 1000 HZ, 2000HZ, and 4000HZ.
3. Auditory brainstem responses were recorded from two channels. The site of electrode placement was prepared with skin preparation gel. Silver chloride electrode

was used with a conducting gel. The auditory brainstem responses were recorded using rarefaction click stimuli with a repetition rate of 11.1 at 80 dB nHL intensity. A filter setting of 100Hz to 3000Hz was used.

4. Otoacoustic emissions evoked by clicks presented at 65 dBSPL for the linear clicks were recorded. The probe with a tip was positioned in the external ear canal and was adjusted to give flat stimulus spectrum across the frequency range. The response was acquired using the linear averaging method. The two averaged TEOAE waveforms of each memory buffer composed of 260 accepted click trains, were automatically cross-correlated and used to determine the reproducibility of the measured TEOAEs by the software. Responses were accepted when the reproducibility was 80% or greater. Broadband noise was fed through GSI-16 audiometer for recording contralateral suppression of Otoacoustic emissions. The intensity of broadband noise was 50dB SPL for the control group and for experimental group first the threshold for broadband noise was obtained and the contralateral noise was presented at 30dB SL with reference to the threshold obtained for broadband noise. A total of two responses with noise and two responses without noise were recorded to ensure the stability of the response. A minimum of one minute gap was given between any two recordings to reduce the influence of the one recording over another recording. Care was taken to ensure that the position of probe was not altered.
5. For recording ECochG subjects were made to relax on reclining chair. ECochG was recorded from one channel. The site of electrode placement was prepared with skin preparation gel. Silver chloride (AGCL) electrode was with conducting gel and a TIPTRODE was used for recording ECochG. For ECochG the noninverting

electrode was placed in the ear canal, ground electrode was placed on the nasion and the inverting electrode was placed on the opposite ear mastoid. It was ensured that impedance for each electrode was less than 5KΩ. ECochG was recorded using the test protocol in the Table 2.

Table 1: Test protocol for the Electrocochleography

Analysis window	5 msec
Filter settings	0 HZ-3000 HZ
Type of stimulus	Broad Band Click
Polarity of stimulus	Rarefaction, Condensation, Alternating
Repetition rate	11.1 /sec
No. of stimuli	1000
Intensity of the stimulus	80dBnHL

Latency and amplitude of cochlear microphonics, summating potential, and action potential (N1) was measured. Latency and Amplitude of cochlear microphonics was estimated from the waveform from rarefaction and condensation stimuli, whereas; latency and amplitude of summating potential and action potential was estimated from waveform obtained for alternating polarity stimuli. The amplitude of cochlear microphonics was estimated from the average of two waveforms. Peak to peak amplitude values of summating potential and N1 action potential was measured from the alternating waveform. Two Audiologists independently analyzed the waveform.

RESULTS AND DISCUSSION

The latency and amplitude of the cochlear potentials (Cochlear microphonics, Summating potentials), action potential and amplitude of OAE were recorded in quiet and in the presence of noise. Mean and standard deviation (SD) was calculated separately for each group. Wilcoxon signed ranks test was administered to check if there is a statistically significant difference between the measures obtained in quiet and in the presence of noise. Mann-Whitney "U" test was carried out to check if there is a significant difference between the measures obtained for the two groups. SPSS software version 10 was used to carry out the statistical analysis.

All the subjects in the control group had normal ABR but ABR was absent for all the subjects in the experimental group. Otoacoustic emissions were present in all the subjects in both the groups. The mean and standard deviation values of otoacoustic emissions amplitudes are for the experimental group and the control groups are given in Table 2. It is clear from the table that the amplitude of the otoacoustic emissions in the experimental group is more than control group. It is also clear from the table that there is a mean reduction in the amplitude of otoacoustic emissions recorded in the presence of noise for the control group whereas for the experimental group there is no mean difference in the amplitude of otoacoustic emissions in presence of noise.

Table 2: Mean and Standard deviation of OAE in the control and experimental group.

	Control group		Experimental group	
	Mean	SD	Mean	SD
OAE amplitude without noise	13.37	2.65	16.75	3.10
OAE amplitude with Noise	11.62	3.12	16.75	3.10

These results are consistent with previous findings in subjects with auditory dys-synchrony reported by other investigators (Hood & Berlin, 2001; Abdala, Sininger & Starr, 2000; Hood, Berlin, Rose & Bordelon, 2003; Starr, Sininger, Picton, Hood & Berlin, 1996).

Cochlear microphonics:

Cochlear microphonics could be recorded in all the subjects in both the conditions i.e. in quiet and in the presence of noise. The mean and standard deviation values of latency and amplitude of cochlear microphonics are given in Table 3 for both the groups. It is clear from the table that the amplitude for the cochlear microphonics in the individuals with auditory dys-synchrony is more than that of the normal hearing individuals. It is also clear from the table that the latency of the cochlear microphonics auditory dys-synchrony is more than that of the normal hearing individuals

Table 3: Mean and SD of Latency and amplitude of cochlear microphonics in control and experimental group

	Control Group		Experimental group	
	Mean	SD	Mean	SD
Latency (msec) without Noise	.33	.1606	.45	.1930
Latency (msec) with noise	.33	.1432	.52	.2315
Amplitude (µv) without noise	0.08	0.03	.23	0.07
Amplitude (µv) with noise	.20	.1036	.21	0.06

Although the mean latency was higher in the experimental group, there was an overlap in the range obtained for the two groups. In the control group the latency ranged from, 0.10 to 0.67 msec, whereas it ranged from 0.20 msec to 0.90 msec for the experimental group. The amplitude ranged from 0.14 µv to 0.36 µv for the experimental group and it ranged from .03 µv to .15 µv for the normal group. There was an increase in the mean amplitude value of the cochlear microphonics for the control group when noise was presented to the contralateral ear whereas for the experimental group there was no difference in the amplitude of the cochlear microphonics across two conditions.

Mann-Whitney “U” test showed that the difference between the two groups for the mean latency value and the mean amplitude value was statistically significant at .05 and .01 level respectively. (Z= 2.083 for latency, and Z=5.691 for amplitude).

Wilcoxon signed ranks test was administered to find out if there is a significant difference in latency and amplitude between two conditions. The results revealed that there was no significant difference in the latencies obtained between the two conditions for both the groups. (Z=0.90; p>.05 for the control group and for the experimental group Z= 0.962; p>.05). The amplitude of the cochlear microphonics across the two conditions differed significantly in the control group (Z = 4.868; p<. 01) but there was no significant difference in the amplitude of cochlear microphonics across two conditions (Z=0.604; p>.05).

The mean latency of the cochlear microphonics in the normal hearing individuals is comparable with that reported in literature. In the present study the amplitude of the cochlear microphonics in the control group than that reported in literature. Starr et al., (2001), reported mean amplitude of 0.38μv for the cochlear microphonics. The difference in the amplitude obtained in the two studies is due to the methodological differences. Starr et al measured the amplitude of the cochlear microphonics from the subtracted averages to condensation and rarefaction waveforms and measured the amplitude at the peak where it had maximum amplitude. It has been found that the amplitude of the cochlear microphonics in the subtracted waveform is twice that of the cochlear microphonics found in the separate averages to the condensation and rarefaction stimuli (Starr et al, 2001). In the present study due to technical limitations the subtracted waveform could not be obtained.

The amplitude of cochlear microphonics was higher in the individuals with auditory dys-synchrony subjects than the normal hearing individuals in the present study. In addition, a long ringing cochlear microphonics up to 1.4 msec was also observed in two of the individuals with auditory dys-synchrony. The cochlear microphonics prominence in auditory dys-synchrony subjects (Starr et al, 1998, 2001) as well as its persistence for several milliseconds after a click stimulus has already been reported by several authors (Berlin, 1999; Starr et al, 2001), who considered this finding an indication of an abnormal cochlear function (Starr et al., 2001). Santarelli & Arslan (2002), Suggested that in subjects with auditory dys-synchrony the enhancement of both cochlear microphonics amplitude and duration of cochlear microphonics may result from the pathology in the afferent & efferent loop.

No effect was observed for amplitude of the cochlear microphonics in individuals with auditory dys-synchrony when contralateral noise was presented but the amplitude was enhanced in the normal hearing individuals when contralateral noise was presented. The absence of enhancement of amplitude in the individuals with auditory dys-synchrony /neuropathy may be due to the deficit in the afferent system. The evidence comes from the previous study on contralateral suppression of Otoacoustic emissions and acoustic reflexes (Hood et al., 2003; Berlin et al., 2005).

Summating potentials:

The summating potentials could be recorded in 60% of the normal hearing individuals whereas it was absent in all the subjects with auditory dys-synchrony. The mean

and standard deviation of latency and amplitude of summating potentials for the control group are given in Table 4. It can be observed from the table that there is no difference in the latency of the summating potentials across the two conditions whereas there is a reduction in the amplitude when it was recorded in the presence of contralateral noise.

Table 4: Mean and Standard deviation of the Summating potentials in the control group

	Mean	SD
Latency (msec) without noise	.70	.20
Latency (msec) with noise	.70	.19
Amplitude (µv) without noise	.21	.11
Amplitude (µv) with noise	.12	0.07

Wilcoxon signed ranks test revealed that there is no significant difference in the latency of the summating potentials whereas there is a significant difference was found for the amplitude of the summating potentials between two conditions. ($Z= 1.357$; $p>.05$ for the latency, and $Z=3.927$; $p<. 01$ for the amplitude).

The range of amplitude of summating potentials amplitude varied between 0.10 µv to 0.48 µv in normal subjects. Previous investigators have reported amplitude range between 0.04 µv to 1.30 µv (Ferraro & Durrant, 2004; Ferraro, 2003; Chatrian, Wrich, Edwards, Turella, Kaufman, & Snyder, 1985).The latencies of for the summating potentials in normals varied between 0.44 msec to 1.17 msec with a mean latency of 0.7 msec. Similar results have been reported by previous investigators (Chatrian, et al.1985).But the upper limit is

higher in present study than reported by earlier investigators. The smaller amplitude and longer latency observed in the present study may be attributed to the placement of the electrodes. Extratympanic placement was used in the present study whereas a majority of the earlier investigators have used transtympanic recording (Santarelli & Arslan, 2002).It has been well established in literature that the amplitude of potentials is higher in transtympanic method compare to the extratympanic method (Starr, et al., 2001; Santarelli & Arslan, 2002).

Furthermore, the amplitude of the summating potentials was suppressed after the presentation of the contralateral stimuli. The suppression of amplitude of the summating potentials may be due to the activation of the efferent system. Fex, 1959; Gans, 1977, reported that the efferent stimulation reduces the amplitude of the summating potentials.

Additional measures of recording summating potentials may be necessary if we are to define whether this cochlear event is normal in subjects with auditory dys-synchrony. The measure is important because the generators for summating potentials include both types of hair cells, with inner hair cells considered the principle generators (Durrant, Wang, Ding, & Salvi, 1998; Zheng, Ding, McFadden & Henderson, 1997).

Action potentials:

Action potentials could be recorded from all the subjects in the control group but it was absent in all the individuals with auditory dys-synchrony. The mean and standard deviation of latency and amplitude of action potentials for the control group are given in

Table 5. It can be seen from the table that there is no difference in the latency of the action potentials between the two conditions whereas a reduction in the amplitude of action potential was observed when recorded in presence of contralateral noise.

Table 5: Mean and Standard deviation value of action potentials in the control group.

	Mean	SD
Latency (msec) without noise	1.46	0.15
Latency (msec) with noise	1.46	0.15
Amplitude (μv) without noise	0.51	0.22
Amplitude (μv) with noise	0.32	0.20

Wilcoxon sign rank test revealed that there is no significant difference in the latency of the action potentials between two conditions whereas there is a significant difference in the amplitude of the action potentials across two conditions ($Z=0.174$; $p>.05$ for latency and $Z= 4.863$; $p<. 01$ for amplitude).

The amplitude value of action potentials in the present study ranged from 0.28μv to 1.20 μv. Previous researchers have reported amplitude of action potentials, which varied between 0.6 μv to 5 μv (Ferraro, 2003; Ferraro & Durrant, 2004; Chatrian et al., 1985). The variations of the amplitude across the different studies are due to the methodological

differences. Such as the intensity used for recording ECochg, and the different electrode used for recording ECochg (Ferraro, 2003; Ferraro & Durrant, 2004; Chatrian et al., 1985).

Further, there was no change in the latency of the action potentials, but there was reduction in the amplitude of the action potentials when the noise was presented to the contralateral ear. Folsom & Owsley, (1987) also reported a reduction in the amplitude of the action potentials but no change in the latency of the action potentials after presentation of the contralateral noise. The reduction in the amplitude of the action potentials is attributed to the activation of the efferent system. It has been reported that activation of efferent system suppresses the amplitude of the action potentials (Folsom & Owsley, 1987; Libermann, 1989).

The action potentials were absent in all the cases with auditory neuropathy/dys-synchrony. The absence of action potential is expected in the subjects with auditory dys-synchrony, as there is a dysfunction of the auditory nerve. However a few investigators have reported presence of wave I or presence of N1 in ECochg in some of the subjects with auditory dys-synchrony (Santarelli, & Arslan, 2002). Santarelli and Arslan, 2002 using transtympanic ECochg reported presence of N1 action potentials component with a broad morphology in few of the subjects with auditory dys-synchrony. Closer the electrode placement to the generator site, higher the chances of recording the action potentials as it enhances the signal to noise ratio. Therefore chances of recording wave I during ECochg is higher compare to far field recording.

SUMMARY AND CONCLUSION

Auditory neuropathy/dys-synchrony is a disorder characterized by the impairment of the peripheral auditory function with the preservation of outer hair cell integrity (Starr, Sininger, Picton, Hood & Berlin, 1996; Berlin et al., 1998; Berlin, 1999). The audiological tests, which are used to diagnose auditory neuropathy/dys-synchrony, are otoacoustic emissions and auditory brainstem response. One another test which has been recently used in the diagnosis of individuals with auditory neuropathy/dys-synchrony is Electrocochleography. Electrocochleography is a method of measuring stimulus related electrophysiologic potentials, which include the cochlear microphonics, the summating potential, and the compound action potential.

In the literature, there have been equivocal findings on summating potentials and action potentials in individuals with auditory dys-synchrony, whereas it has been reported that the cochlear microphonics is always present in individuals with auditory dys-synchrony. In addition, there is dearth of information regarding the contralateral suppression of cochlear microphonics in individuals with auditory dys-synchrony.

The present study was undertaken to record the cochlear receptors (cochlear microphonics and summating potentials) and action potentials in individuals with auditory neuropathy/ dys-synchrony in quiet and in the presence of contralateral noise. Two groups of subjects were selected. The first group of subject of subject consisted of normal hearing individuals and second group consisted of individuals with auditory neuropathy/dys-synchrony. All the subjects in the experimental group had an absence of auditory brainstem

response and presence of otoacoustic emissions and in the control group, the subjects had pure tone threshold no more than 15 dBHL at all the octave frequencies.

The electrocochleography was recorded in both the groups in quiet and in the presence of noise. Electrocochleography was recorded from one channel using Interacoustic EP15 system. The noninverting electrode was placed in the ear canal, the inverting electrode was placed on the mastoid of the opposite ear and the ground electrode was placed on the nasion. A TIPTRODE was used as noninverting electrode. Electrocochleography was recorded using broadband click stimuli, with a repetition rate of 11.1 at an intensity of 80 dBnHL. All the three polarities i.e. rarefaction, condensation, and alternating were used. Latency and amplitude of the cochlear microphonics, summating potentials, and action potentials were measured in quiet and in the presence of contralateral noise. The amplitude of cochlear microphonics was estimated from the waveform obtained for rarefaction and condensation and the amplitude of summating potential, and action potential was estimated from the waveform obtained for alternating stimuli. In addition, otoacoustic emission was also recorded in quiet and in the presence of noise in both the groups. Amplitude of the otoacoustic emission was recorded in quiet and in the presence of contralateral noise. A calibrated 2-channel audiometer GSI-16 was used to deliver the contralateral noise. SPSS software was used to analyze the data.

Analysis of the data revealed the following results:

1. Cochlear microphonics was present in all the individuals in both the groups. Amplitude of the cochlear microphonics was significantly higher in individuals with auditory neuropathy/dys-synchrony subjects, from the normal hearing individuals. Latency of the cochlear microphonics was also significantly prolonged in individuals with auditory neuropathy/dys-synchrony. Further, for the normal hearing individuals the amplitude of the cochlear microphonics was enhanced when noise was presented in the contralateral ear, whereas in individuals with auditory neuropathy/dys-synchrony there was no difference in the amplitude between the two conditions. There was no effect on latency after the presentation of contralateral noise in both the groups.

2. Summating potential was absent in 40 % of the normal hearing individuals and it was absent in all the subjects with auditory neuropathy/dys-synchrony. There was a significant reduction in the amplitude of the summating potentials in the individuals with normal hearing when it was recorded in the presence of noise.

3. Action potential was absent in the all the individuals with auditory neuropathy / dys-synchrony, whereas it was present in all the individuals with normal hearing. The amplitude of the action potential was significantly reduced when it was recorded in the presence of noise.

The following conclusions were drawn from the study:

1. Electrocochleography is a useful tool in assessing the auditory neuropathy/dys-synchrony, since it provides a reliable evaluation of auditory peripheral function.

2. The outer hair cells functioning is normal in individuals with auditory neuropathy/dys-synchrony, but the auditory nerve and the inner hair cells may be involved in these subjects.

3. The signal to noise ratio in extratympanic recording is always low compare to a transtympanic method.

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