COCHLEAR HYDROPS ANALYSIS MASKING PROCEDURE IN INDIVIDUALS WITH NORMAL HEARING AND MENIERE'S DISEASE

[1]Prawin Kumar, & [2]Pallavi Peepal

Abstract

Meniere's disease (MD) is an idiopathic inner ear disorder which is an abnormal increase in the volume of the cochlear fluid in the inner ear. The diagnosis of MD is always a difficult task. Cochlear hydrops analysis masking procedure (CHAMP) is one of the modified versions of auditory evoked potential test which helps in diagnosing active MD. CHAMP measures changes if any in latency of wave V in auditory brainstem response, caused by the addition of high pass masking noise to the click stimulus ipsilaterally.

There were two groups of participants; control group (33 ears) with mean age 22.2 years and experimental group (30 ears) with mean age of 32.1 years were selected for the study. CHAMP was recorded for both individuals with normal hearing and with MD. The results revealed that the latency of wave V response increased with the lowering of high pass masking noise cut-off from 8 kHz to 0.05 kHz along with click stimuli in both the groups. However, the shift in latency was seen more in the individuals with normal hearing than MD. The probable reason of minimal shifting in latency of wave V in individuals with MD could be due to undermasking phenomena. In the present study, it was observed that if the cut-off latency value to diagnose MD is considered to be 1 msec rather than 0.3 msec, 62.5% normal hearing ears can be separated from MD ears. Similarly, 88.45% MD ears will have abnormal short latency shift which was confirmed the diagnosis of MD. Hence, it can be concluded that this test can be used to distinguish objectively individuals with Meniere's disease with modification in cut-off criteria.

Key words: *Meniere's disease, auditory brainstem response (ABR), Vertigo, Basilar membrane*

Meniere's disease (MD) can be defined as abnormal increase in the volume of the cochlear fluid 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). Histological studies show that etiology of the MD can be linked to Endolymphatic Hydrops (Hallpike & Cairns, 1938; Horner, 1991).

The diagnosis of Meniere's disease has always been a source of confusion. There is no single test that is definitive for the diagnosis. In literature there are several tests that can be performed to distinguish individuals with Meniere's disease from non-Meniere's disease. These are pure tone audiometry, glycerol tests, auditory brainstem response (ABR), and Electrocochleography (ECochG) to assess Meniere's disease. However, not a single test as mention above is having good sensitivity and specificity. Further, only histological findings can help in the confirmation of a Meniere's disease, obtained through post-mortem biopsies Roeser, Valente, Hosford & Dunn, 2000). Therefore, the administration of appropriate clinical diagnostic tools remains a challenging task. Recently, an audiological test developed with modification in auditory brainstem response technique to diagnose active Meniere's disease with better accuracy known as Cochlear hydrops analysis of masking procedure (CHAMP).

CHAMP is a method which consists of measurement in 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 (Don, Kwong, & Tanaka, 2005). A reasonable assumption in cochlear hydrops is the increase in endolymphatic pressure could increase the stiffness of the basilar membrane. This increased stiffness could increase the speed of travelling wave propagation (Tonnodorf, 1957; Flottorp, 1980). Using ABR latencies obtained with high pass masking noise and assuming a normal frequency place map in the cochlea, Thornton and Ferrell (1991) and Donaldson and Ruth (1996) calculated abnormally high travelling wave velocities in individuals with Meniere's disease. Thus, in individuals with Meniere's disease it is assumed that increased endolymphatic pressure alters basilar membrane's mechanical

[1]Lecturer in Audiology, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: prawin_audio@rediffmail.com, & [2]Clinical Audiologist, Phonak Pvt. Ltd, Delhi.

properties which in terns increase the apparent travelling wave velocity (Don et al., 2005).

Don et al. (2005) studied CHAMP in non-Meniere’s normal hearing individuals (mean age 27-29 years) and Meniere’s disease individuals (mean age 45-57 years). The results revealed that in Meniere’s disease, the masking noise is insufficient for wave V is still present at latency similar to that of wave V in the response to the clicks alone. However, in Non-Meniere’s normal hearing individuals, this under masking component was either absent or significantly delays because of the masking noise. They conclude that this test is able to distinguish objectively active Meniere’s disease in individuals.

In a similar line, De Valck, Claes, Wuyts and Paul (2007) evaluated the applicability and diagnostic value of CHAMP in a series of Meniere’s disease and Non-Meniere’s disease individuals. They observed a sensitivity of 31% and a specificity of 28%. Hence, they concluded that CHAMP does not differentiate individuals with Meniere’s from Non-Meniere’s disease. There was no significant difference between the mean latency difference for Wave V of the Meniere’s disease group (0.43 ms) and the Non-Meniere’s disease group (0.65 ms). However, when Don et al. (2008) reviewed the data collected in the study by De Valack, et al., (2007) found errors in the data collection that lead to misrepresentation and inappropriate conclusion about CHAMP. Hence, the data were reviewed and analyzed again which increase the sensitivity and specificity to 100% and 80% respectively.

Similar to the finding of Don et al. (2005) were obtained in the study by Singh (2010). The later study was aimed to determine the findings of CHAMP in subjects with suspected & confirmed Meniere’s disease & comparing it with the findings of Non-Meniere’s disease individuals. The results revealed the an overall specificity of CHAMP to be 76.6% & sensitivity to be 73.8% when the shift in latency of wave V responses for 0.5 KHz high pass masking noise from click alone were measured. This study also yields the shift in latency of wave V increases with successive decreases in high pass masking noise from 8 KHz to 0.5 KHz but the shift was lesser in individuals with Meniere’s disease.

The diagnostic value of the CHAMP in terms of sensitivity and specificity in individuals with definite Meniere’s disease was assessed by Ordonez-Ordonez et al. (2009). The participants were individuals with normal hearing and with definite Meniere’s disease, and other audio-vestibular diseases or neurologic disorders. Results showed Sensitivity and specificity of CHAMP in individuals with definite Meniere’s disease were 31.3% and 100% respectively. Based on the above finding, they concluded that CHAMP is more helpful in confirming the diagnosis rather than in rejecting it. If definite Meniere’s disease is suspected, an abnormal result confirms the diagnosis. However, a normal result does not rule out the Meniere’s disease.

Kingma and Wit (2010) investigated the usefulness of the CHAMP as an additional diagnostic test in individuals with definite unilateral Meniere’s disease. Results indicated that latency delays could be measured in both ears. The mean latency delay of wave V responses for the affected ears (0.55 ms) differs significantly from that for the unaffected ears (3.36 ms). These authors considered less than 2 msec as cut-off criteria for latency shift to confirm a diagnosis of Meniere’s disease in CHAMP.

From the above literature, it can be construed that there are different views about CHAMP cut-off criteria for the diagnosis of Meniere’s disease. There are differences observed in sensitivity and specificity of CHAMP in different studies. Hence, there is need to check the utility of CHAMP in Indian population.

Need for the Study

There are differences in the outcome of CHAMP findings in individuals with Meniere’s disease as well as in normal hearing individuals. In recent studies De Valck, et al. (2007) concluded that due to low sensitivity and specificity of CHAMP it cannot be used as a clinical tool to diagnose individual with Meniere’s disease. However, other studies oppose these finding and found that CHAMP findings are consistent with the excellent sensitivity and specificity (Don, Kwong, & Tanaka, 2005; Kingma & Wit, 2010; Singh 2010). Hence, there is a need for further study to correctly distinguish individuals with Meniere’s disease from normal hearing individuals on the basis of the findings of CHAMP.

Aim of the study

To check the outcome of CHAMP whether it is really a promising tool in diagnosis of individuals with Meniere’s disease. Further, to find the diagnostic value of CHAMP in Meniere’s disease in relation to normal hearing non-Meniere’s disease in Indian population.

Method

The present study was carried out with the aim to study the wave V latency shift in individuals with normal hearing and with Meniere's disease. To conduct the study, the following method was used to record the CHAMP in normal hearing individuals and individuals with Meniere's disease.

Participants

There were two groups of participants, individuals with normal hearing served as control group and individuals with Meniere's disease served as experimental group. In control group, 33 ears (10 females & 7 males) with mean age 22.2 years were selected. However in experimental group, 30 ears (9 females & 8 males) with mean age 32.1 years were selected. The less number of participants in experimental group was because of availability of participants till the completion of data. A detailed case history was taken for each participant in each group. Individuals in both the groups with any neurologic deficit were excluded from the study. Oral consent was taken from all the participants.

Participant selection criteria

In control group, all participants had pure tone thresholds less than 15 dBHL at octave frequencies between 250 Hz to 8000 Hz in both the ears. The overall mean pure tone average was 6.01 dBHL. They had normal middle ear functioning as indicated by Immittance evaluation.

In experimental group, Individuals were having their pure tone thresholds in the range of Mild-to-Moderate (26-55 dBHL) at octave frequencies between 250 Hz to 8000 Hz. The overall mean pure tone average of all individuals was 35.69. They had no indication of middle ear pathology, as per immittance finding. Auditory Brainstem Response and otoacoustic emissions were done on each individual, to rule out retro-cochlear pathology and those individuals indicating retro-cochlear 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). A detailed case history was taken for each individual and those individuals who fulfilled the above mentioned criteria along with the ENT provisional diagnosis of Meniere's disease were included.

Instrumentation

A calibrated two channel clinical audiometer (OB-922) with TDH-39 headphones and bone vibrator BC-71 was used for pure tone audiometry. A calibrated immittance meter (GSI-TYMPSTAR) was used to assess the middle ear functioning of all the participants. Otodynamic ILO-V6 was used to record transient evoked otoacoustic emissions. Bio-logic Navigator Pro AEP (version 7.0) system was used to record and analyze the waveform of ABR. Bio-logic Broadband inserts earphones were used for CHAMP recording as these inserts have the extended high frequency response needed to acquire valid data for CHAMP Recording.

Test Environment

All the measurement was carried out in an acoustically treated double room situation. The ambient noise level was within the permissible level according to ANSI (1991).

Procedure

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 to 8000 Hz for air conduction and between 250 Hz to 4000 Hz 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, 1000 Hz, 2000 Hz, and 4000 Hz ipsilaterally and contralaterally. TEOAEs recording were done 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. Click-evoked ABR recording were done to rule out retro-cochlear pathology.

Cochlear Hydrops Analyses Masking Procedure (CHAMP)

For recording CHAMP, individuals were made to relax on reclining chair. The site of electrode placement was prepared with skin preparation gel. Silver chloride (AgCl) electrodes with conducting gel were used for recording CHAMP. The recording electrodes were placed at the upper forehead for non-inverting electrodes and at both mastoid for inverting and ground electrodes respectively. The recorded potential was amplified and band pass filtered at 100 – 3000 Hz. A 16 msec analysis window was used.

Each averaged response was elicited by more than 5000 stimuli repetitions; each condition was repeated once, yielding test and re-test traces. The stimuli were presented monaurally through broadband insert earphones. It was ensured that impedance for each electrode was less than 5 kΩ.

CHAMP responses were obtained to 6 stimulus conditions i.e. clicks presented alone and clicks presented with ipsilateral high pass noise filtered at 8000, 4000, 2000, 1000, & 500 Hz. Hence, there were minimum 12 recording done for one ear (click alone, click + 8000 Hz HPM, click + 4000 Hz HPM, click + 2000 Hz HPM, click + 1000 Hz HPM & click + 500 Hz HPM). To check reliability minimum two times recording were done at each stimulus condition. The broad band pink noise was used at 60 dBnHL for ipsilateral masking of click stimuli.

Result and Discussion

In this section, the results obtained from the present study are discussed. The data obtained was subjected to statistical analysis using the SPSS (version 17.0) software. The results were analyzed to see how the latency shift of wave V responses for click alone and wave V for click + 0.5 kHz high pass masking noise (HPM) in both the groups. Further, analysis were done to measure the changes in latency of wave V for click alone and wave V for different frequencies HPM condition in both the groups. The above measurements were analyzed using descriptive statistics, Independent sample t-test and Wilcoxon signed rank test. Descriptive statistics was done to measure the significant difference between the values obtained from each group. The Wilcoxon sign rank test was administered to check whether there is a significant difference in CHAMP recording between individuals with normal hearing (non-Meniere's disease) and with Meniere's disease.

CHAMP in Individuals with Normal Hearing and with Meniere's disease

In control group, CHAMP was administered on total number of 33 ears (16 right and 17 left ears). 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. All ears had wave V responses in click alone, click + 8 kHz, click + 4 kHz and click + 2 kHz HPM condition. However, 29 ears out of 33 ears (87.87 %) had wave V responses in click + 1 kHz HPM condition and only 24 ears out of 33 ears (72.72 %) had wave V response in click + 0.5 kHz HPM condition. The absence of wave V response in individuals with normal hearing could be because of undermasking condition. As literature suggests, even individuals with normal hearing required higher level of noise than the average which would be slightly under masked (Don, et al., 2005). The mean and the standard deviation of absolute latency of wave V response obtained for all conditions in individuals with normal hearing and with Meniere's disease are given in Table-1.

Table 1: *Mean and standard deviation (SD) of absolute latency of wave V responses in both groups*

	Individuals with Normal hearing			Individuals with Meniere's disease		
	No. of ears	Mean (msec)	SD	No. of ears	Mean (msec)	SD
Click alone	33	5.66	0.24	30	5.83	0.41
Click+8 kHz	33	6.01	0.30	30	5.99	0.43
Click+4 kHz	33	6.44	0.36	30	6.24	0.46
Click+2 kHz	33	6.74	0.54	30	6.44	0.59
Click+1 kHz	29	7.36	1.11	30	6.49	0.78
Click+0.5 kHz	24	7.44	1.34	26	6.50	0.94

In experimental group, 30 ears (16 left ear and 14 right ears) were tested for CHAMP in which 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. All ears had wave V responses in click alone, click + 8 kHz HPM, click + 4 kHz HPM and click + 2 kHz HPM, click + 1 kHz HPM condition but wave V responses for click + 0.5 kHz HPM condition was found only in 26 ears out of 30 ears in this group. That indicates 86.66% Meniere's ears (72.72 % in contrast with normal ears) had wave V responses in click + 0.5 kHz HPM condition. The absence of wave V responses at 500 Hz HPM is sometimes difficult to obtain while recording CHAMP. It could be because of noise contamination or presence of post-auricular muscles artefact at click with ipsilateral 500 Hz HPM noise. Furthermore, sometimes in Meniere's disease individuals, the amplitude is so low at lower frequencies in high pass masking noise condition it is difficult to interpret wave V response. Also, as literature suggests there may be multiple points or peaks in an undermasked condition, probably due to noise contamination (Don et al. 2007). Hence, the present study too could not able to trace wave V at lower frequencies high pass masking noise due to above mentioned reason (Figure 1).

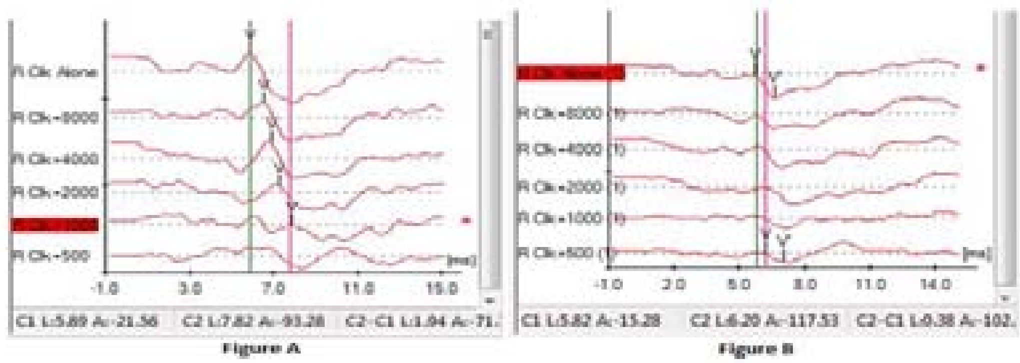

Figure 1: *A sample waveform representing CHAMP in individuals with normal hearing (Figure-A) and Individuals with Meniere's disease (Figure-B)*

Table-1 clearly shows that as the cut-off frequency of the masking noise decreases, the latency of wave V increases since the whole basilar membrane is masked from basal to apical end. Further, this change in the peak could be expected because of the factors related to the travelling wave delay, the peak latency of the response increases as the area of the unmasked cochlea is successively restricted to lower frequencies (Don et al., 2005). The mean latency in control group for click alone condition was 5.66 msec whereas same increased up to 7.44 msec for the click + 0.5 kHz HPM condition.

Study by Singh (2010) showed mean latency of wave V responses for click alone as 5.70 msec and for click + 0.5 kHz HPM condition as 8.70 msec. The present study also showed similar findings for click alone and click + 0.5 kHz HPM condition. Furthermore, it is evident from Table-1 that the standard deviation (SD) is increasing as high pass masking noise is reducing which shows variability is more at low frequency high pass masking noise conditions.

In control group, the latency shift of wave V response from click alone condition to different high pass masking noise condition was determined by subtracting the latency of wave V response of click alone condition. The minimum mean latency shift was observed in click + 8 kHz HPM condition (0.35 msec), and the maximum mean latency shift (1.78 msec) for click + 0.5 kHz HPM condition. Previous studies (Don, et al., 2005; Singh, 2010) also illustrate the similar findings. The mean and the standard deviation of wave V latency shift for click alone and in different high pass masking noise conditions in individuals with normal hearing are summarized in table 2.

In experimental group, the latency shift in wave V response was observed for different high pass masking noise conditions, but it was observed that the latency shift was lesser than individuals with normal hearing group. The minimum mean latency shift was seen for click + 8 kHz HPM condition, 0.15 msec (0.35 msec in control group), and the maximum mean latency shift, 0.74 msec (1.78 msec in control group) was seen for click + 0.5 kHz HPM condition.

The present finding is in consonance with previous finding in literature (Don et al., 2005; De Valck et al., 2007; Ordonez-Ordonez et al., 2009; Kingma & Wit, 2010; Singh, 2010) which concludes that the latency shift of wave V is lesser in individuals with Meniere's disease as compared to individuals with normal hearing (Table 2).

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. The findings of the comparisons are given in the Table 3.

Table 2: *Mean and standard deviation (SD) of wave V latency shift for click alone and different HPM noise condition in both groups*

	Individuals with Normal hearing			Individuals with Meniere's disease		
	No. of ears	Mean (msec)	SD	No. of ears	Mean (msec)	SD
Click+8 kHz - Click alone	33	0.34	0.21	30	0.15	0.32
Click+4 kHz - Click alone	33	0.78	0.32	30	0.41	0.40
Click+2 kHz - Click alone	33	1.08	0.51	30	0.62	0.53
Click+1 kHz - Click alone	29	1.72	1.06	30	0.66	0.77
Click+0.5 kHz - Click alone	24	1.78	1.28	26	0.73	0.94

The comparison in latency shift of wave V response for different HPM noise conditions with wave V response for click alone condition between both groups

Table 3*: Comparison of latency shift of wave V responses obtained from the difference of click alone and different HPM noise condition between both groups*

Different conditions	p-value
(click + 8kHz HPM) – click alone	0.005**
(click + 4kHz HPM) – click alone	0.000***
(click + 2kHz HPM) – click alone	0.004**
(click + 1 kHz HPM) – click alone	0.002**
(click + 0.5 kHz HPM) – click alone	0.002**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

From table-3 it can concluded that two groups i.e., control and experimental, are significantly different with respect to wave V latency shift in different noise conditions. This difference is expected as the physiology of inner ear differs in individual with normal hearing and 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 leads 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.

Several researchers recommended the difference in latency shift from no masking noise condition (click alone) to maximum masking noise condition (click + 0.5 kHz) as the diagnosis criteria for Meniere's disease (Don et al., 1998; Don et al., 2005; De Valck et al., 2007; Ordonez-Ordonez et al., 2009; Singh, 2010). Similar comparison is done in the present study also to measure if the significant difference present between the two groups. Results of the present study revealed that there is a significant difference (Table 3) in the latency shift of wave V for click alone and click +0.5 kHz HPM conditions between the two groups.

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 as compare to Meniere's ear.

Don et al. (2005) reported that Meniere's disease is confirmed if the wave V latency shifts in click + 0.5 kHz HPM from click alone condition is less than 0.3 msec but if it is more than 0.3 msec, Meniere's disease will considered to be absent. In the present study only seven Meniere's diseased ears out of thirty ears showed wave V latency shift less than 0.3 msec. which accounts only 23.3 % ears with Meniere's disease as per Don et al (2005) criteria. On the other hand, Kingma and Wit (2010) reported that latency shift with less than 0.3 ms diagnostic criterion, the sensitivity of the CHAMP reduces. Therefore they suggested using 2 msec as cut-off criterion the sensitivity of the CHAMP can be increases.

Similarly, in the present study if the cut-off latency value to diagnose active Meniere's disease is considered to be 1 msec 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 active Meniere's disease. Hence present study is in consonance of Kingma and Wit (2010) finding.

Conclusions

The purpose of the present study was to find the diagnostic value of CHAMP in detection of Meniere's disease. It was administered on individuals with normal hearing and with Meniere's disease. The analyses was done for both the groups for latency shift of wave V for click alone and wave V for different HPM noise.

It can be concluded that CHAMP are effective diagnostic tool and these should be used for the diagnosis of active Meniere's disease. However, modification in the cut-off value to be incorporated. In the present study, it is observed that if the cut-off latency value to diagnose MD is considered to be 1 msec rather than 0.3 msec, 62.5% normal hearing ears can be separated from MD ears. Similarly, 88.45% MD ears will have abnormal short latency shift which was confirmed the diagnosis of MD. Hence, it can be concluded that this test can be used to distinguish objectively individuals with Meniere's disease with modification in cut-off criteria.

References

American National Standard Institute (1991). *Maximum permissible ambient noise for audiometric test rooms.* ANSI S3.1-1991. New York.

Committee on Hearing and Equilibrium (1972). Meniere's disease: criteria for diagnosis and evaluation of therapy for reporting. *Transactions of the American Academy of Ophthalmology & Otolaryngology, 76,* 1462-1464.

De Valck, C. F. J., Claes, G. M. E., Wuyts, F. L., & Paul, H. (2007). Lack of diagnostic value of high-pass noise masking of auditory brainstem responses in Meniere disease. *Otology and Neurotology, 28,* 700-707.

Don, M., Kwong, B., & Jos, J. (1998). The effect of Sensory Hearing Loss on Cochlear Filter Times Estimated from Auditory Brainstem Response Latencies. *Journal of Acoustics Society of America, 104,* 2280- 2288.

Don, M., Kwong, B., & Tanaka, C. (2005). A Diagnostic Test for Meniere's disease and Cochlear Hydrops: Impaired High Pass Noise Masking of Auditory Brainstem Response. *Otology and Neurotology, 26,* 711-72.

Don, M., Kwong, B., & Tanaka, C. (2007). An Alternative Diagnostic Test for Active Meniere's disease and Cochlear Hydrops Using High-Pass Noise Masked Responses: The Complex Amplitude Ratio. *Audiology and Neurotology,* 12, 359–370.

Donaldson, G. S. & Ruth, R. A. (1996). Derived-band auditory brainstem response estimates of travelling wave velocity in humans: II. Subjects with noise-induced hearing loss and Meniere's disease. *Journal of Speech and Hearing Research, 39,*534-545.

Flottorp, G. (1980). Cochlear non linearity in Meniere's syndrome. *Hearing Research, 2,* 407-409.

Hallpike, C. S., & Cairns, H. (1938). Observations on the Pathology of Meniere's Syndrome. *Proceedings of the Royal Society of Medicine, 31,* 1317-1336.

Horner, K. (1991). Old theme and new reflections: Hearing impairment associated with endolymphatic hydrops. *Hearing Research, 52,* 147-156.

Kingma, C. M., & Wit, H. P. (2010). Cochlear Hydrops Analysis Masking Procedure results in patients with unilateral Meniere's disease. *Otology & Neurotology, 31,* 1004-1008.

Ordonez-Ordonez, L. E., Rojas-Roncancio E., Hernandez-Alarcon, V, Jaramillo-Safon, R., Prieto-Rivera, J., Guzman-Duran, J., Lora-Falquez, J., Escobar, M. & Angulo-Martinez, E. S. (2009). Diagnostic test validation: cochlear hydrops analysis masking procedure in Meniere's disease. *Otology and Neurotolology, 30,* 820-825.

Ries, D. T., Rickert, M., & Schlauch, R. S. (1999). The peaked audiometric configuration in Meniere's disease: Disease related? *Journal of Speech, Language, and Hearing Research, 42,* 829-842.

Roeser, R. J., Valente, M., & Hosford-Dunn, H. (2000). *Audiology Diagnosis.* New York, USA: Thieme Medical Publishers.

Sajjadi, H., & Paparella, M. M. (2008). Meniere's disease. *The Lancet, 372,* 406- 414.

Singh, N. (2010). *Findings of Cochlear Hydrops Analysis Masking Procedure in subjects with suspected and confirm Meniere's disease.* Unpublished Master Dissertation submitted to the University of Mysore, India.

Thornton, A. R. D. & Farrell, G. (1991). Apparent travelling wave velocity changes in cases of endolymphatic hydrops. *Scandavian Audiology, 20,* 13-18.

Tonnodorf, J. (1957). The mechanism of hearing loss in early cases of Endolymphatic hydrops. *Annals of Otology Rhinology and Laryngology, 66,* 766-784.