# THE OUTCOMES OF SPEECH AUDIOMETRY IN VARIOUS STAGES OF MENIERE'S DISEASE: A RETROSPECTIVE STUDY

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## CERTIFICATE

This is to certify that this Dissertation entitled '**The outcomes of speech audiometry in various stages of Meniere's disease: A retrospective study**' is the bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student Registration Number:20AUD023. This has been carried out under the guidance of the faculty of the institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru
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## CERTIFICATE

This is to certify that this master's Dissertation entitled **'The outcomes of speech audiometry in various stages of Meniere's disease: A retrospective study'** has been prepared under my supervision and guidance. It is also being certified that this Dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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## DECLARATION

This is to certify that this Dissertation entitled '**The outcomes of speech audiometry in various stages of Meniere's disease: A retrospective study**' is the result of my own study under the guidance of Dr. Niraj Kumar Singh, Associate Professor, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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## ABSTRACT

Meniere's disease is mainly a labyrinthine pathology; however, other labyrinthine pathologies such as NIHL and ototoxicity have shown that neural involvement begins to occur with disruption of the hair cell within the cochlea. This phenomenon of neural involvement has been linked to the "dying back" of the neurons due to the absence of inputs from the hair cell. Considering the later stage of Meniere's disease, which includes considerable hearing loss, a similar "dying back" of the neuron might be expected, leading to poor performance on speech audiometry; however, this remains unexplored. Hence, the study aimed to investigate the effect of Meniere's disease and its stages on the outcome of speech audiometry. Two groups of participants (age range: 18-60 years) were considered, one with Meniere's disease (N=89) and the other with non-Meniere's cochlear hearing loss (N=108), and they were classified into four stages based on the pure tone average thresholds. The comparison of SIS, SRT and SRT-PTA difference between Meniere's disease and cochlear hearing loss group showed significant difference only at stage III. This indicates pathology restricting to the cochlea till stage II and a beginning of neural involvement due to dying back in stage III of Meniere's disease group.

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# CHAPTER I

## INTRODUCTION

Episodic vertigo, fluctuating hearing loss, tinnitus, aural fullness, nausea and/or vomiting represents a symptom complex associated with classical cases of Meniere's disease (AAO-HNS, 2015). Other symptoms may include intolerance to loud sounds and diplacusis (Paparella, 1983).

The exact etiologic basis of Meniere's disease is unknown. There are several proposed etiologies for Meniere's disease, including genetic anomalies, developmental defects, infections, trauma (Physical or acoustic), syphilis, allergy, and autoimmune disease (Paparella, 1991; Paparella & Djalilian, 2002). Histopathological studies on Meniere's disease have shown clear evidence of an increase in the amount of endolymph within the cochlear duct and the vestibular end organs (Rauch et al. 1989). This increased amount of endolymph is due to altered absorption of endolymph by the endolymphatic duct or sac (Paparella, 1991) or may be due to increased endolymph secretion (Hallpike & Cairns, 1938). The explanations for the pathophysiology of Meniere's disease symptoms are provided on mechanical and chemical grounds. Some believe that rupture of Reissner's membrane, which allows for intermixing of endolymph with perilymph, causes the symptoms (Schuknecht, 1968). However, a review of human temporal bones in well-documented cases of Meniere's disease has shown no evidence of rupture in nearly two-thirds of patients (Paparella, 1991; Sperling et al., 1993); hence other researchers suggested that alteration in permeability of the membrane leads to disturbance in the balance of ions as the primary etiologic factor in creating symptoms (Vosteen & Morgenstern 1986, Paparella 1991.)

The incidence and prevalence vary across studies. The incidence of Meniere's disease is found to be ranging between 4.3 to 46 persons per 100000 populations annually (Bruderer et al., 2017; Jan Stahle et al., 1978; Williams et al., 1999; Wladislavosky-Waserman et al., 1984). The prevalence was found to be as low as 43.2 per 100,000 population and as high as 513 per 100000 population across various studies (Havia et al., 2005; Radtke et al., 2009; Williams et al., n.d.; Wladislavosky-Waserman et al., 1984). In one of the tertiary care hospitals in Mumbai, the incidence of Meniere's disease was found to be 0.61% of all the patients tested for hearing impairment (Penwal & Valame, 2021). Usually, Meniere's disease presents with unilateral symptoms (House et al., 2006); however, the incidence of bilateral Meniere's disease increases with the duration of the disease, reaching 40% after 15 years (Morrison, 1976). Meniere's disease is most commonly seen in adults with an average onset in the fourth decade, with peak onset between 50 to 59 years of age and symptoms appearing between the ages of 20 to 60 years. (Bruderer et al., 2017; Da Costa et al., 2002). Many studies have shown that females are affected nearly three times more than males (Alexander & Harris, 2010; Bruderer et al., 2017). The frequency of occurrence of Meniere's disease in the right and the left ear is nearly (Da Costa et al., 2002).

There are several subjective and objective tests like Pure Tone Audiometry, Auditory Brainstem Response (ABR), Glycerol test, Electrocochleography (ECochG), Electronystagmography, Cochlear Hydrops Analysis Masking Procedure (CHAMP), etc. to measure the extent of Meniere's disease (Pallavi, 2011). But the present study focuses on Pure tone audiometry and speech audiometry findings in individuals with Meniere's disease and Cochlear hearing loss.

Pure tone audiometry is a behavioural test used to measure hearing sensitivity, and it is one of several tests used for evaluating persons with Meniere's disease. Based on pure tone thresholds, the severity of the hearing loss is obtained. In fact, the result of pure tone audiometry is used to classify Meniere's disease into four different stages based on thresholds at 500 Hz, 1000 Hz, 2000Hz and 3000 Hz; stage I is pure tone average less than or equal to 25 dB HL (≤25 dB HL), Stage II includes pure tone average from 26 to 40dB HL (26 to 40 dB HL), Stage III include from 41 to 70 dB HL (41 to 70 dB HL), and Stage IV include greater than or equal to 70 dB HL ( ≥71 dB HL) [Equilibrium Committee of the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS), 1995]. Meniere's disease is characterized by varying degrees of hearing loss. Usually, the hearing loss stabilizes at a moderate to severe degree, and the hearing loss is rarely profound or total (Belinchon et al., 2011; Zhang et al., 2016).

A widely used clinical tool other than pure tone audiometry is speech audiometry. Speech audiometry is a more valid tool to assess hearing in daily life than pure tone audiometry. Since speech audiometry has higher face validity than pure tone audiometry (Bess et al., 1979), it is an integral part of the basic audiometric evaluation. Typically, speech audiometric evaluation includes tests such as speech recognition thresholds (SRT) and speech identification scores (SIS).

The speech identification score, also called the speech discrimination score, is an important test in the audiological test battery, as it points out the patient's ability to hear and understand speech at typical conversational levels. This test is carried out using phonetically balanced (PB) words. A lower score indicates poor speech intelligibility, and

a high score indicates better speech intelligibility. It is more affected in cases with neural involvement than a pure cochlear pathology (Bess et al., 1979; Pauler et al., 1986).

The SRT, as defined by the ASHA guidelines, is the minimum hearing level at which an individual can recognize 50% of the speech material (ASHA, 1988). SRT testing is usually done with spondee words. The difference in dB HL between SRT and PTA (SRT-PTA difference) is reported to be ± 12dB (Kim et al., 2016); however, this correlation is expected to be absent in functional hearing loss and cases with neural involvement. The dissociation of SRT and PTA has been reported in Meniere's disease with duration (Garaycochea et al., 2022).

Few studies have investigated the correlation between Meniere's disease and speech audiometry results. In the study by Mateijsen et al. in 2001, a good agreement between pure tone average and SRT was observed in cases with Meniere's disease (Mateijsen et al., 2001). The majority of studies report speech identification scores similar to other cochlear pathologies (Mateijsen et al., 2001). However, low discrimination scores have also been reported in Meniere's disease (Schuknecht, 1963; Walsh, 1953). Hood and Poole in 1996 reported loudness discomfort level in Meniere's disease ear to be the same as normal hearing ear, indicating recruitment in Meniere's disease ear; however, cases with conductive hearing loss and 8$^{th}$ nerve lesions demonstrated higher LDL than normal hearing (Hood & Poole, 1966).

## Need for the study

The speech audiometry results depend on several factors related to hearing, such as type of hearing loss and degree of hearing loss. As the degree of hearing loss increases, the performance on speech audiometry also deteriorates (Carhart, 1952). Considering that

the staging of Meniere's disease is based on the degree of pure tone hearing thresholds, there should be a proportional decrease in the performance of the speech audiometry from Stage I to stage IV (Mateijsen et al., 2001)

Meniere's disease is primarily a disease affecting the labyrinth (Paparella, 1991). Given this, the hearing loss should be primarily cochlear. However, with disruption of the hair cell within the cochlea, neural involvement has been shown in other pathologies such as noise induced hearing loss (NIHL) and ototoxicity (Spoendlin, 1975). This phenomenon of neural involvement has been linked to the "dying back phenomenon" or "retrograde degeneration" of the neurons due to the absence of inputs from the hair cell (Shibata et al., 2011). In NIHL and ototoxicity, this dying back is usually associated with late stages when the degree of hearing loss has increased considerably, and virtually all frequencies have been involved (Spoendlin, 1975).

Considering that stages III and IV in Meniere's disease include hearing loss of moderate and severe degrees, a similar "dying back" of the neuron might be expected to cause an additional neural component to the otherwise purely cochlear pathology. Since the dying back phenomenon is associated with neural involvement, poor speech audiometric results can be expected at later stages of Meniere's disease. However, there is a dearth of studies showing such an occurrence in the case of Meniere's disease.

## Aim

The above discussion points to the dearth of research studying the dying back phenomenon in Meniere's disease. Given this, the present study attempts to explore such dying back phenomenon in cases with Meniere's disease by employing speech audiometric results as the indicator of the dying back phenomenon. Therefore, the present study aims

to investigate the effect of stages of Meniere's disease on the outcome of speech audiometry.

## Objectives

1. To examine the association between the stages of Meniere's disease and the outcome on speech audiometry (SRT, SIS and SRT-PTA difference).

2. To compare speech recognition thresholds between Meniere's disease group and the cochlear hearing loss group across various stages.

3. To compare speech identification scores between Meniere's disease group and the cochlear hearing loss group across various stages.

4. To compare SRT-PTA difference between Meniere's disease group and cochlear hearing loss group across various stages.

# CHAPTER II
# REVIEW OF LITERATURE

Meniere's disease is a cochlear pathology described by symptoms such as episodic vertigo, fluctuating hearing loss, tinnitus, aural fullness, nausea and/or vomiting (AAO-HNS, 2015). It is believed to be caused by over-accumulation of endolymph in the inner ear, which may occur due to malabsorption of endolymph by the endolymphatic sac or duct (Paparella, 1991) or overproduction of endolymph (Hallpike & Cairns, 1938). This elevated endolymph level eventually results in either rupturing the Reissner's membrane, causing intermixing of endolymph and perilymph fluid or a change in permeability of the Reissner's membrane because of distension caused by elevated fluid level (Paparella, 1991; Sperling et al., 1993). Both of these activities could result in chemical contamination of endolymph, leading to injury to hair cells of the cochlea and vestibular system. This change in the balance of ions between endolymph and perilymph fluid or intermixing of perilymph and endolymph fluid creates the above mentioned symptom complex. While the pathophysiology of Meniere's disease involves injury to inner ear structures, a few studies have shown evidence for coexisting neural involvement in these cases. Neural involvement is not the leading cause of hearing loss in Meniere's disease, and rather it is said to occur due to the loss of cochlear structures themselves (Garaycochea et al., 2022; Nadol & Thornton, 1987).

Many previous microscopic studies of temporal bone have shown the progressive loss of the cochlear nerve followed by the destruction of the organ of Corti in conditions like ototoxicity (Kong et al., 2010a; Nie et al., 2015; Spoendlin, 1975), presbycusis (Pauler et al., 1986), NIHL (Spoendlin, 1975), sudden deafness (Ishii & Toriyama, 1977; H. F. Schuknecht & Donovan, 1986), including Meniere's

disease (Nadol et al., 1995; Nadol & Thornton, 1987). This progressive loss of the cochlear nerve is referred to as the "retrograde degeneration" or "dying back" of neurons. This retrograde degeneration has been theorized as being caused by the destruction of inner hair cells, injury to the peripheral terminal processes of neurons below the hair cells (Spoendlin, 1984), the destruction of pillar and Dieters cells, or a combination of these insults (Zimmermann et al., 1995).

**2.1 Histological studies showing neural involvement in Meniere's disease**

Nadol and Thornton (1987) did a temporal bone examination of an 83-year-old male diagnosed with Meniere's disease using light and electron microscopy. The patient had the first attack of vertigo four years before his death. The patient was diagnosed with moderate to moderately severe hearing loss in Meniere's disease ear (Left ear). The non-Meniere's disease ear (right ear) had normal hearing till 1kHz with an elevated threshold of 30 dB HL at 2kHz, 55 dB HL at 4kHz, and 70 dB HL at 8kHz. This elevated threshold at higher frequencies in the right ear was believed to be a result of ageing. The patient had a speech discrimination score of 34% in the Meniere's ear and 90% in the non-Meniere's ear. In this study, hair cells, dendritic fibres in the osseous spiral lamina, spiral ganglion cells, afferent and efferent endings, and afferent synaptic contacts were all morphometrically analyzed. The results were then compared between both Meniere's and non-Meniere's ears. The results showed a striking difference in the number of afferent endings (number of neurons with at least one synaptic connection with hair cell) and the synaptic contacts with hair cells between Meniere's and non-Meniere's ears. The number of afferent endings in Meniere's disease ear was 3.1 endings/cell, whereas it was 11.1 endings/cell in non-Meniere's disease ear. Similarly, for outer hair cells, the number was 3.1 endings/cell

and 7.6 endings/cell for Meniere's and non- Meniere's disease ear, respectively. The number of synaptic contacts was 4.4 contacts/cell in Meniere's disease ear and 20.7 contacts/cell in the non-Meniere's disease ear. This study demonstrates neural involvement in the ear with Meniere's disease and the absence of neural involvement in the non-Meniere's ear. This finding also correlated with the lower discrimination scores in the Meniere's ear (Nadol & Thornton, 1987). Although this was the first human study to show the neural involvement in Meniere's disease, the findings were from a single case. Additionally, the contribution of ageing cannot be completely ruled out.

The evidence from a few animal studies done by inducing endolymphatic hydrops showed that there is an involvement of afferent neurons in endolymphatic hydrops (Nadol et al., 1995). Megerian, in 2005, did a histological study on female albino guinea pigs by surgically inducing endolymphatic hydrops. The result showed significant deterioration of the cochlear nerve (reduced diameter) after inducing endolymphatic hydrops (Megerian, 2005). While a neural involvement was demonstrated in endolymphatic hydrops, the animal model not always encourages generalization to human beings. Additionally, the study does not show the functional impact of neural involvement in the hydropic ears.

Pure tone and speech audiometry are the basic audiological tests for all auditory disorders. The results of pure tone audiometry help diagnose the severity or degree of hearing loss, whereas the outcomes of speech audiometry give information on the patient's speech understanding ability. It is well established that these tests can be used to underscore the functional impact of neural involvement in several disorders. Studies on pure tone audiometry and speech audiometry can therefore

provide a better picture of the impact of neural involvement in ears with Meniere's disease.

### 2.2 Pure tone audiometry in Meniere's disease

Fluctuating and progressive hearing loss is observed in Meniere's disease during the initial stage, which usually stabilizes in later stages. In most cases, hearing loss at later stages is irreversible and stabilizes at a moderate to severe level, and the loss is rarely profound (Belinchon et al., 2011; Zhang et al., 2016).

In a retrospective study, 115 cases with unilateral Meniere's disease were considered. They included patients diagnosed from August 2013 to November 2015 in the age range 17 to 70 years with an average age of 47.9. They did the staging of Meniere's disease based on a pure tone average of frequencies 0.5, 1, 2, and 3kHz. The results showed the mean pure tone average in the Meniere's disease ear of 45.24. Further, 64 out of 115 (55.65%) were in Stage III, 24 (20.87%) were in Stage II, 18 (15.65%) were in Stage I, and 9 (7.82%) were in Stage IV. This shows the number of patients in Stage IV (hearing loss greater than 70 dB HL) was the least, and the majority were in stage III (Zhang et al., 2016).

Many other studies have also shown that the mean hearing loss in Meniere's disease is about 50-60 dB HL. A majority of these studies had a fair number of participants of 12 (Okuno & Watanabe, 1990), 161 (Friberg et al., 1984), 334 (Enander & Stahle, 2009), and 356 (J Stahle, 1976).

From the above studies, we can conclude that in most Meniere's disease cases, hearing loss stabilizes in the moderate to moderately severe range (Stage III). Although there are studies on staging of Meniere's disease based on Hearing loss,

speech audiometry across these stages has not been studied, which would give a better picture of functional impairment because of Meniere's disease across the different stages than the pure tone audiometry alone.

### 2.3 Speech recognition threshold and speech identification score in Meniere's disease

The results of speech audiometry help predict a neural involvement, although the confirmation can only be done using histopathological work-up. However, histopathological work-up is not viable in the day-to-day clinical practice, and they are mostly done post-mortem. Therefore, speech audiometry remains a clinical alternative to understanding neural involvement in Meniere's disease in live people. A proof of this was shown by Pauler et al. in 1986, who did a histological examination of 28 human cochleae of elderly adults with recorded discrimination scores. A correlation was made between neuronal population and discrimination scores. The discrimination score was directly correlated with the innervation density (Pauler et al., 1986). Therefore, the speech discrimination score can be used as an indicator of nerve pathology.

In a study by Stahle (1976), pure tone audiometry was done on 356 participants, and speech audiometry was done on 234 participants. The average SRT found was 62 dB HL, which agrees with the mean pure tone average of 55 dB HL (of 500, 1k, 2k and 3k Hz). This study reported mean discrimination scores of 52% (J Stahle, 1976). Speech discrimination was studied by Fribrtg et al. (1984) on 161 participants with Meniere's disease showed a speech discrimination score of 50 to 60% (Friberg et al., 1984).In both studies, a reduced discrimination score was observed in, suggesting possible neural involvement in Meniere's disease.

Mateijsen et al. (2001) studied speech audiometry in Meniere's disease. Their study included 111 individuals with Meniere's disease with a mean age of 50 years. A good correlation was found between average hearing loss, speech recognition threshold and discrimination scores. Also, the speech discrimination score was comparable to the expectation based on pure tone loss (Mateijsen et al., 2001). In this study, a good correlation was present between pure tone and speech audiometry findings, which adds to the evidence of the absence of neural involvement in Meniere's disease.

Okuno & Watanabe (1990) studied speech discrimination scores in 12 ears having Meniere's disease. The duration of the disease ranged from three years to thirty years. The patients included in this study had no fluctuation of hearing loss at least six months prior to the testing. The thresholds of all the 12 ears selected were at about 60 dB HL. The speech discrimination scores ranged from 35% to 90%. Word discrimination curves were normal for 9 ears; rollover was present in 3 ears indicating neural involvement (Okuno & Watanabe, 1990). The data from this study tend to suggest neural involvement in some, but not all, despite a non-fluctuating stage at the time of data collection.

In a recent study, pure tone audiometry, SRT and SDS were studied on 27 individuals with Meniere's disease and 27 individuals with known progressive, non-fluctuating hearing loss (control group) (Garaycochea et al., 2022). For each case, 2 to 4 follow-ups were done, with an average follow-up time of 79.9 months for Meniere's disease and 83.4 months for the control group. The testing was done periodically. The average difference between the two follow-ups was 25 months for Meniere's disease. The result revealed good PTA and SRT correlation till 21 months; after 21 months,

the dissociation of PTA and SRT was seen, which increased as the duration increased. On the contrary, no dissociation in successive follow-up visits was seen in the control group. In Meniere's disease group, speech discrimination scores also worsened with time. The results pose the question of possible neural involvement in Meniere's disease after a certain duration. This study hypothesized the concept of ganglionopathy after the disturbance of hair cells in the context of hydrops as the reason for the dissociation between PTA and speech recognition tests during the evolution of the disease.

Even though a study by Mateijsen et al. (2001) showed a good correlation between pure tone audiometry and speech audiometry indicating the absence of neural involvement, few other studies showed poor speech audiometry findings, indicating neural involvement in later stages of Meniere's disease. This poor correlation is also supported by histopathological evidence described above

Overall, it appears that there is still a controversy about neural involvement in the case of Meniere's disease. While the SRT tend to correlate with the PTA, thereby suggesting a peripheral pathology, the poor correlation of SIS with PTA and SRT seems to suggest a possible neural involvement. However, contrasting findings suggest that the ball has not stopped rolling for the studies investigating neural involvement in ears with Meniere's disease.

# CHAPTER III

# METHODS

## Research design

The present study is a retrospective study. In this, we used a multiple static group comparison research design.

## Participants

The study was conducted at the All India Institute of Speech and Hearing (AIISH). The total number of participants considered for the study is 197. Two groups were considered for this study Meniere's disease group (MDG) and the cochlear hearing loss group (CHLG). MDG included individuals diagnosed with Meniere's disease, and CHLG included individuals with cochlear hearing loss other than Meniere's disease. The participants included in this study were in the age range of 18 to 60 years, with a mean age of 42.97 for MDG and 34.42 for CHLG. Out of 191 participants, 89 were in MDG (55 males and 34 females), and 102 (64 males and 38 females) were in CHLG. In CHLG, 23 had tinnitus in both ears, and 3 had tinnitus in the right ear. The remaining 76 did not have tinnitus.

Case numbers of patients diagnosed with Meniere's disease from November 2010 to December 2019 were taken from the medical records maintained at the department of ENT, AIISH. The reason for not considering the cases after 2019 was that different protocols followed for hearing evaluation due to the COVID 19 crisis, and this may have altered the evaluations. Case numbers of subjects with cochlear hearing loss were taken from the AIISH database from 2015 to 2019. Pure tone thresholds and speech audiometry outcomes (SRT & SIS), were taken from the individual case files of the patients who met the inclusion and exclusion criteria of the present study.

## Subject selection criteria

Participants diagnosed with Meniere's disease were included in MDG. Participants with a history of middle ear disease, abnormal findings in the otoscopic examination, any history of otologic surgery, and an incomplete audiological evaluation or missing audiological information were excluded from MDG.

Inclusion criteria for CHLG were the presence of acoustic reflex thresholds within 60dB SL of the pure tone thresholds to ensure a cochlear hearing loss till stage III; this criterion was not considered for stage IV as it is unlikely to get reflexes in severe hearing loss cases, irrespective of cochlear origin or neural origin. Further absence of OAEs was also considered as an inclusion criterion.

Exclusion criteria for CHLG were history of middle ear disease, abnormal findings in the otoscopic examination, any history of otologic surgery, an incomplete audiological evaluation or missing audiological information as the MDG. Other exclusion criteria considered for the CHLG were the presence of vertigo and aural fullness.

Initially, 238 case numbers of Meniere's disease were obtained from the medical record. Out of which 89 cases with Meniere's disease were considered for the study due to the presence of the middle ear component, missing case files and incomplete data.

## Test Environment

All audiological test rooms in the department of Audiology are well-illuminated, air-conditioned, electrically shielded and sound treated rooms with ambient noise levels within the acceptable limits of the specifications of the American National Standard Institute (ANSI S3.1, 1999, R2013). All audiological tests were

carried out in these rooms.

## Instrumentation

The evaluations were done in AIISH with different diagnostic audiometers, all calibrated and also checked with subjective calibration on each day of the testing, as is customary in the institute. All audiometers in the department have impedance-matched transducers.

## Procedure

According to the Equilibrium Committee of the American Academy of Otolaryngology-Head and Neck Surgery (AAOHNS, 1995), Meniere's disease can be staged based on pure tone average at the frequencies 500, 1000, 2000, and 3000Hz. I.e. Stage I includes PTA of less than or equal to 25 dB HL, Stage II includes PTA from 26 to 40 dB HL, Stage III 41 to 70-dB HL, and Stage greater than 70 dB HL. However, the routine audiological evaluation at AIISH does not include testing at 3000Hz unless the difference between the thresholds of 2000Hz and 4000Hz is more than 20dB HL. As the threshold at 3000Hz was unavailable, to meet the criteria given by AAOHNS (1995), the operational threshold at 3000Hz was computed as the average of thresholds at 2000Hz and 4000Hz. This value was retained if the average was a whole number; however, in the case of fraction, it was equated to the nearest whole number that can be obtained using the 5 dB step. For example, if the average was 28.75dB HL, the threshold at 3000Hz was equated to 30dB HL. However, if the average was 30dB HL, it was retained as 30 dB HL.

The participants were grouped based on the pure tone average. The participants in MDG were matched for their stages with those of CHLG. The number of participants in each stage based on pure tone thresholds is shown in Table 3.

**Table 3.** *The number of participants in each of the stages*

| Stages | Number of participants in Meniere's disease group (MDG) | Number of participants in cochlear hearing loss group (CHLG) |
|---|---|---|
| **1** | 13 | 06 |
| **2** | 21 | 30 |
| **3** | 49 | 66 |
| **4** | 06 | 06 |
| **Overall** | 89 | 108 |

Speech recognition threshold and speech identification scores of each case were also taken. SRT was estimated using spondee words, and SIS was done using phonetically balanced words.

In the MDG, out of 89 subjects, 74 had Kannada, 1 had Hindi, 4 had Tamil, 1 had Coorgi, 5 had Malayalam, and 4 had Urdu as their mother tongue. In the CHLG, out of 102 subjects, 82 had Kannada, 3 had Telugu, 7 had Urdu, 6 had Malayalam, 1 had Coorgi, 2 had Hindi and 1 had Marathi as their mother tongue. Language-specific wordlist was used to obtain the SRT and SIS in all instances. In languages with no wordlist available (Coorgi, Urdu, and Marathi), testing was done in languages with available wordlist in which participants were comfortable.

In MDG, the staging was done based on the PTA of the ear with a Meniere's disease, and the SRT and SIS of the ear with Meniere's disease were considered irrespective of the ear being a right ear or left ear. Whereas, in CHLG, the staging was done based on only right ear PTA. The right ear SRT and SIS of CHLG were considered for comparison with MDG.

**Measures and statistical analysis**

The Shapiro–Wilk's test was administered to check the normality of the data distribution for SRT and SIS data. The data was not normally distributed ($p<0.05$), and hence a non-parametric statistical analysis was used. Kruskal-Wallis test was carried out for overall comparison of SIS, SRT and SRT-PTA difference between among stages of MDG and CHLG. The Mann-Whitney U test was used for pairwise comparison of stages within the group. The chances of type I error increase with the number of paired comparisons, for this α-correction was done by dividing the *p*-value (0.05) by the number of paired comparisons. Mann-Whitney test was also done to compare SIS, SRT and SRT -PTA between MDG and the CHLG across each stage. The statistical analysis was done using Statistical Package for Social Sciences (SPSS) version 20.

# CHAPTER IV

## RESULTS

The present study aimed to investigate the effects of stages of Meniere's disease on the outcome of speech audiometry. In order to achieve the above aim, speech audiometry outcomes such as SIS, SRT and SRT-PTA difference were compared among the PTA stages of each group. Speech audiometry results were also compared between the groups, MDG and CHLG, at different PTA stages and also irrespective of stages. The total cases considered for the study were 197, out of which 89 were Meniere's disease cases, and 108 were cochlear hearing loss cases other than Meniere's disease. Each group was further divided into four PTA stages given by AAO-HNS (2015).

The mean, median, and SD of PTA, SRT and SIS for each of the stages of the MDG are given in Table 4.1. and for the CHLG in Table 4.2. It can be seen that the SRT increased with stages in both groups. SIS decreased with stages in both the groups; stage I had the highest SIS scores, and stage IV had the least scores. The box plot of the same is shown in Figure 4. The average SRT-PTA difference was 1.98 in MDG and 0.78 in CHLG.

**Table 4.1.** *Pure tone average, speech recognition threshold, and speech identification scores across stages in Meniere's disease group (MDG)*

| Stage | Number of cases | Pure tone average | | | | | Speech recognition threshold | | | | | Speech identification scores | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Median | SD | Range | | Mean | Median | SD | Range | | Mean | Median | SD | Range | |
| | | | | | Minimum | Maximum | | | | Minimum | Maximum | | | | Minimum | Maximum |
| **I** | 13 | 19.30 | 19.00 | 2.81 | 15.00 | 24.00 | 20.00 | 20.00 | 5.40 | 10.00 | 30.00 | 98.53 | 100.00 | 2.40 | 92.00 | 100.00 |
| **II** | 21 | 34.23 | 35.00 | 5.46 | 26.00 | 40.00 | 32.85 | 30.00 | 9.56 | 10.00 | 50.00 | 93.04 | 96.00 | 8.52 | 68.00 | 10.00 |
| **III** | 49 | 55.32 | 56.00 | 8.32 | 41.00 | 69.00 | 59.18 | 60.00 | 10.72 | 25.00 | 75.00 | 81.53 | 84.00 | 11.20 | 48.00 | 100.00 |
| **IV** | 06 | 76.50 | 75.00 | 5.64 | 71.00 | 96.00 | 72.50 | 70.00 | 6.89 | 65.00 | 85.00 | 70.66 | 68.00 | 13.54 | 60.00 | 96.00 |
| **Total** | 89 | 46.51 | 48.00 | 17.24 | 16.00 | 86.00 | 48.14 | 50.00 | 19.26 | 10.00 | 85.00 | 86.00 | 88.00 | 12.58 | 48.00 | 100.00 |

***Note.*** 'SD'- standard deviation

**Table 4.2** *Pure tone average, speech recognition threshold, and speech identification scores across stages in the cochlear hearing loss group (CHLG)*

| Stage | Number of cases | Pure tone average | | | | | Speech recognition threshold | | | | | Speech identification scores | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Median | SD | Range | | Mean | Median | SD | Range | | Mean | Median | SD | Range | |
| | | | | | Minimum | Maximum | | | | Minimum | Maximum | | | | Minimum | Maximum |
| **I** | 06 | 22.00 | 22.00 | 2.28 | 19.00 | 25.00 | 22.50 | 22.50 | 9.35 | 10.00 | 35.00 | 98.66 | 100.00 | 2.06 | 96.00 | 100.00 |
| **II** | 30 | 34.62 | 35.00 | 3.96 | 26.00 | 42.00 | 35.96 | 35.00 | 7.68 | 20.00 | 50.00 | 95.61 | 100.00 | 5.69 | 84.00 | 100.00 |
| **III** | 66 | 53.23 | 51.00 | 7.52 | 41.00 | 70.00 | 53.53 | 55.00 | 9.95 | 30.00 | 75.00 | 88.52 | 92.00 | 9.88 | 60.00 | 100.00 |
| **IV** | 06 | 80.00 | 83.00 | 6.72 | 71.00 | 86.00 | 79.16 | 82.00 | 8.01 | 65.00 | 85.00 | 69.33 | 70.00 | 13.54 | 52.00 | 84.00 |
| **Total** | 108 | 47.64 | 47.00 | 14.29 | 19.00 | 86.00 | 48.19 | 50.00 | 15.30 | 10.00 | 85.00 | 90.05 | 92.00 | 10.72 | 52.00 | 100.00 |

***Note.*** 'SD'- standard deviation

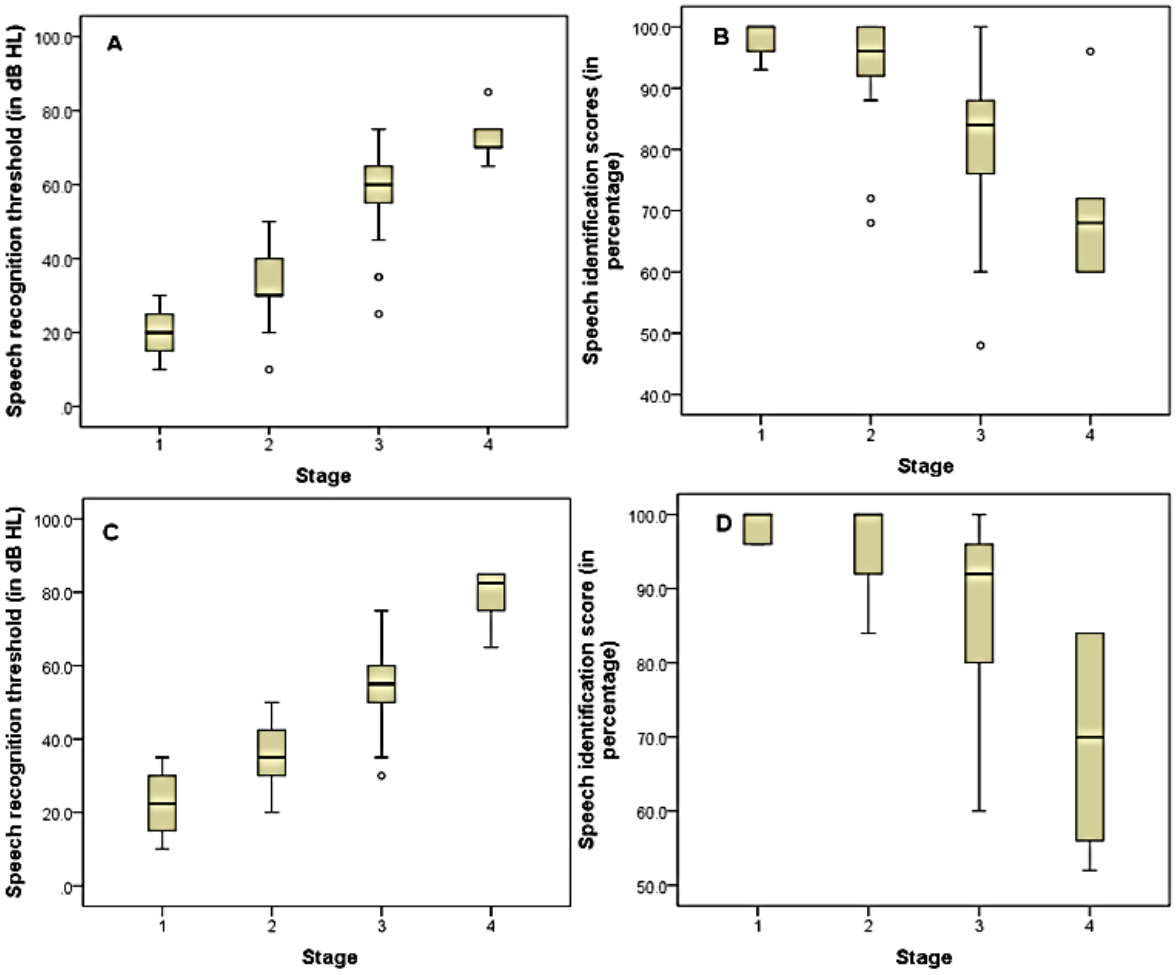


*Figure 4:* Box plot of (A) Speech recognition threshold of Meniere's disease group; (B) Speech identification score of Meniere's disease group; (C) Speech recognition threshold of Cochlear hearing loss group; (D) Speech identification score of Cochlear hearing loss group

### 4.1. The comparison of speech audiometry outcomes between MDG and CHLG

Mann Whitney U test was used for comparison between MDG and CHLG. A comparison of SIS between the groups showed a statistically significant difference [Z = 2.315, $p$ = 0.021]. No significant difference was observed when SRT was compared between the groups irrespective of stages [Z = -0.535, $p$ = 0.593]. The comparison of

SRT-PTA difference between groups also showed no significant difference [Z = -1.034, $p = 0.301$].

**4.2 Comparison of speech audiometry outcomes between stages in MDG**

Comparison of SIS, SRT and SRT- PTA difference between the stages of MDG was made using Kruskal-Wallis test. Analyses showed a significant difference for SIS [$\chi^2(3) = 42.48$, $p < 0.001$], SRT [$\chi^2(3) = 63.07$, $p < 0.001$] and SRT-PTA difference [$\chi^2(3) = 13.081$, $p = 0.004$].

Pairwise comparisons were made using the Mann-Whitney U test as the Kruskal-Wallis test showed a significant difference in SIS, SRT and SRT-PTA difference between the stages. These comparisons were made for all possible stage pairs. The results of the Mann-Whitney U test are given in Table 4.1.1. The α-corrected values indicate no significant difference between stages I-II and stages I-IV for SIS and all other stages were significantly different from each other. When SRT was compared among the stages, result showed a significant difference between all the comparison pairs. Pairwise comparison of SRT-PTA revealed a significant difference only between stages III-IV, while the rest of the stages showed no significant difference.

**Table 4.1.1.** *Results of Mann Whitney U test for pairwise comparison of SRT and SIS across the stages of Meniere's disease group and cochlear hearing loss group*

| Comparison stages | Meniere's disease group | | | | | | Cochlear hearing loss group | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SRT | | SIS | | SRT-PTA difference | | SRT | | SIS | |
| | Z-value | *p*-value | Z-value | *p*-value | Z-value | *p*-value | Z-value | *p*-value | Z-value | *p*-value |
| I-II | 3.835 | <0.001 | -2.644 | 0.012 | -0.18 | 0.986 | 2.832 | 0.03 | -1.006 | 0.385 |
| I-III | 5.500 | <0.001 | -5.120 | <0.001 | -1.717 | 0.086 | 4.019 | <0.001 | -2.63 | 0.008 |
| I-IV | 3.470 | <0.001 | -3.404 | <0.001 | -1.677 | 0.094 | 2.903 | 0.002 | -2.939 | 0.002 |
| II-III | 6.076 | <0.001 | -4.423 | <0.001 | -2.198 | 0.028 | 6.614 | <0.001 | -3.532 | <0.001 |
| II-IV | 3.707 | <0.001 | -2.850 | 0.003 | -1.786 | 0.74 | 3.885 | <0.001 | 3.854 | <0.001 |
| III-IV | 2.880 | 0.003 | -2.037 | 0.042 | -3.007 | 0.003 | 3.854 | <0.001 | -3.046 | 0.002 |

**4.3 Comparison of speech audiometry outcomes between stages in CHLG**

Comparison of SIS, SRT and SRT- PTA difference between the stages of CHLG was made using Kruskal-Wallis test. The analyses showed a significant difference for SIS [$\chi^2(3) = 24.44$, $p < 0.001$], and SRT [$\chi^2(3) = 64.293$, $p < 0.001$]. No significant difference was observed for SRT-PTA difference [$\chi^2(3) = 1.314$, $p = 0.726$].

Pairwise comparisons using the Mann-Whitney U test were made for the SIS and SRT as the Kruskal-Wallis test showed a significant difference in SIS and SRT among the stages, and pair wise comparisons were not made for SRT-PTA difference as the Kruskal-Wallis test did not show any difference among the stages. The results of the Mann-Whitney U test for pairwise comparisons between the stages in CHLG are given in Table 4.1.1. The α-corrected values indicate no significant difference between stages I-II for SIS; however, all other stages were significantly different from each other. When SRT was compared between stages, all the stages were significantly different from each other.

**4.4 Comparison of speech audiometry outcomes between MDG and CHLG at each stage.**

A comparison between MDG and CHLG at each stage revealed a statistically significant difference only in stage III for SIS [Z= 3.350, p = 0.001], SRT [Z= -3.167, $p = 0.002$] and SRT-PTA difference [Z= -2.366 p= 0.019]. Comparison at stages I, II and IV showed no significant difference. The results of Mann-Whitney test for comparison between MDG and CHLG at each stage are given in Table 4.4.

**Table 4.4.** *A comparison of speech recognition threshold and speech identification scores at various stages between Meniere's disease group and cochlear hearing loss group*

| **Stages** | **I** | | **II** | | **III** | | **IV** | | **Overall** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Z-value | *p*-value | Z-value | *p*-value | Z-value | *p*-value | Z-value | *p*-value | Z-value | *p*-value |
| **PTA** | 1.958 | 0.058 | -0.202 | 0.840 | -1.127 | 0.260 | 0.724 | 0.485 | 0.347 | 0.729 |
| **SRT** | 0.585 | 0.579 | 1.075 | 0.282 | -3.167 | 0.002 | 1.401 | 0.180 | -0.535 | 0.593 |
| **SIS** | -0.267 | 0.831 | 1.106 | 0.269 | 3.350 | 0.001 | -0.162 | 0.937 | 2.315 | 0.021 |
| **SRT-PTA difference** | -0.133 | 0.895 | -0.605 | 0.545 | -2.366 | 0.019 | -1.451 | 0.147 | -1.304 | 0.301 |

To summarize, the overall comparison of SIS, SRT, and SRT-PTA difference between MDG and CHLG showed a significant difference for only SIS. The comparison between MDG and CHLG at each stage revealed a significant difference only in stage III. Comparison of SIS between stages in MDG showed a significant difference between all the stages except for stage I-II and III-IV. When SRT was compared between the stages of MDG, all the stages were significantly different from each other. The pairwise comparison of SRT-PTA difference in MDG showed no significant difference between stages except for stage III-IV. In case of CHLG, results of comparison of SIS and SRT between stages were similar to that of MDG except for SIS between stage III-IV, which showed a significant difference along with stage I-II. In CHLG significant difference was not observed for comparison of SRT-PTA difference among the stages.

# CHAPTER V

# DISCUSSION

The present study included two groups, MDG and CHLG. The groups were further divided into four stages based on PTA. The main objective of this study was to compare speech audiometry outcomes (SIS, SRT & SRT-PTA difference) between the two groups, MDG and CHLG at all four stages and also irrespective of stages. These measures were also compared between stages of each group in order to investigate the presence of neural involvement.

## 5.1 The comparison of speech audiometry outcomes between MDG and CHLG

The comparison between MDG and CHLG showed a significant difference only for SIS and not for SRT and SRT-PTA difference. Relatively poorer SIS scores for MDG point to the increased coexisting neural involvement in MDG compared to the CHLG. These results are in accordance with a study by Stahle (1976), even though the SRT was well correlated with pure tone average (PTA= 55, SRT= 65 & SIS= 52%), a reduced discrimination score was observed in this study which suggests possible coexisting neural involvement in Meniere's disease. Poor SIS scores are also seen in a study by Friberg et al. (1984). In a study by Mateijsen et al. (2001), no indication was found of reduced discrimination scores relative to the expected pure tone hearing loss. This is because the average SRT shift in this study was 33.8 dB HL, whereas the average SRT shift found in the present study was 48.14 dB HL. SIS scores are expected to be good when the average hearing loss is less.

In a study by Garaycochea et al. (2022), SRT-PTA difference was compared between Meniere's disease and a control group, including patients with progressive non-fluctuating hearing loss. In this study, the SRT-PTA difference showed a

significant difference between the two groups with duration. SRT-PTA dissociation was observed after 21 months of the onset of Meniere's disease. Even though this dissociation started to be seen at 21 months, this dissociation became significant at 108 months (9 years). However, this dissociation with duration was not seen in the control group (Garaycochea et al., 2022). In the present study, Meniere's disease with different duration was considered, and the duration of the disease ranged from one month to 120 months with an average duration of 20.89 months. The absence of difference between MDG and CHLG for SRT-PTA difference could be due to durational effects.

### 5.2 Comparison of speech audiometry outcomes between stages in MDG

There was no significant difference between stages I-II and between stages III-IV on SIS. However, all other stages were significantly different from each other. Since stage II involves hearing loss of 26 to 40 dB HL and SIS is done at a comfortable level, a good SIS score similar to stage I was obtained. Hence no significant difference was observed between stages I-II in both the groups. The absence of a significant difference between III-IV in MDG could be because of less number of cases in stage IV. Less number of cases (six) was considered in stage IV as the cases with PTA exceeding greater than 70 dB HL were not available. Hearing loss usually does not exceed greater than 70 dB HL in most cases with Meniere's disease; this is because of the burnout stage (Stahle et al., 1991). In the burnout stage of Meniere's disease, the patient will be free of vertigo and have a fixed hearing loss of over 60 dB HL (Gibson, 2019). Few other studies have shown that this stabilization of hearing loss occurs at moderate to severe hearing loss (Belinchon et al., 2011; Zhang et al., 2016).

The comparison between stages showed a significant difference between all stages

for SRT. This is because SRT increased or worsened proportionately with the PTA stages. This is in accordance with the study by Carhart (1952), wherein performance on speech audiometry deteriorates with the degree of hearing loss.

The comparison of SRT-PTA difference showed a difference only between stage III-IV and all other stages showed no difference from each other. This can be a chance factor because of the difference in the number of cases in stage III (N=49), and stage IV (N=06), wherein less number of cases were considered in stage IV.

### 5.3 Comparison of speech audiometry outcomes between stages in CHLG

A comparison of SIS between stages in CHLG showed a significant difference between all the stages except for stages I-II. This is because of the same reason mentioned above since stage II involves a lesser degree of hearing loss (26 to 40 dB HL) and SIS is obtained at a comfortable level, a good SIS score similar to stage I can be expected.

The comparison of SRT between stages showed a significant difference between all stages. This result is similar to that of MDG. The reason for this difference is mentioned above, i.e. as PTA worsens with each stage, SRT is also expected to worsen (Carhart, 1952).

### 5.4 Comparison of speech audiometry outcomes between MDG and CHLG at each stage.

A significant difference between MDG and CHLG was seen only in stage III for all three measures of speech audiometry considered in this study. In stages I-II, no difference in SIS was seen between MDG and CHLG, indicating pathology restricting to the cochlea. A significant difference in stage III indicates a neural involvement

probably due to dying back in stage III in MDG. The difference in SIS was not seen in stage IV, even though it is the later stage of Meniere's disease. This may be because of the small number of cases fulfilling the inclusion criteria for stage IV. Another possible reason would be the beginning of neural involvement or the dying back of neurons (Ishii & Toriyama, 1977; Kong et al., 2010b; Pauler et al., 1986; Spoendlin, 1975) in the CHLG during stage IV which may have resulted in poorer SIS scores similar to that of MDG. Since the pathophysiology of Meniere's disease involves intermixing of endolymph and perilymph contents which is neurotoxic (Semaan & Megerian, 2010), neural involvement may begin earlier, i.e. stage III in MDG than CHLG resulting in difference in SIS in stage III, but in cases with cochlear hearing loss, which is due to various etiologies, neural involvement may begin in stage IV. The present study's results agree with the previous study by Garaycochea et al. (2022), which showed neural involvement in cases with Meniere's disease (Garaycochea et al., 2022). The results of the present study are also in accordance with the histopathological studies, which have shown a reduced neuronal population in cases of Meniere's disease (Megerian, 2005). Even though the lesser SIS scores were obtained in MDG than CHLG, SIS scores were not poorer as it is seen in retro cochlear pathologies.

A comparison of SRT between MDG and CHLG showed a difference only in stage III. However, SRT was within 12 dB HL in most cases except 4 cases in MDG and 2 cases in CHLG. Since PTA and SRT correlation was within $\pm$12 dB in most of the cases in both MDG and CHLG, neural involvement cannot be commented based on SRT alone.

SRT- PTA difference also showed a significant difference only in stage III.

However, the difference in mean of SRT-PTA difference between MDG and CHLG was only 3.02 dB HL. The difference at stage III could be due to the beginning of dissociation between SRT and PTA in Meniere's disease. In a study by Garaycochea et al. (2022), the authors showed a dissociation between SRT and PTA in Meniere's disease starts at 21months, but this dissociation becomes statistically significant at 108 months. The reason for the difference seen only in stage III could be due to the durational effects. This dissociation was not seen for stage IV which could be due to the less number of cases considered for the study, as explained in the earlier sub-sections.

As mentioned earlier, the dying back phenomenon happens because of the absence of input from the hair cell, but this process is also affected by various factors such as age, degree of hair cell loss, duration of hearing loss, pathophysiology and others. Dying back can also occur in various cochlear pathology, including NIHL, ototoxicity, presbycusis etc. The present study showed poor SIS in MDG than CHLG in stage III, indicating the dying back process starts at stage III for Meniere's disease and starts at stage IV for CHLG. These results show, along with reduced input from hair cells, another possible factor contributing to this neural involvement in Meniere's disease could be the underlying pathophysiology which involves the intermixing of perilymph and endolymph, which has neurotoxic effects. This pathophysiology can be one of the reasons for beginning neural involvement in stage III itself in Meniere's disease. Hence we can conclude even though hearing loss occurs because of pathology in the cochlea, the degree and onset of coexisting neural involvement depend upon other factors, including the underlying pathophysiology.

# CHAPTER VI

# SUMMARY AND CONCLUSIONS

Meniere's disease is an inner ear disorder characterized by the symptom complex of vertigo, hearing loss, tinnitus, nausea, vomiting and aural fullness. The pathophysiology of Meniere's disease includes malabsorption of endolymph by the endolymphatic duct or sac or overproduction of endolymph. This results in over accumulation of endolymph in the cochlea, leading to rupture of Reissner's membrane or causing distention of Reissner's membrane. This causes intermixing of endolymph and perilymph fluid or a change in the balance of ions resulting in injury to inner ear structures. This change in the balance of ions between endolymph and perilymph fluid or intermixing of perilymph and endolymph fluid creates the above mentioned symptom complex. Even though the pathophysiology involves injury to inner ear structures, a neural involvement can be suspected in these cases in the later stages because of the dying back phenomenon, which is the retrograde degeneration of neurons because of an absence of input from hair cells. Hence the present study aimed to investigate the presence of such a phenomenon in Meniere's disease by employing speech audiometry.

To achieve the above aim, measures of speech audiometry such as SIS, SRT, and SRT-PTA difference were employed to indicate the coexisting neural involvement. For this purpose, two groups were considered for the study – a Meniere's disease group (MDG) and a cochlear hearing loss group other than Meniere's disease (CHLG). MDG consisted of a total of 89 participants, and CHLG consisted of 108 participants. Both the groups were further grouped into four stages based on PTA as given by AAO-HNS (1995). SIS, SRT and SRT-PTA difference

were then compared between the stages of Meniere's disease and CHLG. These measures were also compared between MDG and CHLG at each stage and also irrespective of stages to see whether the MDG shows any deviant results from CHLG because of neural involvement.

Comparison of SIS, SRT and SRT-PTA difference between MDG and CHLG was done which showed a significant difference for only SIS, indicating possible neural involvement in MDG. SRT and SRT-PTA difference did not show any difference between MDG and CHLG which could be due to the durational effects as the significant dissociation between SRT-PTA is seen after 108 months of the onset of Meniere's disease (Garaycochea et al., 2022) and in the present study as the average duration was 20.89 significant difference was not seen for SRT-PTA difference.

Kruskal-Wallis test was done to compare SIS, SRT and SRT-PTA difference among the four stages of MDG and CHLG. Kruskal-Wallis test showed a difference in all the measures among stages for MDG; hence a pairwise comparison was performed between each stage of MDG. A pairwise analysis showed a significant difference for all the pairs except for stages I-II and III-IV. A significant difference was not observed between stages I-II as stage II involves a lesser degree of hearing loss, and SIS was done at a comfortable level. No significant difference between stages III and IV can be due to the less number of cases considered in stage IV. All the stages were significantly different from each other when SRT was compared between the stages of MDG. As the SRT increases or worsens with the degree of hearing loss, the result showed a significant difference among all the stages. Comparison of SRT-PTA difference showed a significant difference only between stage III-IV, which can be due to the lesser number of cases in stage IV.

In CHLG, as the Kruskal-Wallis test showed a significant difference for SIS and SRT and not for SRT-PTA difference, hence pairwise comparisons were made between the stages for SIS and SRT. The pairwise analyses showed a significant difference for all the pairs except for stages I-II. As mentioned above, this difference is because of the lesser degree of hearing loss in stage II and the presentation of stimulus at a comfortable level. For SRT, similar to MDG all the stages were significantly different from each other as the SRT increases proportionately with PTA stages.

A comparison of SIS, SRT and SRT-PTA difference between MDG and CHLG at various stages showed a significant difference only at stage III. This indicates the beginning of neural involvement at stage III of Meniere's disease. This difference was not observed at stage IV even though it is the later stage, probably because less number of cases in stage IV or the beginning of the dying back phenomenon in stage IV of CHLG. Since dying back occurs because of decreased input from hair cells, CHLG can also undergo dying back at a later stage. As Meniere's disease involve intermixing of perilymph and endolymph or the change in the balance of ions which is neurotoxic, dying back occurs in Meniere's disease at stage III itself, whereas, in CHLG, it starts at stage IV.

The dying back phenomenon is also affected by various factors such as age, degree of hair cell loss, duration of hearing loss, pathophysiology and others. Dying back can also occur in other cochlear pathologies, including NIHL, ototoxicity, presbycusis etc. The present study showed poor SIS scores in MDG than CHLG in stage III, indicating the dying back process starts at stage III for Meniere's disease and starts at stage IV for CHLG which is the beginning of neural involvement at early

stage in Meniere's disease compared to cochlear hearing loss. This neural involvement starting at an early stage in Meniere's disease could be due to the additional contributing factor for neural involvement along with the reduced input from hair cell. The additional factor contributing to this neural involvement in Meniere's disease could be the underlying pathophysiology which involves the intermixing of perilymph and endolymph, which is neurotoxic, which could accelerate the degeneration of hair cells, thereby prompting an early onset of the dying back phenomenon. This pathophysiology can be one of the reasons for beginning neural involvement in stage III itself in Meniere's disease. Hence it can be concluded that even though hearing loss occurs because of pathology in the cochlea, the degree and onset of coexisting neural involvement depend upon other factors, including the underlying pathophysiology.

**Clinical implication of the study**

From this study, it is known that even though hearing loss is of sensory origin, neural involvement can be coexisting. Also, the degree of coexisting neural involvement varies with the underlying pathophysiology. SIS is one of the easily available and interpreted tools for judging neural involvement. Hence the present study will help in understanding neural involvement in cases with Meniere's disease and its relationship with the PTA stage. The understanding of coexisting neural involvement in Meniere's disease and its relationship with stages would aid in diagnosis, management and counselling of patients with Meniere's disease.

**Limitations of the study and future directions**

The present study is a retrospective research, where the outcome on speech audiometry was studied in various stages of Meniere's disease. The results of the present study help in understanding coexisting neural involvement along Meniere's

disease and its relationship with its stages. The following are the limitations of the present study.

- The present study did not examine SIS, SRT and SRT-PTA difference changes with duration, as the information about duration since the onset was not documented in all case files. Studying durational effects would give a better picture of the course of Meniere's disease and the course of coexisting neural involvement.
- Lesser number of cases were considered in stage IV of both MDG and CHLG.

The present study is a retrospective study. In future longitudinal study can be done by having considerable number of cases in each stage of the Meniere’s disease to study durational effects on Speech audiometry.

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