Section: ENT

Original Research Article

CORRELATION BETWEEN EAR CANAL VOLUME AND SUSCEPTIBILITY TO NOISE-INDUCED HEARING LOSS

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ABSTRACT

Background: Noise-induced hearing loss (NIHL) is a prevalent type of sensori-neural hearing impairment, constitutes a significant health issue, and is predominantly preventable. The National Institute on Deafness and Other Communication Disorders estimates that 15% of the population experiences diminished hearing attributable to loud noise from occupational settings, recreational activities, or mobile phone usage. The volume of the ear canal is a crucial factor in forecasting noise-induced hearing loss (NIHL). Therefore, the current study was undertaken to evaluate the prevalence of Noise-Induced Hearing Loss (NIHL) in persons with varying ear canal volumes.

Material and Methods: A cross-sectional study was done among 60 industrial workers presented to the ENT department in a tertiary care centre for ENT complaints. Information was gathered about hearing thresholds, ear canal volume, occupational noise exposure, and demographic traits. Tympanometry was used to estimate the volumes of the ear canals in both ears, and pure-tone audiometry was used to evaluate hearing loss. Pearson's correlation coefficient was used to analyse the relationship between hearing loss and ear canal volumes.

Results: The majority of people had normal hearing in both ears (right: 73.4%; left: 71.6%), whereas a smaller percentage had mild to moderate hearing loss. Ear canal volume and hearing loss were significantly correlated negatively in both ears (right ear: $r = -0.791$, $p = 0.01$; left ear: $r = -0.804$, $p = 0.01$). Ear canal volumes were 1.108 ± 0.162 mL on the right and 1.117 ± 0.156 mL on the left. The mean ear canal volume was highest among participants with normal hearing (1.195 mL), followed by those with mild hearing loss (0.932 mL) and moderate hearing loss (0.777 mL).

Conclusion: The study found that significant correlations were identified between ear canal volume and calculated length (resonance). Subjects with subjects with smaller ear canal volumes suffered with more hearing loss compared to normal ear canal volume.

Keywords: Noise induced hearing loss, ear canal volume, ear canal resonance.

INTRODUCTION

Noise-induced hearing loss (NIHL) is the second most prevalent cause of sensori-neural hearing loss, following age-related hearing loss, and impacts roughly 5% of the global population.[1] In humans, there exists considerable heterogeneity in susceptibility to noise-induced hearing loss among people, even when subjected to identical or comparable levels of noise exposure. Noise-induced hearing loss results from multifactorial damage to auditory structures due to exposure to loud sounds from occupational, environmental, or recreational causes.[2]

Noise-Induced Hearing Loss can be unilateral, impacting one ear, or bilateral, affecting both ears, with hearing impairments that may be transitory or permanent. The duration and severity of NIHL are contingent upon the degree and site of cellular damage, which correlates with the strength and duration of the auditory stimuli. The mammalian auditory sensory epithelium, known as the organ of Corti, lacks the ability to spontaneously regenerate

following the loss of sensory cells. Consequently, noise-induced degeneration of hair cells or neural structures can lead to irreversible hearing loss, especially with repeated exposure. Moreover, NIHL is often permanent and can significantly detriment an individual's quality of life as well as the economy and society as a whole.[3,4]

The ear canal volume (ECV) significantly affects the risk and severity of noise-induced hearing loss. ECV denotes the physical volume within the external auditory canal, which differs among individuals owing to variations in anatomical structure, age, and sex. This volume influences the transmission of sound pressure levels (SPLs) to the eardrum and, subsequently, to the inner ear.[5,6]

Reduced ear canal capacities yield elevated sound pressure levels at the eardrum when subjected to same external noise compared to larger volumes. This phenomenon, elucidated by the principles of acoustic impedance, heightens the danger of harm to the fragile hair cells in the cochlea, which are fundamental to sound transduction. Thus, persons with reduced ECVs may exhibit increased vulnerability to NIHL at diminished noise exposure levels.

Larger ECVs typically disseminate sound energy across a wider region, hence diminishing the intensity of sound that reaches the eardrum.[7] Although this may provide some natural protection, extended or sustained exposure to high-decibel noise can still result in Noise-Induced Hearing Loss, regardless of canal volume. Ear canal resonance is believed to contribute to the significant hearing loss in the 3.0 to 6.0 kHz range resulting from excessive noise exposure.[8]

Only very few studies were shown the significant relationship between the frequency of maximum transient threshold shift (TTS) and the physical parameters of the ear canal.

Comprehending the correlation between ECV and NIHL is essential for the development of efficient hearing protection devices. Custom-molded earplugs or earmuffs designed to fit an individual's ear architecture can deliver optimal attenuation and diminish the risk of Noise-Induced Hearing Loss (NIHL).

Aim & Objective

To assess the prevalence of NIHL in individuals with varying ear canal volumes.

MATERIALS AND METHODS

Our study was conducted in the Department of ENT at a tertiary care centre to assess ear canal volume and its susceptibility to noise-induced hearing loss. A cross-sectional study design was used among patients who worked in the industry with an occupational history of noise exposure. The patients presented to the Department of ENT with complaints of being hard of hearing, and aged 18 – 60 years, were included in this study. The patients with a history of ear diseases, infections, medical and surgical procedures in the ear canal or middle ear, patients with pre-existing hearing impairment, or diagnosed hearing conditions such as presbycusis, otosclerosis, or acoustic trauma, Participants with current or past ear diseases (e.g., chronic otitis media, ear infections, or tympanic membrane perforation), Participants who cannot complete pure-tone audiometry or tympanometry due to physical or cognitive limitations and Participants using ototoxic drugs (e.g., certain chemotherapy drugs or high doses of aspirin) were excluded from this study.

A study conducted by G.P. Rodriguez et al6 showed a significant positive correlation between ear canal morphology and NIHL. Assuming a similar level of correlation will be obtained in our study, an adequate sample size for this study, with 90% power at a 5% level of significance, is 40. However, considering the subgroup analysis, we recruited 60 workers as per the inclusion and exclusion criteria. The participants were selected using a non-probability sampling method, purposive sampling.

This study was approved by the institutional ethical committee of Trichy SRM Medical College Hospital, Trichy, and the study was carried out. The baseline characteristics of participants were collected by interviewing the patient using a semi-structured questionnaire. The ear canal volume was measured by Tympanometry among the participants after getting written consent. The otoscopic examination was done to visualize any infections or foreign bodies in the middle ear. If any participants were found with abnormal examination, they were excluded from this study. The probe part of the tympanometer was inserted into the right as well as the left ear to record the tympanogram values.

Hearing thresholds were classified according to the standard WHO criteria into normal, mild, moderate, severe, and profound hearing loss using Pure Tone Audiometry (PTA). Every audiogram in the study was assessed using an Arphi audiometer. Both bone and air conduction tests, covering frequencies from 1000 Hz to 8000 Hz, were performed on each ear. Based on the results, hearing loss was divided into five groups according to hearing threshold levels: Mild hearing loss (HL) was defined as 26–40 dB, moderate HL (41–55 dB), moderately severe HL (56–70 dB), severe HL (71–90 dB), and profound HL (any threshold above 90 dB).

The data that were collected were interpreted using Microsoft Excel 2021 version and Statistical software SPSS version 21. The continuos variable like ear canal volume was represented as mean and standard deviation and categorical variables was expressed as proportions. The correlation coefficient was interpreted using the Pearson correlation coefficient, considering a significant p value of < 0.05.

RESULTS

This study was conducted among industrial workers who were presenting to the ENT department to

determine the ear canal volume and its susceptibility to noise-induced hearing loss.

The baseline characteristics of the 60 study participants are summarised in Table 1. Those between the ages of 20 and 30 made up the largest percentage of participants (45%), followed by those between the ages of 31 and 40 (36.7%) and 41 and 50 (18.3%). Women made up 21.7% of the sample, while men made up the majority of participants (78.3%). In terms of noise exposure at work, 75% of participants had been exposed for less than five years, whereas 25% had been exposed for five years or longer.

Table 1: Baseline characteristics of participants (n = 60)

S No	Variables		Frequency	Proportion
1	Age	20 – 30 years	27	45%
		31 – 40 years	22	36.7%
		41 – 50 years	11	18.3%
2	Gender	Male	47	78.3%
		Female	13	21.7%
3	Duration of occupational noise exposure	≥ 5 years	15	25%
		< 5 years	45	75%

The distribution of hearing loss among individuals is shown in Figure 1. The majority of people had normal hearing in both ears (71.6% (43) in the left ear and 73.4% (44) in the right). The prevalence of mild hearing loss was marginally higher in the left ear (21.6%) than in the right (18.3%). Only 8.3% of participants had moderate hearing loss in their right ear and 6.6% in their left. This study shows that neither ear showed any signs of profound or severe hearing loss.

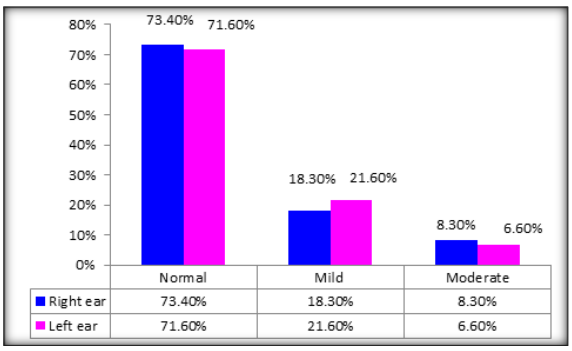

Figure 1: Hearing loss among participants

The mean ear canal volume in the right ear among participants was 1.108±0.162 ml, and it was 1.117±0.156 in the left ear.

Figure 2 shows the mean ear canal volume measured in both ears compared with hearing loss (n = 120). The mean values among participants with normal hearing, mild hearing loss, and moderate hearing loss were 1.195 ml, 0.932 ml, and 0.777 ml, respectively.

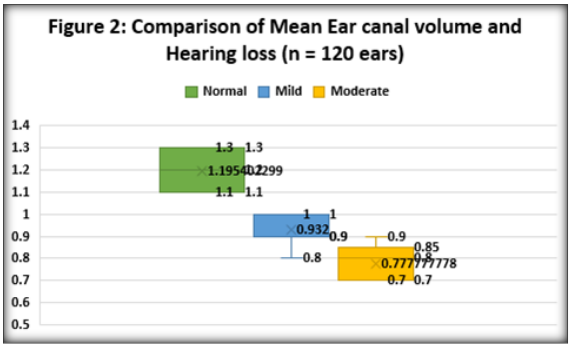

Figure 2: Comparison of mean Ear canal volume and Hearing loss (N= 120 ears)

Table 2 shows the correlation between ear canal volume and hearing loss among participants (n = 60) The association between ear canal volume and the extent of hearing loss in both ears in 60 people was evaluated using a Pearson correlation analysis. Ear canal volume and hearing loss were shown to be strongly correlated negatively for both ears, as indicated in Table 2. A statistically significant inverse association was indicated for the right ear by the correlation coefficient, which was r = -0.791 with a p-value of 0.01. Correlation for the left ear was r = -0.804, with a p-value of 0.01 as well

Table 2: Correlation of Ear canal volume and Hearing loss (n = 60)

S No	Ear	r value	p value
1	Right ear	-0.791	0.01
2	Left ear	-0.804	0.01

DISCUSSION

Hearing loss caused by exposure to occupational noise results in a devastating disability that is 100% preventable. Our study report found that majority were in the age group of 20- 30 yrs. followed by those between the ages of 31 and 40 (36.7%) and 41 and 50 (18.3%). Most of the study participants around 78.3% were males and the rest were females. Around 75% of the study population had been exposed for occupational noise for less than five years, whereas 25% had been exposed for five years or longer.

The majority of people had normal hearing in both ears (71.6% (43) in the left ear and 73.4% (44) in the right). The prevalence of mild hearing loss was marginally higher in the left ear (21.6%) than in the right (18.3%). Only 8.3% of participants had moderate hearing loss in their right ear and 6.6% in

their left. This study shows that neither ear showed any signs of profound or severe hearing loss. The mean ear canal volume in the right ear among participants was 1.108±0.162 ml, and it was 1.117±0.156 in the left ear. The mean ear canal volume measured in both ears compared with hearing loss (n = 120). The mean values among participants with normal hearing, mild hearing loss, and moderate hearing loss were 1.195 ml, 0.932 ml, and 0.777 ml, respectively. A statistically significant inverse association was indicated for the right ear by the correlation coefficient, which was r = -0.791 with a p-value of 0.01. Correlation for the left ear was r = -0.804, with a p-value of 0.01 as well.

Our study report aligns with the research conducted by Gerhardt et al,[9] which indicated that thirty subjects had the most significant TTS at 4.0 kHz, while seventeen and nine subjects exhibited the highest shift at 3.0 and 6.0 kHz, respectively. Subjects categorized by frequency of maximum TTS exhibited a statistically significant difference in mean ear canal volume. Subjects with greater levels were more prone to experience the most significant loss at 3.0 kHz. Consequently, individuals with reduced ear canal sizes experienced maximum hearing loss at 6.0 kHz. Notable connections were observed between ear canal volume and computed length (resonance). Additionally, modest associations were observed between the frequency of maximum TTS and volume, as well as between TTS and length.

Our study report is compared to research by Rodriguez et al., which indicated that among 31 normal-hearing subjects, measurements of acoustic gain of the external ear and temporary threshold shift (TTS) revealed a correlation between the frequency most affected by noise exposure (Max TTS) and the primary resonant frequency of the outer ear (Max RF). A notable positive association between these two metrics was established. A 100 Hz variation in Max RF led to about 140 Hz alterations in Max TTS. Consequently, the external ear significantly influences the frequencies impacted by wideband noise exposure.[10]

NIHL is defined by high-frequency hearing loss, which may exhibit a high-frequency notch on the audiogram. The resonance theory posits that the characteristic 4K notch in noise-induced hearing loss (NIHL) is attributable to the physiological characteristics of the human external auditory canal. Barrs et al.10 identified a minor noise-induced hearing loss (NIHL) notch at 3–6 kHz in nearly one-third (37%) of the workers in their study, despite the absence of symptoms. Pierson et al,[11] reported that in their investigation, the mean frequency of maximal hearing loss was 4,481 Hz, while the mean peak outer ear resonant frequency was 2,814 Hz for 43 ears, with a statistically significant P value of < .0001.

A review article by Akhtar NH et al,[12] indicated a positive correlation between outer ear resonance frequency and the frequency of maximum hearing loss, highlighting the significant influence of external ear characteristics on the emergence of the 4 kHz audiometric notch, which aligns with our study findings.

CONCLUSION

The study found that significant correlations were identified between ear canal volume and calculated length (resonance). Subjects with subjects with smaller ear canal volumes suffered with more hearing loss compared to normal ear canal volume. The study highlighted that ear canal volume may serve as potential anatomical predictor of hearing loss. The study also recommends that awareness and screening program should be emphasized for prevention and early detection of noise induced hearing loss.

Limitations

- The larger sample size might be considered for generalising results.

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