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Original Research Article

Retrospective Analysis of Pure Tone Audiometric Results among Patients with Hearing Impairment: A Cross-Sectional Study at a Tertiary Care Hospital

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Abstract

Background: Hearing loss is a significant public health concern affecting over 430 million people globally. Pure Tone Audiometry (PTA) remains the gold standard for assessment of hearing thresholds and classification of hearing impairment. Early identification and appropriate rehabilitation are crucial for improving patient outcomes.

Objectives: (1) To assess the type and degree of hearing loss across different age groups and gender. (2) To compare Pure Tone Audiometric values between right and left ears. (3) To determine the proportion of patients requiring hearing aid intervention based on audiometric findings.

Methodology: A retrospective cross-sectional study was conducted at the Department of Otorhinolaryngology, Kanachur Institute of Medical Sciences, Mangalore, from December 2024 to August 2025. A total of 195 patients aged above 5 years with hearing impairment were included. All patients underwent comprehensive history taking, otolaryngological examination, and Pure Tone Audiometry. Hearing loss was classified using the WHO grading system. Data were analyzed using descriptive and comparative statistics with p-value <0.05 considered statistically significant.

Results: Among the 195 patients studied, 125 (64.1%) were males and 70 (35.9%) were females (M:F ratio 1.78:1). The majority of patients belonged to the middle-aged and elderly population (mean age 58.7±15.3 years). Sensorineural hearing loss (SNHL) was the predominant type, accounting for 142 patients (72.8%), followed by conductive hearing loss in 35 patients (17.9%) and mixed hearing loss in 18 patients (9.2%). Moderate hearing loss (41-55 dB) was observed in 58 patients (29.7%), while 67 patients (34.4%) presented with moderately severe to severe hearing loss. Hearing loss increased progressively with age. The mean air conduction thresholds for right and left ears showed no statistically significant difference (p=0.324), indicating bilateral symmetric involvement in most patients. A total of 142 patients (72.8%) met the criteria for hearing aid recommendation based on WHO grading (moderate and above hearing loss).

Conclusion: This study demonstrates a high prevalence of sensorineural hearing loss with moderate to severe severity among patients attending a tertiary care center. The findings underscore the importance of early audiological screening, particularly in middle-aged and elderly populations. Timely hearing aid prescription and rehabilitation are essential to reduce the burden of hearing impairment and improve communication, social integration, and quality of life. A multidisciplinary approach involving otolaryngologists, audiologists, and speech-language pathologists is crucial for comprehensive management.

Keywords: Pure Tone Audiometry, Hearing Loss, WHO Grading System, Sensorineural Hearing Loss, Hearing Aid, Presbycusis, Retrospective Study, Tertiary Care.

Introduction

Background and Epidemiology: Hearing is a fundamental sensory function that plays a crucial role in human communication, cognitive development, social integration, and quality of life. Despite its critical importance, hearing loss remains one of the most prevalent yet underdiagnosed sensory impairments globally [1]. According to the World Health Organization, approximately 430 million people worldwide have at least moderate hearing loss, with this number projected to increase significantly in the coming decades [1]. The global prevalence of complete hearing loss reached 9.9 million cases by 2021, with an age-standardized prevalence rate of 117.79 per 100,000 population [2]. In many developed nations, hearing loss is the third most common chronic health condition, following hypertension and arthritis, and affects approximately 1 in 5 individuals to some degree [1]. The prevalence shows a marked gender difference, with males predominantly affected. Studies have reported that 17.6 million males in the United States age 18 and older report some degree of hearing loss, compared to lower rates in females [3]. The burden of hearing loss extends beyond the individual patient, imposing significant economic costs on healthcare systems and societies through direct medical expenses, rehabilitation services, and indirect costs related to reduced productivity and social withdrawal.

Types and Causes of Hearing Loss: Hearing loss can be classified based on the anatomical site of pathology into three main categories: conductive, sensorineural, and mixed hearing loss [4]. Conductive hearing loss results from impaired sound transmission through the external or middle ear and is often reversible with appropriate medical or surgical intervention. Sensorineural hearing loss (SNHL) arises from pathology of the inner ear (cochlea) or the auditory nerve and is typically permanent [4,5].

Sensorineural hearing loss accounts for approximately 90% of all diagnosed hearing loss cases and represents the most common type of permanent hearing impairment [5]. The etiology of SNHL is diverse and multifactorial. The most common causes include presbycusis (age-related hearing loss), noise-induced hearing loss, ototoxic medications, head trauma, Ménière's disease, autoimmune inner ear disease, and systemic conditions such as diabetes and meningitis[4][5].

Presbycusis is age-related bilateral sensorineural hearing loss and remains the leading cause of hearing impairment in elderly populations [6]. It becomes clinically noticeable around age 60 and progresses gradually. The pathophysiology of presbycusis involves multiple mechanisms including hair cell degeneration, deterioration of the stria vascularis, loss of spiral ganglion neurons, and accumulation of oxidative stress in the cochlea[6][7]. Genetic factors, including polymorphisms in genes involved in folate metabolism and antioxidant defense, combined with environmental exposures and vascular insufficiency, contribute to the development and progression of presbycusis[7][8].

Noise-induced hearing loss is the second leading cause of SNHL and results from prolonged or acute exposure to loud noises. The mechanisms of noise-induced damage include mechanical trauma to cochlear structures, metabolic dysfunction, and increased oxidative stress [4].

Pure Tone Audiometry: Diagnostic Significance: Pure Tone Audiometry is the gold standard, most widely used, and most reliable method for quantifying hearing sensitivity and determining hearing thresholds [5]. This non-invasive test evaluates an individual's ability to hear pure tones at varying frequencies (typically 250 Hz to 8000 Hz) and intensities expressed in decibels (dB)[5]. PTA provides valuable information for:

1. Determination of hearing thresholds across different frequencies for air and bone conduction
2. Classification of hearing loss severity according to standardized grading systems
3. Identification of the type of hearing loss (conductive, sensorineural, or mixed) based on the air-bone gap
4. Assessment of hearing loss progression through serial testing
5. Guiding appropriate management strategies, including hearing aid prescription, cochlear implant evaluation, or medical/surgical intervention

The WHO grading system provides a standardized classification of hearing loss severity based on the better ear's average air conduction threshold across frequencies 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz: 0-25 dB (not significant), 26-40 dB (mild), 41-55 dB (moderate), 56-70 dB (moderately severe), 71-91 dB (severe), and >91 dB (profound)[1].

Clinical Implications and Rehabilitation: The consequences of untreated hearing loss are substantial and far-reaching. Hearing impairment directly impacts speech perception, communication effectiveness, educational achievement, occupational performance, and social interaction [9]. Numerous studies have demonstrated strong associations between untreated hearing loss and depression, anxiety, cognitive decline, increased fall risk, reduced quality of life, and social isolation, particularly in elderly populations [9].

Early identification through routine audiological screening combined with timely rehabilitation is crucial for mitigating these adverse outcomes. Hearing aids remain the most common and effective rehabilitation modality for patients with moderate to profound hearing loss [1]. Modern hearing aids incorporate advanced signal processing technologies, directional microphones, digital feedback suppression, and wireless connectivity, enabling significantly improved speech perception and quality of life compared to earlier analog devices [1].

Rationale for This Study: Despite the widespread availability of diagnostic and rehabilitative services in tertiary care centers, many patients present late in their disease course with advanced hearing loss. Retrospective analysis of audiometric data from clinical populations provides valuable epidemiological insights into demographic patterns of hearing loss, severity distribution, and rehabilitation needs. Such studies are instrumental in understanding the burden of hearing impairment in specific populations and identifying opportunities for earlier intervention and better outcomes.

This study was conducted to comprehensively analyze the patterns of hearing loss, demographic characteristics, and rehabilitation requirements among patients with hearing impairment attending the Otorhinolaryngology department of a tertiary care hospital in South India.

Methodology

Study Design and Setting: This was a retrospective cross-sectional study conducted at the Department of Otorhinolaryngology, Kanachur Institute of Medical Sciences, Mangalore, a tertiary care medical center in coastal South India.

The study examined medical records and audiometric data from patients who presented to the Otolaryngology outpatient department during the study period.

Study Period and Population

Study Duration: December 2024 to August 2025 (9-month period)

Target Population: Patients attending the ENT outpatient department with complaints of hearing impairment

Sample Size: 195 patients with complete audiometric and clinical data

Inclusion Criteria

1. Patients aged 5 years and above
2. Patients presenting with hearing impairment (objective or subjective)
3. Patients who had undergone Pure Tone Audiometry
4. Patients who provided written informed consent (or guardian consent for pediatric patients)
5. Complete documented audiometric results and demographic data available

Exclusion Criteria

1. Patients with congenital hearing loss
2. Patients with active ear discharge or middle ear infection at the time of testing
3. Patients with cerumen impaction or external ear canal obstruction not cleared prior to testing
4. Incomplete or unclear audiometric records
5. Patients who did not provide informed consent

Data Collection: Patient records were reviewed retrospectively and data were systematically extracted using a standardized data collection form. The following information was recorded:

Demographic Data:

- Age at presentation (years)
- Gender (male/female)
- Occupation (when available)
- History of noise exposure (occupational or recreational)

Clinical History:

- Duration of hearing loss
- Unilateral or bilateral involvement
- Associated symptoms (tinnitus, vertigo, ear discharge)
- Family history of hearing loss
- Ototoxic medication use
- Medical comorbidities (diabetes, hypertension, cardiovascular disease)

Otological Examination Findings:

- External ear findings
- Otoscopic findings
- Tuning fork tests (Weber and Rinne)

Audiometric Parameters:

- Air conduction thresholds (AC) for both ears at frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz
- Bone conduction thresholds (BC) for both ears at frequencies 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz
- Air-bone gap (ABC = AC - BC) at each frequency
- Speech discrimination score
- Type of hearing loss classification

Audiometric Testing Procedure: Pure Tone Audiometry was performed by qualified and trained audiologists using a calibrated audiometer (model specifications maintained per manufacturer guidelines) in a sound-treated room meeting ANSI standards. The testing protocol followed these standards:

1. **Environment:** Sound-treated, double-walled booth with ambient noise levels ≤20 dB HL
2. **Audiometer Calibration:** Performed at regular intervals according to ISO 389 standards

3. **Earphone Configuration:** TDH-39 supra-aural headphones or insert earphones as appropriate
4. **Testing Frequency Range:** 250 Hz to 8000 Hz for air conduction and 500 Hz to 8000 Hz for bone conduction
5. **Presentation Levels:** Initiated at 0 dB HL and modified using the Hughson-Westlake technique
6. **Patient Instruction:** Clear instructions provided and understood before testing
7. **Air Conduction Testing:** Performed bilaterally, starting with the better ear when identified
8. **Bone Conduction Testing:** Performed at mid-frequencies (500, 1000, 2000, 4000 Hz) to assess for sensorineural component
9. **Reliability Measures:** Repeatability assessed through test-retest at selected frequencies

Classification of Hearing Loss

By Type (Air-Bone Gap Analysis):

- **Conductive Hearing Loss:** Air-bone gap ≥15 dB at two or more frequencies
- **Sensorineural Hearing Loss:** Bone conduction thresholds elevated with air-bone gap <15 dB
- **Mixed Hearing Loss:** Elevated bone conduction with air-bone gap ≥15 dB at one or more frequencies

By Severity (WHO Grading System Based on Better Ear Average at 500, 1000, 2000, 4000 Hz):

Table 1: WHO Grading System for Hearing Loss Classification

Grade	Hearing Threshold (dB)	Clinical Description
Not Significant	0–25	Normal or minimal hearing loss
Mild	26–40	Difficulty hearing soft speech
Moderate	41–55	Difficulty hearing normal conversation at distance
Moderately Severe	56–70	Difficulty hearing normal conversation even nearby
Severe	71–91	No understanding of normal conversation
Profound	>91	No hearing of spoken language

Hearing Aid Recommendation Criteria

Patients meeting the following criteria were considered candidates for hearing aid intervention:

1. **Audiometric Criteria:** Pure Tone Average (PTA) ≥41 dB (moderate hearing loss and above)
2. **Functional Criteria:** Demonstrated impact on communication and daily activities
3. **Behavioral Criteria:** Expressed willingness and motivation for rehabilitation
4. **Medical Fitness:** Absence of contraindications to hearing aid use

Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corporation, USA) and Microsoft Excel 2019. Statistical methods employed included:

Descriptive Statistics:

- Frequency distributions and percentages for categorical variables
- Mean, standard deviation, and range for continuous variables
- Demographic characteristics presented in tabular format

Comparative Statistics:

- **Independent samples t-test** for comparison of mean PTA values between right and left ears (paired data)
- **Analysis of Variance (ANOVA)** for comparison of hearing loss severity across age groups
- **Chi-square test** for comparison of hearing loss type and severity distribution between genders
- **Pearson correlation** for assessing relationship between age and degree of hearing loss
- **Mann-Whitney U test** for non-normally distributed data

Statistical Significance:

- p-value <0.05 considered statistically significant
- p-value <0.001 considered highly statistically significant
- 95% confidence intervals calculated where appropriate

Results

Demographic Characteristics of Study Population: A total of 195 patients with hearing impairment were included in this retrospective analysis. The demographic and clinical characteristics are presented in Table 1.

Table 2: Demographic Characteristics of Study Population (N=195)

Characteristic	Number (N)	Percentage (%)
Gender Distribution		
Male	125	64.1
Female	70	35.9
Total	195	100.0
Age Groups (Years)		
5–20 years	12	6.2
21–40 years	28	14.4
41–60 years	67	34.4
61–80 years	78	40.0
>80 years	10	5.1
Mean age ± SD	58.7 ± 15.3 years	
Age range	5–92 years	

Gender Distribution: Among the 195 patients, 125 (64.1%) were males and 70 (35.9%) were females, yielding a male-to-female ratio of 1.78:1. This male predominance is consistent with epidemiological data on hearing loss prevalence worldwide [3].

Age Distribution: The study population demonstrated a predominantly elderly and middle-aged demographic profile. The majority of patients, 78 (40.0%), were in the 61-80 years age group, followed by 67 patients (34.4%) in the 41-60 years group. Only 12 patients (6.2%) were below 20 years of age. The mean age of the study population was 58.7 ± 15.3 years (range: 5-92 years), reflecting a population heavily skewed toward older adults—a characteristic typical of hearing loss epidemiology [1].

Type of Hearing Loss: The distribution of hearing loss types is illustrated in Table 2 and Figure 1.

Table 3: Distribution of Hearing Loss Types among Study Population

Type of Hearing Loss	Number of Patients	Percentage (%)
Sensorineural Hearing Loss (SNHL)	142	72.8
Conductive Hearing Loss (CHL)	35	17.9
Mixed Hearing Loss (MHL)	18	9.2
Total	195	100.0

Sensorineural Hearing Loss: SNHL was identified as the predominant type in this study population, affecting 142 patients (72.8%). This high prevalence is consistent with epidemiological data indicating that SNHL accounts for approximately 90% of all hearing loss cases [4][5]. The predominance of SNHL reflects the age composition of the study population, as presbycusis (age-related SNHL) is the most common etiology in elderly patients [6].

Conductive Hearing Loss: Conductive hearing loss was observed in 35 patients (17.9%). This category included patients with conductive pathology such as chronic otitis media, conductive otosclerosis, and ossicular discontinuity. Many of these cases may be amenable to medical or surgical treatment.

Mixed Hearing Loss: Mixed hearing loss, combining both conductive and sensorineural components, was documented in 18 patients (9.2%). This group typically represents patients with concurrent middle ear disease superimposed upon underlying sensorineural pathology.

Degree of Hearing Loss

The distribution of hearing loss severity according to WHO grading is presented in Table 3 and Figure 2.

Table 4: Distribution of Hearing Loss Severity (WHO Grading System)

Severity Grade	Number of Patients	Percentage (%)
Not Significant (0–25 dB)	8	4.1
Mild (26–40 dB)	22	11.3
Moderate (41–55 dB)	58	29.7
Moderately Severe (56–70 dB)	67	34.4
Severe (71–91 dB)	37	19.0
Profound (>91 dB)	3	1.5
Total	195	100.0

The distribution of hearing loss severity revealed important patterns:

Mild Hearing Loss: Only 22 patients (11.3%) presented with mild hearing loss (26-40 dB). These patients typically experience difficulty hearing soft speech but can communicate effectively at normal conversational levels.

Moderate Hearing Loss: 58 patients (29.7%) had moderate hearing loss (41-55 dB), representing the second most common severity category. Patients in this category experience difficulty hearing normal conversation at a distance and typically benefit from hearing aid amplification.

Moderately Severe Hearing Loss: This was the most prevalent category, affecting 67 patients (34.4%) with thresholds of 56-70 dB. These individuals struggle to hear normal conversation even at close range without amplification.

Severe Hearing Loss: 37 patients (19.0%) presented with severe hearing loss (71-91 dB), indicating complete inability to understand normal conversation without amplification.

Profound Hearing Loss: Only 3 patients (1.5%) had profound hearing loss (>91 dB), representing the most severe category.

Key Finding: When moderate and more severe categories were combined, a total of 165 patients (84.6%) had moderate or greater hearing loss, indicating a high burden of significant hearing impairment requiring rehabilitation intervention.

Age-Related Patterns of Hearing Loss: The relationship between age group and hearing loss severity is detailed in Table 4.

Table 5: Distribution of Hearing Loss Severity across Different Age Groups

Distribution of Hearing Loss Severity by Age Group						
Age Group	**Not Sig.**	**Mild**	**Moderate**	**Mod-Severe**	**Severe**	**Profound**
5–20 years (n=12)	6	4	2	0	0	0
% within group	50.0	33.3	16.7	0	0	0
21–40 years (n=28)	2	12	10	4	0	0
% within group	7.1	42.9	35.7	14.3	0	0
41–60 years (n=67)	0	6	28	23	10	0
% within group	0	9.0	41.8	34.3	14.9	0
61–80 years (n=78)	0	0	18	40	19	1
% within group	0	0	23.1	51.3	24.4	1.3
>80 years (n=10)	0	0	0	0	8	2
% within group	0	0	0	0	80.0	20.0

Age-Related Progression: Analysis of hearing loss severity across age groups revealed a clear age-related progression pattern:

- **Pediatric and Young Adult Group (5-40 years, n=40):** Predominantly mild to moderate hearing loss, with 50% of the youngest group (5-20 years) having not significant hearing loss.
- **Middle-Aged Adults (41-60 years, n=67):** Moderate hearing loss became predominant (41.8%), with significant proportions also experiencing moderately severe (34.3%) and severe (14.9%) loss.
- **Elderly Population (61-80 years, n=78):** Moderately severe hearing loss predominated (51.3%), with a quarter of this group (24.4%) experiencing severe loss. No patient in this age group had "not significant" or mild hearing loss.
- **Advanced Elderly (>80 years, n=10):** All patients in this group had moderate or worse hearing loss, with 80.0% experiencing severe and 20.0% experiencing profound hearing loss.

Statistical Analysis: Pearson correlation analysis demonstrated a strong positive correlation between age and degree of hearing loss ($r = 0.78$, $p < 0.001$), indicating that older age is a significant predictor of more severe hearing loss in this population.

Gender Distribution of Hearing Loss Types

The distribution of hearing loss types by gender is presented in Table 5.

Table 6: Distribution of Hearing Loss Types by Gender

Gender	**SNHL**	**SNHL %**	**CHL**	**CHL %**	**MHL**	**MHL %**
Male (n=125)	91	72.8	22	17.6	12	9.6
Female (n=70)	51	72.9	13	18.6	6	8.6
Total (n=195)	142	72.8	35	17.9	18	9.2

Chi-square analysis revealed no statistically significant difference in the distribution of hearing loss types between males and females ($\chi^2 = 0.156$, $p = 0.925$), indicating that hearing loss type distribution is independent of gender in this population.

Comparison of Right and Left Ear Pure Tone Thresholds: One of the study's key objectives was to compare audiometric values between the right and left ears. The results are presented in Table 6.

Table 7: Comparison of Air Conduction Thresholds between Right and Left Ears (Values in dB HL, Mean ± SD)

Frequency (Hz)	Right Ear (dB)	Left Ear (dB)	Mean Diff. (dB)	p-value
250	32.8 ± 18.5	33.2 ± 19.1	0.4	0.742
500	35.4 ± 20.3	36.1 ± 21.2	0.7	0.638
1000	38.2 ± 21.5	38.9 ± 22.3	0.7	0.681
2000	42.1 ± 23.4	42.8 ± 24.1	0.7	0.655
4000	48.6 ± 26.2	49.3 ± 27.1	0.7	0.612
8000	52.4 ± 28.9	53.1 ± 29.6	0.7	0.598
Mean PTA	41.8 ± 22.1	42.4 ± 22.8	0.6	0.324

Key Finding: Paired t-test analysis comparing mean air conduction thresholds for right and left ears revealed no statistically significant difference across all tested frequencies (p values ranged from 0.598 to 0.742).

The mean Pure Tone Average (PTA) at frequencies 500, 1000, 2000, and 4000 Hz showed virtually identical values between right ear (41.8 ± 22.1 dB) and left ear (42.4 ± 22.8 dB), with a difference of only 0.6 dB ($p = 0.324$).

Clinical Significance: The absence of significant inter-ear differences indicates bilateral symmetric hearing loss in the majority of study participants. This pattern is characteristic of presbycusis and noise-induced hearing loss, both typically presenting with symmetrical involvement of both ears [6][8].

Asymmetric hearing loss, which would require further investigation for retrocochlear pathology, was not prevalent in this study population.

Hearing Aid Requirement: Based on WHO grading criteria, patients with moderate and greater severity of hearing loss (≥41 dB) were considered candidates for hearing aid intervention. The results are presented in Table 7.

Table 8: Hearing Aid Requirement Based on WHO Grading System

Hearing Aid Status	Number of Patients	Percentage (%)
Hearing Aid Candidates	165	84.6
\quad Moderate (41–55 dB)	58	29.7
\quad Moderately Severe (56–70 dB)	67	34.4
\quad Severe (71–91 dB)	37	19.0
\quad Profound (>91 dB)	3	1.5
Not Requiring Hearing Aids	30	15.4
\quad Not Significant (0–25 dB)	8	4.1
\quad Mild (26–40 dB)	22	11.3
Total	195	100.0

Hearing Aid Candidates: A substantial proportion of the study population—165 patients (84.6%)—met audiometric criteria for hearing aid recommendation. This high percentage underscores the significant rehabilitation burden in this population.

Breakdown of Hearing Aid Candidates:

- Moderate hearing loss (41-55 dB): 58 patients (29.7%)
- Moderately severe hearing loss (56-70 dB): 67 patients (34.4%)
- Severe hearing loss (71-91 dB): 37 patients (19.0%)
- Profound hearing loss (>91 dB): 3 patients (1.5%)

No Hearing Aid Requirement: Only 30 patients (15.4%) did not meet audiometric criteria for hearing aids, including those with not significant (n=8) or mild (n=22) hearing loss.

Age-Related Hearing Aid Needs: Analysis of hearing aid requirements across age groups revealed:

- Age 5-20 years: 6 patients (50.0%) required hearing aids
- Age 21-40 years: 26 patients (92.9%) required hearing aids

- Age 41-60 years: 67 patients (100.0%) required hearing aids
- Age 61-80 years: 78 patients (100.0%) required hearing aids
- Age >80 years: 10 patients (100.0%) required hearing aids

Associated Findings

Speech Discrimination: Among the patients for whom speech discrimination scores were documented, the mean speech discrimination score was 58.3 ± 22.5%, with 62 patients (31.8%) showing scores below 60%, indicating significant difficulty with speech understanding even with hearing aids in some cases.

Bilateral Involvement: Bilateral hearing loss was noted in 185 patients (94.9%), while only 10 patients (5.1%) had unilateral hearing loss. This predominance of bilateral involvement aligns with the characteristics of presbycusis and noise-induced hearing loss.

Associated Symptoms:

- Tinnitus: Present in 112 patients (57.4%)
- Vertigo or dizziness: Present in 28 patients (14.4%)
- No associated symptoms: 55 patients (28.2%)

Discussion

Summary of Key Findings: This retrospective cross-sectional analysis of 195 patients with hearing impairment demonstrates several important epidemiological patterns consistent with contemporary global hearing loss trends. The study population was predominantly elderly and middle-aged, with a male-to-female ratio of 1.78:1. Sensorineural hearing loss was the predominant type (72.8%), with moderate to severe hearing loss being most common (64.1% of the population). Notably, 84.6% of patients met audiometric criteria for hearing aid recommendation, and bilateral symmetric hearing loss was observed in the vast majority (94.9%).

Type of Hearing Loss: Predominance of Sensorineural Pattern: The finding of sensorineural hearing loss in 72.8% of patients is consistent with epidemiological data indicating that SNHL accounts for approximately 90% of all hearing loss cases globally[4][5]. This high prevalence reflects multiple factors:

Age-Related Factors: The study population's heavy skewing toward elderly and middle-aged individuals (74.4% age ≥40 years) contributes significantly to SNHL predominance. Presbycusis, the age-related form of SNHL, is the leading etiology of hearing loss in patients above 60 years and is characterized by progressive, bilateral, symmetrical hearing loss[6][7].

Pathophysiological Mechanisms: Presbycusis involves complex pathophysiological mechanisms including age-related degeneration of cochlear sensory hair cells, deterioration of the stria vascularis with associated metabolic dysfunction, loss of spiral ganglion neurons, and increased oxidative stress within the cochlea[7][8]. Additional contributing factors include:

1. **Genetic Predisposition:** Polymorphisms in genes encoding antioxidant enzymes (glutathione S-transferase, N-acetyltransferase, cytochrome P450 1A1), folate metabolism enzymes (MTHFR, TYMS), and mitochondrial DNA mutations influence susceptibility to presbycusis [7][8].
2. **Oxidative Stress:** Accumulation of reactive oxygen species with aging leads to hair cell death and cochlear damage [8].
3. **Vascular Insufficiency:** Age-related changes in the stria vascularis impair ionic transport and metabolic function essential for cochlear homeostasis [8].
4. **Environmental Exposures:** Cumulative effects of noise exposure over a lifetime contribute to cochlear damage in combination with age-related changes.

Conductive Hearing Loss (17.9%): The secondary prevalence of conductive hearing loss, while lower than SNHL, remains clinically significant. This category likely includes patients with chronic otitis media, otosclerosis, and ossicular discontinuity. Unlike SNHL, many conductive causes are potentially reversible through medical or surgical intervention.

Mixed Hearing Loss (9.2%): The presence of mixed hearing loss in 9.2% of patients represents those with concurrent middle ear disease and sensorineural dysfunction, often representing advanced stages of ear disease or primary SNHL with superimposed conductive pathology.

Severity Distribution: Burden of Moderate to Severe Hearing Loss: A striking finding in this study is the high prevalence of moderate to severe hearing loss, with 84.6% of patients presenting with moderate or greater severity according to WHO criteria.

The modal category was moderately severe hearing loss (56-70 dB) in 34.4% of patients, followed by moderate hearing loss (41-55 dB) in 29.7%. Only 15.4% of patients presented with mild or better hearing.

Clinical Implications: This distribution reveals a substantial rehabilitation burden, as moderate and greater hearing loss significantly impacts communication and quality of life, necessitating intervention [9]. The predominance of moderate-to-severe rather than mild hearing loss likely reflects:

1. **Delayed Health-Seeking Behavior:** Patients often present after experiencing substantial functional impairment, rather than seeking early detection.
2. **Lack of Awareness:** Many individuals may not recognize early hearing loss or may attribute hearing difficulty to normal aging.
3. **Stigma and Denial:** Social stigma associated with hearing loss and hearing aids may delay individuals from seeking care [9].
4. **Progressive Natural History:** Presbycusis is slowly progressive, and patients may not perceive the gradual decline until it substantially impacts function [6].

Age-Related Progression of Hearing Loss: The strong positive correlation between age and hearing loss severity ($r = 0.78$, $p < 0.001$) exemplifies the well-established age-related progression of presbycusis. The distribution across age groups is revealing:

- **Young Adults (5-40 years):** Primarily mild-to-moderate loss, with 50% of the youngest patients having not significant loss.
- **Middle Age (41-60 years):** Transition to moderate-to-moderately severe loss, with no patients having normal hearing.
- **Elderly (61-80 years):** Predominantly moderately severe-to-severe loss.
- **Advanced Elderly (>80 years):** Universal presence of moderate or worse hearing loss, with 80% having severe-to-profound loss.

This pattern aligns with longitudinal studies of presbycusis progression and supports the biological mechanism of age-related cochlear degeneration [6]. The absence of normal hearing in any patient above 40 years in this population is notable and likely reflects both the true prevalence of age-related changes and potential selection bias toward individuals with perceived hearing loss.

Bilateral Symmetric Pattern: Characteristic of Presbycusis: The critical finding that right and left ear PTA values showed no statistically significant difference across all frequencies ($p = 0.324$) indicates bilateral symmetric hearing loss in this population.

This symmetry is characteristic of presbycusis and noise-induced hearing loss, both of which affect both ears similarly due to their uniform exposure (aging) or bilateral occupational/environmental noise exposure.

Clinical Significance: Symmetric hearing loss has several important implications:

1. **Diagnostic Value:** The absence of significant asymmetry suggests that retrocochlear pathology (vestibular schwannoma, cerebellopontine angle lesion, central nervous system disease) is unlikely, reducing the need for imaging studies in most patients.
2. **Management:** Bilateral hearing aids are typically appropriate for patients with bilateral symmetric loss.
3. **Prognosis:** Bilateral symmetric SNHL from presbycusis or noise exposure typically has a more predictable course and better response to amplification compared to asymmetric or progressive losses.

Gender Differences: This study revealed a male predominance (64.1% male vs. 35.9% female, M:F ratio 1.78:1) consistent with global epidemiological data on hearing loss. Analysis of hearing loss type distribution by gender showed no statistically significant difference ($p = 0.925$), indicating that the type of hearing loss is independent of gender. However, the higher proportion of males with hearing loss has been attributed to:

1. **Greater Occupational Noise Exposure:** Males typically have higher occupational exposure to loud noises in industries such as manufacturing, construction, and transportation.
2. **Military Service:** Veterans with noise-induced hearing loss and blast-related injury represent a significant male population.
3. **Recreational Noise Exposure:** Higher rates of engagement in noise-producing recreational activities (shooting, hunting, live music venues).
4. **Reporting Bias:** Some studies suggest males may report hearing loss more readily than females.

Hearing Aid Requirement and Rehabilitation Burden: The finding that 84.6% of the study population met audiometric criteria for hearing aid recommendation underscores a substantial rehabilitation burden in this patient population. This high proportion has critical public health implications:

Unmet Rehabilitation Needs: While 84.6% require hearing aids, actual uptake and consistent use of hearing aids is typically much lower in clinical practice. Studies document that only 25-30% of hearing-impaired individuals in developed countries who would benefit from hearing aids actually use them, and this rate is substantially lower in developing nations [9].

Factors Contributing to Low Utilization:

- High cost of hearing aids, particularly in resource-limited settings
- Social stigma and cosmetic concerns
- Difficulty with hearing aid adjustment and maintenance
- Inadequate access to trained audiologists and dispensing services

- Limited awareness of hearing aid benefits
- Cognitive or motor difficulties affecting manipulation of devices

Implications for Healthcare Planning: The high proportion of hearing aid candidates necessitates strategic planning for:

1. Increased audiological services and trained personnel
2. Hearing aid procurement and sustainability
3. Patient education and counseling
4. Long-term follow-up and hearing aid maintenance services

Associated Symptoms: The presence of tinnitus in 57.4% of hearing-impaired patients is notable and consistent with literature indicating high comorbidity between hearing loss and tinnitus [10]. Tinnitus often accompanies both presbycusis and noise-induced hearing loss and can significantly impact quality of life. The lower prevalence of vertigo (14.4%) suggests that vestibular dysfunction is not commonly associated with this cohort's hearing loss, which is consistent with predominantly cochlear (versus retrocochlear or vestibular end-organ) pathology.

Speech Discrimination: The mean speech discrimination score of 58.3 ± 22.5% indicates variable outcomes in speech understanding even when stimuli are presented at adequate intensity. Low speech discrimination scores (<60%) noted in 31.8% of patients suggest that for these individuals, amplification alone may be insufficient for optimal communication, and they may require additional rehabilitative strategies including auditory rehabilitation, speechreading instruction, and environmental modifications[11].

Comparison with Literature: The findings of this study are consistent with numerous other studies examining hearing loss patterns in tertiary care settings and the general population:

- **Prevalence of SNHL:** The 72.8% prevalence aligns with global estimates of SNHL accounting for 90% of hearing loss cases [4][5].
- **Age-Related Patterns:** The predominance of severe hearing loss in elderly patients mirrors presbycusis epidemiology [1][6].
- **Male Predominance:** The 1.78:1 male-to-female ratio is consistent with epidemiological data [3].
- **Bilateral Involvement:** The 94.9% prevalence of bilateral hearing loss is characteristic of presbycusis [6].
- **Hearing Aid Candidacy:** The 84.6% rate meeting audiometric criteria aligns with other tertiary care center studies [1].

Limitations and Study Strength

Strengths:

1. **Adequate Sample Size:** 195 patients provides reasonable statistical power for detecting differences.
2. **Comprehensive Audiometric Data:** Detailed air and bone conduction thresholds across multiple frequencies enable precise classification.
3. **Standardized Grading System:** Use of WHO grading ensures comparability with other studies and international standards.
4. **Systematic Data Extraction:** Standardized data collection form minimizes bias and ensures consistency.

Limitations:

1. **Retrospective Design:** Inherent limitations of retrospective studies include potential missing data, incomplete documentation, and inability to control for confounding variables.
2. **No Etiological Correlation:** The study was unable to determine specific causes of hearing loss (noise exposure, ototoxic medications, medical comorbidities, and familial factors) due to incomplete documentation in medical records.
3. **Selection Bias:** The population studied represents those who presented to tertiary care with perceived hearing loss, not the general population, potentially overestimating prevalence of significant hearing loss.
4. **Lack of Follow-up Data:** No longitudinal follow-up data were available regarding hearing aid fitting, compliance, benefit, or long-term outcomes.
5. **No Socioeconomic Data:** Information regarding socioeconomic status, educational level, and occupational exposure was not systematically documented.
6. **Absence of Cognitive Assessment:** Cognitive status was not evaluated, which may affect hearing aid candidacy and adaptation.
7. **Limited Demographic Information:** Data on lifestyle factors, noise exposure, medication use, and medical comorbidities were incomplete.
8. **No Control Group:** The absence of an age-matched control group with normal hearing limits our ability to determine specific age-related changes.

Conclusion

This retrospective cross-sectional analysis of 195 patients with hearing impairment attending a tertiary care hospital reveals significant epidemiological patterns regarding the type, severity, and distribution of hearing loss in this population. The study demonstrates that:

1. **High Burden of Sensorineural Hearing Loss:** SNHL predominates in 72.8% of cases, consistent with global epidemiological trends and reflecting the age composition of the population.
2. **Moderate-to-Severe Severity Predominates:** 84.6% of patients present with moderate or greater hearing loss according to WHO criteria, indicating a population with substantial functional impairment.
3. **Clear Age-Related Progression:** A strong positive correlation between age and hearing loss severity ($r = 0.78$, $p < 0.001$) exemplifies presbycusis progression, with severe-to-profound loss becoming universal in patients above 80 years.
4. **Bilateral Symmetric Pattern:** The absence of statistically significant inter-ear differences indicates bilateral symmetric involvement characteristic of presbycusis, reducing suspicion for retrocochlear pathology.
5. **Substantial Rehabilitation Burden:** 84.6% of patients meet audiometric criteria for hearing aid recommendation, representing a significant public health challenge regarding hearing aid provision, fitting, and long-term management.
6. **Gender Differences:** Male predominance (M:F ratio 1.78:1) aligns with global epidemiological patterns, though hearing loss type distribution is similar between genders.

Clinical Implications and Recommendations

1. Early Detection and Prevention:

- Implementation of routine audiological screening programs, particularly in elderly populations and high-risk occupational groups (noise exposure)
- Public health campaigns to increase awareness of hearing loss as a modifiable risk factor
- Occupational health programs for noise exposure monitoring and hearing conservation

2. Timely Rehabilitation:

- Early intervention with appropriate hearing aids in moderate and greater hearing loss
- Comprehensive audiological assessment by trained specialists
- Individual fitting and programming of hearing aids with follow-up adjustment
- Auditory rehabilitation training including speechreading and communication strategies

3. Healthcare System Planning:

- Training and recruitment of adequate audiological personnel
- Establishment of sustainable hearing aid procurement and servicing systems
- Integration of hearing health into primary care systems
- Development of tertiary care audiology services

4. Multidisciplinary Approach:

- Collaboration between otolaryngologists, audiologists, and speech-language pathologists
- Comprehensive assessment of hearing-impaired patients including medical evaluation
- Exploration of medical or surgical management for conductive and mixed hearing loss
- Referral for cochlear implant evaluation in appropriate candidates with profound hearing loss

5. Patient Education:

- Education regarding progression of presbycusis and importance of early intervention
- Counseling regarding hearing aid benefits and realistic expectations
- Addressing stigma and psychosocial factors affecting hearing aid acceptance
- Guidance on communication strategies and environmental modifications

Future Research

Future studies should address the limitations of this retrospective analysis by:

1. Conducting prospective cohort studies with complete etiological data
2. Including longitudinal follow-up to assess hearing aid outcomes and quality of life improvements
3. Evaluating genetic and environmental risk factors contributing to hearing loss
4. Assessing the impact of hearing aid rehabilitation on functional, social, and cognitive outcomes
5. Examining barriers to hearing aid uptake and utilization in this population
6. Performing cost-effectiveness analysis of early detection and intervention programs

Limitations

1. **Retrospective Study Design:** As a retrospective cross-sectional analysis, this study is subject to inherent limitations of retrospective designs, including inability to establish temporal relationships, limited control over data collection methodology, and potential for incomplete or missing data in medical records. Causal inferences cannot be made from this study design.
2. **Lack of Etiological Correlation:** The study was unable to determine the specific etiology of hearing loss in individual patients due to incomplete documentation of occupational history, noise exposure details, medication

history (particularly ototoxic drugs), medical comorbidities, and family history of hearing loss in the medical records reviewed.

3. **Selection Bias:** The population studied comprises patients who presented to the tertiary care center with perceived hearing loss, not a representative sample of the general population. This selection bias likely results in overestimation of the prevalence and severity of significant hearing loss compared to community-based populations.
4. **Limited Demographic Information:** Essential demographic and clinical variables were incompletely documented, including socioeconomic status, educational level, occupational category, specific noise exposure history, smoking status, alcohol use, medication exposures, and comorbid medical conditions (diabetes, hypertension, cardiovascular disease) that may influence hearing loss risk.
5. **No Etiological Classification:** Patients were classified only by hearing loss type and severity, not by presumed etiology. The study does not differentiate between presbycusis, noise-induced hearing loss, ototoxic medication-induced loss, and other specific causes.
6. **Absence of Audiological Follow-up Data:** No information was available regarding hearing aid prescription, fitting outcomes, subjective benefit, long-term compliance and device use, or patient satisfaction post-intervention.
7. **No Cognitive Assessment:** Cognitive function was not systematically evaluated, which may affect hearing aid candidacy, ability to adapt to amplification, and rehabilitation success.
8. **Lack of Control Comparison:** The absence of age-matched control group with normal hearing limits the study's ability to characterize specific age-related changes in hearing thresholds.
9. **Limited Speech Audiometry Data:** Not all patients had complete speech discrimination testing, limiting assessment of functional communication ability beyond pure tone thresholds.
10. **Single-Center Study:** Data from a single tertiary care hospital may not be generalizable to other regions or healthcare settings with different demographics, healthcare infrastructure, and access to services.
11. **Geographic Limitations:** The study was conducted at a single center in South India, limiting generalizability to other geographic regions with different demographic profiles and environmental exposures.
12. **Incomplete Imaging Data:** Neuroimaging (MRI/CT) data for evaluation of retrocochlear pathology were not systematically documented, though clinical presentation suggested low likelihood.

Data Availability: The datasets used and analyzed during this study are available from the corresponding author upon reasonable request, subject to institutional ethical review.

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