Correlation of Cochlear Hydrops Analysis Masking Procedure and Electrocochleography in Meniere's Disease

[1]Pallavi & [2]Prawin Kumar

Abstract

Meniere's disease is an idiopathic inner ear disorder which is characterized by episodes of vertigo, fluctuating hearing loss, aural fullness and tinnitus or a combination of these symptoms. Diagnosing Meniere's disease is always a matter of controversies because of its so frequent fluctuation of symptoms. Recent researches are focused on Cochlear hydrops analysis masking procedure (CHAMP) and electrocochleography (ECochG), as these tools are more reliable. The present study was undertaken to investigate the correlation between these two tests to diagnose Meniere's disease and also. The study was conducted on two groups, individuals with Meniere's disease (experimental group) and individuals with normal hearing (control group). ECochG and CHAMP were administered on both the groups. Results revealed that, in CHAMP, wave V latency was significantly shorter in experimental group as compared to control group. In ECochG, there was a significant difference between the two groups with respect to(a) longer latency and larger amplitude of action potential (AP) in experimental group, (b) larger amplitude of summating potential (SP) in experimental group and c) larger SP/AP amplitude ratio in experimental group. Thus it can be concluded that both test give reliable results to diagnose Meniere's disease, but the correlation of both the tests was found to be low negative. Therefore, along with these two tools, other aspects like ENT confirmation and other tests should also be administered for confirm diagnosis of Meniere's disease.

Key Words: *Meniere's disease, CHAMP, ECochG.*

Introduction

Meniere's disease is an idiopathic inner ear disorder, an abnormal increase in the volume of the cochlear fluid (endolymph) in the inner ear (Ries, Rickert & Schlauch, 1999). Further, it is characterized by recurrent, spontaneous episodes of vertigo, fluctuating hearing loss, aural fullness and tinnitus or with a combination of these signs and symptoms fluctuating over months and years (Sajjadi & Paparella, 2008). The Reissner's membrane as being displaced from the basilar membrane in some instance and at the apex of the cochlea, the membrane was seen to bulge through the helicotrema (Morrison, Moffat & O'Conor, 1980).

The etiology of Meniere's disease has been linked to endolymphatic hydrops, with evidence from histological studies (Hallpike & Cairns, 1938; Horner, 1991). Endolymphatic hydrops refers to swelling of cochlea at the boundaries of the scala media from excessive accumulation of the endolymph (Hall, 2007).

There are various subjective and objective tests to measure the extent of Meniere's disease. In recent studies, to diagnose Meniere's disease, electrocochleography (ECochG) and cochlear hydrops analysis masking procedure (CHAMP) are found to be most popular tests. However, the histological findings, which help in the confirmation of a Meniere's disease diagnosis, can only be obtained through post-mortem biopsies (Roeser, Valente & Hosford, 2000).

ECochG is an ideal test for the diagnosis of Meniere's disease (Levin, Margolis & Daly, 1998). It is thought to reflect changes in the anatomic position of the hair cells and this change in position of the hair cell is what is expected to occur in active Meniere's disease (Levine et al., 1998). It was shown that the amplitude ratio of summating potential (SP) and action potential (AP) is much more useful indication for detecting endolymphatic hydrops. A mean values of SP/AP amplitude ratio being near 0.25. From 0.30 to 0.40 of SP/AP amplitude ratio was considered adequate as the upper limit (Aso, Watanabe & Mizukoshi, 1991). Ferraro and Durrant (2006) also reported that ECochG is an important tool in the diagnosis/assessment/monitoring of Meniere's disease. Al-momani, Ferraro, Gajewski, and Ator, (2009) suggested that more sensitive and specific ECochG parameters include SP amplitude and area, total SP-AP area, and SP/AP area ratio to click stimuli. Sensitivity and specificity values associated with these measures are 92% and 84%, respectively.

CHAMP was introduced as a method to distinguish objectively active Meniere's disease individuals (Don, Kwong & Tanaka, 2005). The method consists of

[1]E-mail: peepal.pallavi@gmail.com; [2]Lecturer in Audiology, E-mail: prawin_audio@rediffmail.com.

measurement of the change of the latency of wave V response in the auditory brainstem response, caused by the addition of high-pass making noise to the click stimulus. Abnormal ABR latencies obtained with high pass masking noise in individuals with Meniere's disease is due to abnormally high travelling wave velocities (Thornton & Ferrell, 1991; Donaldson & Ruth, 1996). Thus, in individuals with Meniere's disease it is assumed that increased endolymphatic pressure alters basilar membrane's mechanical properties which in turn increase the apparent travelling wave velocity (Don et al., 2005). CHAMP findings are consistent with the excellent sensitivity and specificity (Don et al., 2005; Kingma & Wit, 2010; Singh, 2010). But different studies considered different cut-off criteria for latency shift to confirm a diagnosis of Meniere's disease in CHAMP. Don et al., (2005) and Singh (2010) considered less than 0.3 ms as cutoff criteria but Kingma and Wit (2010) reported if less than 2 ms is considered as cutoff criteria then the sensitivity can be improved. Other studies however opposed these finding and found low sensitivity and specificity of CHAMP by considering wave V latency shift less than 3 ms as a criterion and hence, it cannot be used as a clinical tool to diagnose individual with Meniere's disease (De Valck, Claes, Wuyts & Paul, 2007).

Hence, the aim of the present study were to determine (1) the summating potential (SP) and action potential (AP) amplitude and the ratio (SP/AP) between the two potentials in individuals with normal hearing and with Meniere's disease, (2) the diagnostic value of CHAMP in individuals with normal hearing and individuals with Meniere's disease and (3) the correlation in the findings of ECochG and CHAMP in individual with normal hearing and individuals with Meniere's disease.

Method

Participants

Two groups, individuals with normal hearing (control group) and individuals with Meniere's disease (experimental group) participated in the study. The control group comprising of thirty three ears of 10 females and 7 males with the age range of 20 to 40 years, with the mean age was 22.2 years. They all had pure tone thresholds better than 15 dBHL at octave frequencies between 250 Hz to 8000 Hz in both the ears. The overall mean pure tone average (0.5 kHz, 1 kHz & 2 kHz) was 6.01 dBHL. They had no indication of middle ear pathology, revealed by 'A' type tympanogram with present reflexes. In experimental group, thirty ears of 9 females and 8 males with the mean age of 32.1 years were considered. The pure tone thresholds were within the range of 26 to 55 dBHL and the overall mean pure tone threshold was 35.69 dBHL at octave frequencies between 250 Hz to 8000 Hz. They all had no indication of middle ear pathology, as per immittance finding. Auditory brainstem response and oto-acoustic emissions were done on each individual, to rule out retrocochlear pathology and those individuals indicating retrocochlear pathology were excluded. They all had at least 3 of the 4 hallmark symptoms (tinnitus, vertigo, fluctuating hearing loss & fullness) used in the diagnosis of Meniere's disease (Committee on Hearing and Equilibrium, 1995). Tinnitus and vertigo were reported in all affected ears. Eighteen ears had fluctuating hearing loss, fifteen ears with aural fullness and nine ears had all the four symptoms. A detailed case history was taken for each individual and the individuals who fulfilled the above mentioned criteria along with the ENT provisional diagnosis of Meniere's disease were included.

Procedure

CHAMP and ECochG recording was done on both the groups. All individuals were tested in an acoustically sound treated room with adequate illuminations as per ANSI (1991). Pure tone thresholds were obtained at octave frequencies between 250 Hz and 8 kHz for air conduction and between 250 Hz and 4 kHz for bone conduction thresholds. Tympanometry was carried out with a probe tone frequency of 226 Hz and acoustic reflexes thresholds were measured for 500 Hz, 1 kHz, 2 kHz, and 4 kHz ipsilaterally and contralaterally. OAEs were obtained using click presented at 70 dBSPL. The probe tip was positioned in the external ear canal and was adjusted to give flat stimulus spectrum across the frequency range. Responses with the reproducibility more than and equal to 80% was accepted.

CHAMP Recording: Individuals were made to relax on a reclining chair. CHAMP was recorded from a single channel. The site of electrode placement was prepared with skin preparation gel. Silver chloride electrodes with conducting gel were used. Non inverting electrode was placed on vertex, inverting on mastoid of the test ear and ground electrode at opposite ear. It was ensured that impedance for each electrode was less than 5 kOhms. Repetition rate was 45.1/seconds. CHAMP was recorded with rarefaction polarity using click and click with different high pass masking (HPM) noise (click+8 kHz HPM, click+4 kHz HPM, click+2 kHz HPM, click+1kHz HPM, click+0.5 kHz HPM). Broadband insert earphones were used to record the CHAMP waveforms.

ECochG Recording: Individuals were made to relax on reclining chair. ECochG was recorded from a single

channel. The site of electrode placement was prepared with skin preparation gel. Silver chloride electrodes with conducting gel were used. TIPtrode was used as non-inverting electrode and placed in the ear canal, inverting was on opposite ear while ground electrode was on forehead. It was ensured that impedance for each electrode was less than 5 kOhms. Alternating polarity was used with the repetition rate of 7.1/seconds to record ECochG. Click was used as stimulus for ECochG recording. Both the test was done on control and experimental groups separately.

Results and Discussion

CHAMP and ECochG were administered on both the groups. For CHAMP recording, the latency of wave V in six conditions (click alone, click+8 kHz HPM, click+4 kHz HPM, click+2 kHz HPM, click+1 kHz HPM & click+0.5 kHz HPM) was measured in each group. The latency and amplitude of SP and AP and the SP/AP amplitude ratio were measured while recording ECochG. Mean and standard deviation were calculated for each group separately. Independent sample t-test was carried out to check if there is a statistical difference in ECochG recording between individuals with normal hearing and with Meniere's disease. Descriptive statistics was done to measure the significant difference between the values obtained from each group. Pearson correlation two tailed test was carried out to measure the correlation between the two tests administered on two groups. The Wilcoxon sign rank test was administered to check whether there is a significant difference in CHAMP recording between individuals with normal hearing and with Meniere's disease.

Findings of CHAMP

Absolute latency of wave V responses was measured in six different high pass masking noise conditions i.e., click alone, click+8 kHz HPM, click+4 kHz HPM, click+2 kHz HPM, click+1 kHz HPM and 0.5 kHz HPM in both the groups. In control group, all thirty three ears had wave V responses in click alone, click+8 kHz, click+4 kHz and click+2 kHz HPM condition. However, 87.87 % ears had wave V responses in click+1 kHz HPM condition and only 72.72 % ears had wave V response in click+0.5 kHz HPM condition. The absence of wave V responses in individuals with normal hearing could be because of undermasking condition (Don et al., 2005). In experimental group, all thirty ears had wave V response in click alone condition but only 86.66% ears had wave V responses in click+0.5 kHz HPM condition. The absence of wave V at 500 Hz HPM along with click may be because of noise contamination or presence of PAM artifact. Furthermore, sometimes in Meniere's disease individuals, the amplitude is so low at lower frequencies with high pass masking noise condition that it is difficult to interpret wave V response. Also, as literature suggests that there may be multiple points or peaks in an undermasked condition, probably due to noise contamination (Don, Kwong & Tanaka, 2007). Even the present study, could not trace wave V for all individuals with Meniere's disease at lower frequencies high pass masking noise, this may be because of the reasons mentioned above.

It was noticed that the latency shift was lesser for individuals with Meniere's disease than individuals with normal hearing group. The minimum mean latency shift seen for click+8 kHz HPM condition was 0.15 ms (0.35 ms in control group) and the maximum mean latency shift was 0.74 ms (1.78 ms in control group) for click+0.5 kHz HPM condition. The lesser shift in Meniere's disease could be explained in terms of presence of endolymph in the inner ear which is suppressing the effect of masking in affected ear or making the basilar membrane stiffen, therefore restricting the normal movement of it. The present finding is in consonance with previous studies in literature (Don et al., 2005; De Valck et al., 2007; Ordonez-Ordonez et al., 2009; Kingma & Wit, 2010; Singh, 2010). The comparison of mean absolute latency of wave V in both the groups is summarized in the Figure 1.

The comparison of latency shift of wave V responses for different high pass masking noise conditions (click+8 kHz, click+4 kHz, click+2 kHz, click+1 kHz & click+0.5 kHz) with wave V responses for click alone condition was done across the two groups using Wilcoxon signed ranks test. It was concluded that two groups are significantly different (at the level $p<0.01$) with respect to wave V latency in different noise conditions. This difference is expected as the physiology of inner ear differs in individuals with normal hearing and those with Meniere's disease. The basic principle is that the endolymphatic hydrops in Meniere's disease causes changes in the physical properties of the basilar membrane. These changes lead to significant undermasking of the high frequency regions by the noise, resulting in a large undermasked component in the 500 Hz high pass response. This undermasked component is valuable in the detection of endolymphatic hydrops. The findings of the comparisons are given in the Table 1.

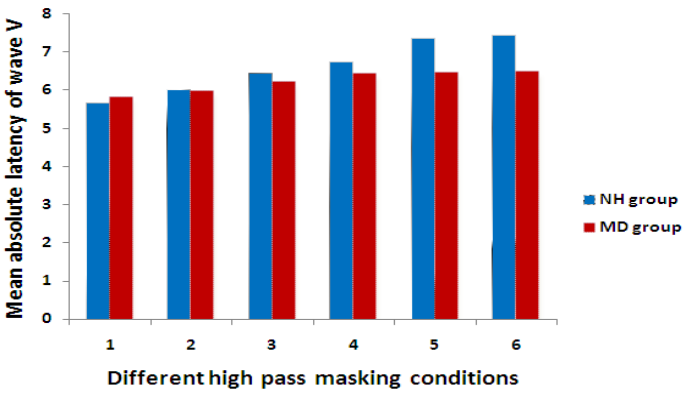

Figure 1: Comparison of absolute latency of wave V responses between individuals with normal hearing and Meniere's disease (Note in x-axis: 1 - Click alone; 2 - Clicks+8 kHz; 3 - Clicks+4 kHz; 4 - Clicks+2 kHz; 5 - Clicks+1 kHz; 6 - Clicks+500 Hz).

The results of the present study also revealed that there is a significant difference in the latency shift of wave V for click alone and click+0.5 kHz HPM conditions between the two groups. The comparison summary is also given in Figure 2. This significant difference in the latency between two groups could be explained in terms of stiffness of the basilar membrane. The Endolymphatic hydrops might be confined at the apical part of the basilar membrane (Tonndorf, 1957) whereas in normal ears such stiffness is not seen. Therefore the cochlea can easily be masked by 0.5 kHz high pass noise, hence there is more shift in latency of wave V in normal ears compared to Meniere's ears.

Don et al., (2005) suggested the cutoff criterion of wave V latency shifts in click + 0.5 kHz HPM from click alone condition should be less than 0.3 ms to confirm Meniere's disease. On the other hand, Kingma and Wit (2010) reported that with latency shift less than 0.3 ms diagnostic criterion, the sensitivity of the CHAMP reduces. Therefore they suggested using 2 msec as cutoff criterion the sensitivity of the CHAMP can be increases. In the present study only 23.3% Meniere's diseased ears showed wave V latency shift less than 0.3 ms. But the sensitivity will improve to 96.6 % if the cutoff criterion is set to 2 ms. Hence present study is also supported by findings of Kingma and Wit (2010).

For the control group, none of the ears had an abnormally short latency with a separation at 0.3 ms. But 66.66% showed abnormality with a separation at 2 ms. Therefore, in the present study both the criteria are not sensitive to distinguish normal ears from Meniere's ears. If the cutoff latency value to diagnose Meniere's disease is considered to be 1 ms then 62.5% normal hearing ears can be separated from Meniere's disease ears and 88.45% Meniere's disease ears will have abnormal short latency shift, which will confirm the diagnosis of Meniere's disease.

Findings of the ECochG

ECochG waveforms were recorded in both the groups. In control group, SP waveform was traced for only 75.75% ears. Literature also suggests that only in 60% of individuals with normal hearing SP is traceable (Kitahara, Takeda, Yazawa & Matsubara, 1981). In experimental group also, SP and AP waveforms were recorded. Only twenty two ears out of thirty ears (73.33%) had AP waveforms, however fourteen ears out of thirty ears (46.66%) had SP waveforms. The mean latency and amplitude of SP is

Table 1: Comparison of latency shift of wave V responses obtained from the difference of click alone and different high pass masking noise condition (click + 8 kHz HPM, click + 4 kHz HPM, click + 2 kHz HPM, click + 1 kHz HPM & click + 0.5 kHz HPM) between individuals with normal hearing and Meniere's disease

Different conditions	Z-Value	p-Value
(click+8 kHz HPM) – click alone	-2.87	0.005*
(click+4 kHz HPM) – click alone	-4.43	0.000*
(click+2 kHz HPM) – click alone	-4.71	0.004*
(click+1 kHz HPM) – click alone	-4.74	0.002*
(click+0.5 kHz HPM) – click alone	-4.46	0.002*

* - significant difference at p<0.01

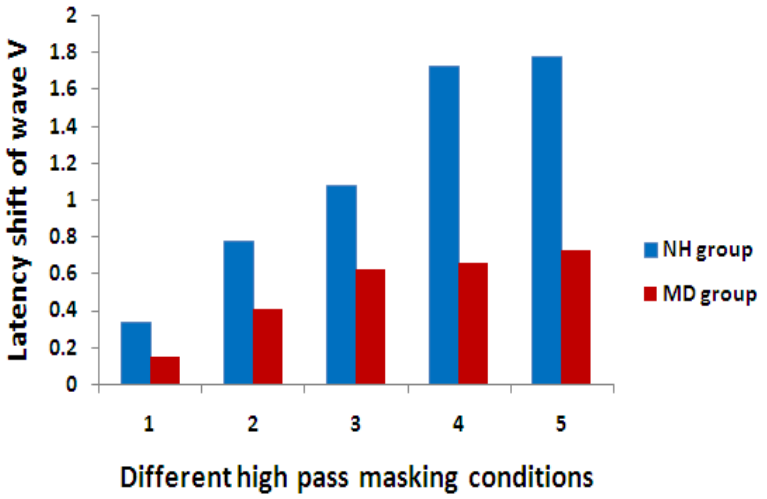

Figure 2: Comparison of latency shift of wave V responses between individuals with normal hearing and Meniere's disease {Note in x-axis: 1 (click+8 kHz - click alone); 2 (click+4 kHz-click alone); 3 (click+2 kHz - click alone); 4 (click+1 kHz-click alone); 5 (click+500 Hz - click alone)}.

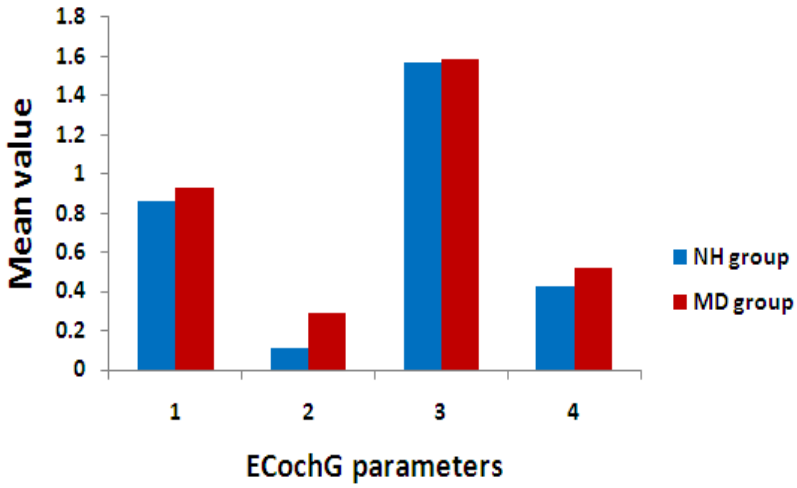

Figure 3: Comparison of mean SP and AP latency and amplitude for individuals with normal hearing and Meniere's disease. {Note in x-axis: 1 (Latency of SP); 2 (Amplitude of SP); 3 (Latency of AP); 4 (Amplitude of AP)}.

0.93 ms and 0.29 µV in experimental group whereas in control group, it was 0.86 ms and 0.11 µV respectively. It indicates that the SP values increase both in terms of latency and amplitude in pathological condition. These findings could be explained by the fact that the SP is thought to result from the sum of the alternating current of the cochlear microphonic, resulting in a direct current shift from the baseline. This shift is exacerbated by asymmetrical basilar membrane movement, as found in hydrops (Conlon & Gibson, 2000). Hence the amplitude of SP in the experimental group is abnormally larger than the control group.

The difference of SP and AP amplitude and latency between the two groups was statistically analyzed using independent sample t-test. Results showed that the SP amplitude is significantly different ($t=-2.40$; $p<0.005$) in both groups whereas no significant difference is found in SP latency ($t=-0.87$; $p>0.05$). However significant difference was reported for both amplitude ($t=-1.05$; $p<0.002$) and latency ($t=-3.20$; $p<0.001$) for AP in both groups. The differences in SP and AP amplitude between both the groups are summarized in Figure 3.

The SP/ AP amplitude ratio was measured separately for each group. The mean SP/AP amplitude ratio for

normal hearing ear was 0.12 whereas for individuals with Meniere's disease, it was 0.28. In the present study, the SP/AP amplitude ratio value in control groups is little lower than the value mentioned in literature using extra tympanic recording (Kitahara et al., 1981; Ferrao, Best & Arenberg, 1983). Researches using either extratympanic recording or transtympanic (Gibson, Moffat & Ramsden, 1977; Kitahara et. al., 1981; Ferrao et al., 1983; Aso et al., 1991; Conlon & Gibson, 2000) accept this fact that SP/AP ratio considerably differentiates Meniere's disease from normal group and same findings are also illustrated from the present study.

The difference in SP/AP amplitude ratio of each group was measured by using Wilcoxon signed rank test. It was found that there is a significant difference ($Z=2.98$, $p=0.003$, significance level at $p<0.05$) in SP/AP amplitude ratio between control and experimental group. Hence with these findings it can be concluded that SP/AP amplitude ratio can differentiate individuals with Meniere's disease from normal hearing.

The correlation in the finding of EcochG & CHAMP in individuals with normal hearing and those with Meniere's disease.

In the present study, by taking all the measurements into consideration from both the tests, CHAMP and EcochG of both group, the correlation was measured using Pearson correlation two-tailed test and it was found that there is a low negative correlation ($r=-0.09$, $n=16$, $p>0.05$) between the two tests for Meniere's disease. Similarly correlation between CHAMP and EcochG was measured using Pearson correlation test for individuals with normal hearing and it was found that there is a low positive correlation ($r=0.09$, $n=20$, $p>0.05$) between the two test.

Hence, it can be concluded from the present study that both the test can be used to diagnose the Meniere's disease as both the test showed significant differences in the findings, but there is low correlation between the two tests. This could be because of differences in recording technique and interpretation of these two tests irrespective of same pathological condition. One limitation with the both tests could be higher degree of hearing loss.

Conclusions

The purpose of the present study was to find the diagnostic value of CHAMP and ECochG in Meniere's disease and also the inter-method reliability in the detection of Meniere's disease using these two methods. These two diagnostic tests (CHAMP & ECochG) were administered on individuals with normal hearing and with Meniere's disease. Through this study it can be concluded that ECochG and CHAMP are effective diagnostic tool and these should be used as assessment tool for the diagnosis of Meniere's disease. ECochG and CHAMP are generally in agreement regarding a patient's diagnosis of Meniere's disease.

On examining the data of the present study, several conclusions can be drawn. Analyzing CHAMP separately one can conclude that it can be used as a diagnostic tool for Meniere's disease. Abnormality in wave V latency can distinguish Meniere's disease but the cutoff latency criteria should be revised so that the sensitivity of the test will improve. ECochG can also be used as a tool to diagnose Meniere's disease as this test has shown. In present study, the significant difference in amplitude and latency of SP and AP waveforms between Meniere's disease and normal ears. Literature has also suggested the significant importance of these tools in the diagnoses of Meniere's disease. Further research can be warranted by taking a cut-off criterion of wave V latency shift less than 1 msec in CHAMP. Bilaterality, ear effect and also the gender effect can be considered in further researches.

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