

A Prospective Observational Study to Establish a Correlation Between Tinnitus and Hearing Loss

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ABSTRACT

Introduction

The prevalence of tinnitus in adults with hearing problems is very high (59 - 86%). Both tinnitus and sensorineural hearing loss can occur when there is damage throughout the auditory pathway from the inner ear to auditory cortex. Our aim of the study was to evaluate the prevalence of hearing loss in patients with tinnitus and to assess the association between tinnitus and hearing loss.

Materials and Methods

This prospective observational study was conducted for 12 months between May 2022 and April 2023. 60 patients of both the sexes >15 years of age presenting with tinnitus in one or both ears were included in our study. Mentally ill and/or intoxicated patients were excluded. After clinical examination patients underwent Pure Tone Audiometry - average was calculated across 500, 1000, 2000, 4000 Hz in terms of air conduction, bone conduction and air bone gap. Hearing loss was classified as conductive, sensorineural and mixed types. Tinnitus pitch and loudness matching was done for which opposite ear was taken as test ear. In cases of bilateral tinnitus with equal intensity, right ear was taken first as test ear. In case of bilateral tinnitus with unequal intensity, ear with higher intensity tinnitus was tested first. Sensation level of tinnitus was calculated by subtracting the hearing loss threshold from tinnitus loudness in decibel.

Results

In our study the mean age was found to be 44.20 ± 17.01 years, with a male preponderance, and maximum number of cases complaining of left sided tinnitus. In an attempt to find a correlation between tinnitus and hearing loss, in right and left ears separately, 'P' value calculated to be <0.001 . We also attempted to find a correlation between highest hearing loss and tinnitus loudness. We found that relative coefficient, 'r' being 0.309 on right side and 0.270 on left side. 'P' value on right is 0.097 and on left is 0.117.

Conclusion

Since most of the cases of tinnitus also complaints of hearing loss, so it is necessary to identify a relation between the two. If a relation between tinnitus and hearing can be identified, it helps to identify the pathophysiology, which will further be helpful to plan the line of management. There are very limited number of studies conducted. Our study suggests a definite relation between tinnitus and hearing loss though there is no statistically significant correlation found between tinnitus loudness and highest hearing loss in the same ear.

Keywords

Tinnitus; Hearing Impairment

The prevalence of tinnitus in adults with hearing problems is very high (59 - 86%), and it is estimated that tinnitus is present in 50% of patients with sudden hearing loss, 70% with presbycusis and 50 - 90% with noise-induced hearing loss.^{1,2}

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Both tinnitus and sensorineural hearing loss can occur when there is damage throughout the auditory pathway from the inner ear to auditory cortex. Tinnitus might be coded in the auditory cortex in three presumed ways. One - that tinnitus originates from an increase in spontaneous activity which could be a result of several different excitatory and inhibitory changes from the brainstem. Second - that tinnitus represents an increase in synchrony across nerve fibres. Third - that tinnitus originates from reorganization of the central auditory system after hearing loss.³

Hearing loss, specifically the extent of high-frequency impairment in the worse ear, is one of the main predicting factors for tinnitus.^{1,4} Conductive hearing loss seems to be a separate factor,^{1,5} and noise exposure has been correlated with tinnitus as well.^{1,6} Tinnitus is also experienced by those with normal hearing; 18% of tinnitus patients were reported to have normal hearing.^{1,5}

Although tinnitus is normally associated with hearing loss, air-conduction levels at 1000 and 4000 Hz were equal to or less than 25 dB HL for 18% of sample in a study by Stouffer and Tyler. Thus, some patients had relatively normal hearing up to 4000 Hz, and the communication handicap resulting from their hearing loss was minimal. These patients may respond to tinnitus maskers better than they do to hearing aids.⁵

There are many difficulties which tinnitus sufferers share with hearing impaired listeners. Both feel that their particular symptom has contributed to difficulties in listening to speech, music, environmental sounds and in auditory localization. Both groups also complain about difficulties at work, family problems, loneliness, insecurity and irritability. Barcham and Stephens found that majority of hearing-impaired respondents had problems associated with work, whereas in tinnitus group work problems were ranked 16th most difficulty.⁷

Men seem to report a higher prevalence, although the difference is not so large (6.6% in men and 5.6% in women).⁸ In children, prevalence is in hearing impaired children, but interestingly, only 3% complained of this spontaneously.^{8,9}

Hearing loss is a risk factor for tinnitus and even tinnitus patients with normal audiogram might have

restricted cochlear damage or hearing loss at frequencies above 8 KHz, which is not detected by normal clinical audiometry. The tinnitus sensation and the frequency range of hearing loss are related, when subjects match their tinnitus pitch to a pure tone, most of the matches are at frequencies at which hearing is impaired. When subjects are asked to judge the contribution of comparison tones to their tinnitus sensation, the resulting spectra span wide frequency ranges that correspond to the frequencies where hearing loss is present. However, not all patients with hearing loss develop tinnitus, as demonstrated by the higher prevalence of hearing loss compared to tinnitus.¹⁰

George F Reed did a study of audiometric evaluation of 200 patients with tinnitus. Pure tone audiometry and tinnitus matching was done in all the patients. 87% of the patients described the tinnitus as being constant. 53% of the patients were aware of decreased hearing while 92.5% were found to have decreased hearing (more than 10dB at 500, 1000, and 2000 Hz) when tested audiometrically. It is interesting to note that Venters et al reported tinnitus occurred without deafness in 7.5% of cases.¹¹ This is exactly the same result as George F Reed found in their study. In this study George F Reed also found deafness in 10% was conductive, in 83.5% sensorineural and mixed in 6.5%.¹²

Loudness matching procedures for measuring tinnitus "intensity" usually yield figures of less than 10dB SL for more than half of the subjects tested. In other words, complaining subjects who say that their tinnitus is disturbing appears to be matching external sounds which would be judged by most other people as "quiet".¹²

In a review of assessment procedures for tinnitus McFadden noted several measurement problems.¹³ He points out the error of thinking that near-threshold intensities cannot be perceived as loud or that annoyance is a function of loudness. Moreover, an internal sound might behave differently in response to a weak external sound in its ability to produce annoyance. He quotes the finding that a constant external sound can gradually lose its masking effect over a tinnitus through the course of about 30min of continuous listening.^{13,14} In contrast, the masking threshold remained fairly constant for an external

sound of intensity less than 10dB SL. Further a tinnitus localized in one ear can be effectively masked by sounds presented to the other. The sound intensities required for contralateral masking do not appear to differ significantly from ipsilateral masking levels.^{13,15}

Since the well-known Heller and Bergman experiment, it is widely believed that tinnitus is a common subaudible physiological phenomenon of the normal auditory system. In their study, 94% of apparently normal hearing individuals experienced tinnitus when placed in a soundproof room for 5 mins.^{16,17}

Tucker et al also investigated the effect of silence on the perception of tinnitus in 120 normal hearing young adults. Each person was seated in the sound booth and given instructions for the “listening experiment” for a period of 2 mins. No acoustic signal was presented, but auditory activation was strongly activated again, and tinnitus-like sounds were perceived in 64% of listeners.^{17, 18}

Materials and Methods

Our aim of the study was to evaluate the prevalence of hearing loss in patients presenting with tinnitus coming to our institute and to assess the association between tinnitus and hearing loss. 60 patients of both the sexes >15 years of age presenting with complaints of tinnitus in one or both ear were included in our study. Mentally ill and/or intoxicated patients were excluded from our study. This prospective observational study was conducted for 12 months between May 2022 and April 2023.

The 38 male and 22 female patients were aged between 15 yrs to 80 yrs. Patients presenting with complaint of unilateral or bilateral tinnitus with or without hearing loss or any audiological symptoms, irrespective of duration of tinnitus were taken in the study.

After complete otorhinolaryngological examination patients underwent pure tone audiometry. We used

automatic Diagnostic Shree Electronics Audiometer Aryan 5000A for pure tone audiometry and tinnitus pitch matching which could measure up to 8000 Hz. A pure tone average was calculated across 500, 1000, 2000, 4000 Hz. For each ear air conduction, bone conduction and air bone gap was calculated. Accordingly, type of hearing loss was estimated between conductive, sensorineural and mixed type. Tinnitus pitch and loudness matching was done for which opposite ear was taken as test ear. In case of bilateral tinnitus with equal intensity, right ear was taken first as test ear. In case of bilateral tinnitus with unequal intensity, ear with higher intensity tinnitus was taken first as test ear. Sensation level of tinnitus was then calculated by subtracting the hearing loss threshold from tinnitus loudness in decibel. After audiological tests and tinnitus matching we tried to assess whether there is any relation between tinnitus and hearing loss.

Results

Our study, “A prospective observational study to establish a correlation between tinnitus and hearing loss” was conducted in the Department of ENT of our institute from May 2022 to April 2023. 60 patients were selected for the study that had complaints of tinnitus with or without any other ENT complaints. All patients underwent complete ENT examination followed by pure tone audiometry and tinnitus matching for pitch and loudness. The aim of our study was to find a correlation between hearing loss and tinnitus.

The patients selected in our study were above 15 years of age. There was no upper limit for age. Out of 60 patients 5 (8.3%) were in the age group of 0-20 years, 22 (36.7%) in 21-40 years group, 22 (36.7%) in 41-60 years group and 11 (18.3%) in 61-80 years age group. On analysis, the mean age of these groups was 44.20 ± 17.01 with minimum age being 15 years and maximum being 80 years. Among 60 patients, 23 (38.3%) were female and 37 (61.7%) were male patients. Out of all 60 patients, 27 (45%) experienced tinnitus in left ear while 20 (33.3%) experienced on their right side. Bilateral tinnitus was noted in 13 patients.

On audiometry, it was found that air conduction mean on right ear is 45.97dB with a standard deviation of

18.68dB and the mean on left side is 45.16dB with a standard deviation of 21.66dB. The bone conduction mean on right side is calculated to be 24.21dB with standard deviation of 15.56dB and on left side it was 25.18dB with standard deviation of 15.83dB. The mean of A-B gap was evaluated on right to be 21.76 ± 10.56 dB and on the left to be 19.89 ± 9.47 dB. (Table I)

Table I: Pure tone audiometry results

	SITE OF TINNITUS	
	RIGHT	LEFT
	MEAN \pm SD	Mean \pm SD
N	33	40
Air conduction (dB)	45.97 \pm 18.68	45.16 \pm 21.66
Bone conduction (dB)	24.21 \pm 15.56	25.18 \pm 15.83
A-B gap (dB)	21.76 \pm 10.56	19.89 \pm 9.47

Conductive hearing loss is noted in 6(18.2%) on right side and 7(17.5%) on left side. While sensorineural loss noted in 6(18.2%) on right side while 11 (27.5%) cases had left sided sensorineural hearing loss. Mixed loss is seen in 12 (36.4%) patients on right and 10 patients (25%) on left patient. Patients with normal hearing too experienced tinnitus 9 (27.3%) on right and 12 (30%) on left.

Pitch matching of tinnitus was done and it was noted that 18.2% on right and 2.5% on left tinnitus were matched for narrow band sound. 2 (6.1%) patients on right and 4 (10%) on left were matched at 250Hz, none on right and 3(7.5%) on left were matched at 500Hz, at 1000Hz 1(3%) was matched on right and 6(15%) on left. At 2000Hz matching was found in 3(9.1%) on right and none on left. At 4000 Hz 2 (6.1%) were matched on right and 7 (17.5%) on left. 11(33.3%) in right and 6(15%) in left were matched at 6000Hz. At 8000 Hz 5(15.2%) on right and 6 (15%) on left were matched. Wide band noise noted 3(9.1%) on right and 6(15%) on left. (Table II)

Table II: Pitch matching

PITCH MATCHING	RIGHT	LEFT
NB	6 (18.2%)	1 (2.5%)
NIL	0 (0%)	1 (2.5%)
250 HZ	2 (6.1%)	4 (10%)
500 HZ	0 (0%)	3 (7.5%)
1000 HZ	1 (3%)	6 (15%)
2000 HZ	3 (9.1%)	0 (0%)
4000 HZ	2 (6.1%)	7 (17.5%)
6000 HZ	11 (33.3%)	6 (15%)
8000 HZ	5 (15.2%)	6 (15%)
Wide band	3 (9.1%)	6 (15%)
Total	33 (100%)	40 (100%)

Sensation level of tinnitus loudness was noted in dB. In 1(1.7%) case with left sided tinnitus no match was found. In 1(1.7%) case with right sided tinnitus SL was found to be 5dB. 10dB SL found in 4(6.7%) cases on right side and 5(8.3%) cases on left. 15dB SL seen in 12(20%) on right and 15 (25%) on left.. 20dB SL seen in 7(11.7%) on right and 8 (13.3%) on left. 25dB SL seen in 6(10%) on right and 8 (13.3%) on left. 30dB SL seen in 3(5%) on right and 2 (3.3%) on left. 40dB SL seen in 1 (1.7%)case on left side. (Table III)

In an attempt to find a correlation between tinnitus and hearing loss, following data was revealed. In RE, 2 (100%) cases had tinnitus at 250 Hz with maximum hearing loss at the same frequency. 1 (100%) case had tinnitus at 1000Hz and matched with at the same frequency with maximum hearing loss. At 2000Hz out of 3 cases no relation was observed. At 4000Hz in 2 (100%) cases, relation was found. At 6000 Hz 7 (63.6%) cases, relation was observed. In 4 (80%) relation was observed at 8000Hz. 'P' value calculated to be <0.001. (Table IV)

Table III: Loudness matching

SENSATIONAL LEVEL IN DB	RIGHT		LEFT	
	N	%	N	%
Nil	0	0.0%	1	1.7%
5 dB	1	1.7%	0	0.0%
10 dB	4	6.7%	5	8.3%
15 dB	12	20.0%	15	25.0%
20 dB	7	11.7%	8	13.3%
25 dB	6	10.0%	8	13.3%
30 dB	3	5.0%	2	3.3%
40 dB	0	0.0%	1	1.7%

Table IV: Relation between maximum hearing loss pitch and tinnitus matching pitch for RE

RE FREQUENCY AT WHICH MAXIMUM HEARING LOSS NOTED	RE PITCH MATCHING								P VALUE
	250Hz FRE- QUENCY (%)	1000Hz FRE- QUENCY (%)	2000Hz FRE- QUENCY (%)	4000Hz FRE- QUENCY (%)	6000Hz FRE- QUENCY (%)	8000Hz FRE- QUENCY (%)	NB FRE- QUENCY (%)	Wide Band FRE- QUENCY (%)	
250Hz	2 (100%)	0 (0%)	0 (0%)	0 (0%)	4 (36.4%)	1 (20%)	0 (0%)	0 (0%)	< 0.01
1000Hz	0 (0%)	1 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
4000Hz	0 (0%)	0 (0%)	2 (66.7%)	2 (100%)	0 (0%)	0 (0%)	2 (33.3%)	2 (66.7%)	
6000Hz	0 (0%)	0 (0%)	0 (0%)	0 (0%)	7 (63.6%)	0 (0%)	1 (16.7%)	0 (0%)	
8000Hz	0 (0%)	0 (0%)	1 (33.3%)	0 (0%)	0 (0%)	4 (80%)	3 (50%)	1 (33.3%)	
Total	2 (100%)	1 (100%)	3 (100%)	2 (100%)	11 (100%)	5 (100%)	6 (100%)	3 (100%)	

On left ear, at 250Hz no correlation was seen. At 500Hz, out of 3 cases 2 (66.7%) cases the correlation was seen. At 1000Hz in 2(40%) out of 5 cases correlation was seen. At 4000Hz in 5 (71.4%) cases correlation was

observed out of 7 cases. At 6000 Hz correlation was observed in 4(66.7%) out of 6 cases. In 3 (50%) correlation was seen at 8000Hz. The 'P' value is <0.001. (Table V)

Table V: Relation between maximum hearing loss pitch and tinnitus matching pitch for LE

LE FREQUENCY AT WHICH MAXIMUM HEARING LOSS NOTED	RE PITCH MATCHING								P VALUE
	250Hz FRE-QUENCY (%)	500Hz FRE-QUENCY (%)	1000Hz FRE-QUENCY (%)	4000Hz FRE-QUENCY (%)	6000Hz FRE-QUENCY (%)	8000Hz FRE-QUENCY (%)	NB FRE-QUENCY (%)	Wide Band FRE-QUENCY (%)	
250 Hz	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (33.3%)	< 0.01
500 Hz	4 (100%)	2 (66.7%)	2 (40%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
1000 Hz	0 (0%)	0 (0%)	2 (40%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
2000 Hz	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)	
4000 Hz	0 (0%)	1 (33.3%)	1 (20%)	5 (71.4%)	0 (0%)	2 (33.3%)	0 (0%)	2 (33.3%)	
6000 Hz	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (66.7%)	0 (0%)	0 (0%)	0 (0%)	
8000 Hz	0 (0%)	0 (0%)	0(0%)	2 (28.6%)	2 (33.3%)	3 (50%)	1 (100%)	1 (16.7%)	
Total	4 (100%)	3 (100%)	5 (100%)	7 (100%)	6 (100%)	6 (100%)	1 (100%)	6 (100%)	

In both ears we attempted to find a correlation between highest hearing loss and intensity of tinnitus. No significant relation was identified in this case in either ear with relative coefficient, 'r' being 0.309 on right side and 0.270 on left side. 'P' value on right is 0.097 and on left is 0.117, showing insignificant correlation. (Table VI)

Table VI : Relation between highest hearing loss and sensation level of tinnitus

		RE SENSATION LEVEL IN DB	LE SENSATION LEVEL IN DB
Highest hearing loss in RE	r	0.309	
	P value	0.097	
Highest hearing loss in LE	r		0.270
	P value		0.117

Discussion

The patients selected for our study were in the age group of 15-80 years. Of these, maximum number of cases were (36.7% each) in the age group of 21-40 and 41-60 years. The mean age was found to be 44.20± 17.01years.

Similar age distribution was reported by George F Reed et al in 1959 in their study, where they found maximum number of cases (25%) in the age group of 20-50 years.¹² Kafka in his study of 25 cases found the greatest number of patients between 40-78 years.¹²

The results differ from a study by Richard S Tyler (1983) where the average age was 60.7 years with SD of 13.1.⁷

In the current study, out of 60 patients, 23 (38.3%) were female and 37(61.7%) were male, showing a male preponderance. Heller AJ has mentioned that men seem to report a higher prevalence of tinnitus than women, although this is not a large difference (6.6% in men versus 5.6% in women, according to the Canadian study). This may be related to higher hearing thresholds in the male population.¹⁹ Reed F George in his study found equal distribution in both sexes.¹²

In our study, of the 60 patients, maximum number of cases 27 (45%) patients complained of left sided tinnitus. Heller AJ has mentioned that tinnitus is 1.5 times more likely to occur in the left ear.¹² Axelson Alf in his study (1989) found that for both men and women it was more

common on left side. That is in his study he reported 62% females and 68% males had left sided tinnitus which is in agreement to our study.⁶ Although most of the studies have not given any suggestive reason for left sided tinnitus.

In our study, we did pure tone audiometry for all the cases and estimated air conduction, bone conduction and A-B gap for each ear. It was found that the mean air conduction on right side is 45.97 ± 18.68 dB and for left ear is 45.16 ± 21.66 dB. The mean of bone conduction on right side is 24.21 ± 15.56 dB and on left side is 25.18 ± 15.83 dB. The A-B gap calculated on right with a mean of 21.76 ± 10.56 dB on right and on left is 19.89 ± 9.47 dB.

Erlandsson et al (1992) in their study also had similar findings. In their study pure tone average thresholds were 26.3 dB and 27.4 dB for right and left respectively. Also they found 41% of cases were with left sided localization and 32% right sided localization.¹⁹

The study revealed that in the study population most common type of hearing loss is mixed (36.4% on right and 25% on left) followed by normal (27.3% on right and 30% on left), sensorineural (18.2% on right and 27.5% on left). Least common was conductive loss (18.2% on right and 17.5% on left). Unlike our study, Reed F George et al in their study found 10% conductive, 83.5% sensorineural and 6.5% mixed.¹²

In most cases, tinnitus pitch was found to be of high frequency. Maximum number of Cases had pitch matching in 6000 Hz (33.3% on right and 15% on left), followed by 8000 Hz (15.2% on right and 15% on left) and 4000 Hz (6.1% on right and 17.5% on left). Pan Tao et al (2009) in their study found that average pitch was 4968 Hz with 50% of cases had tinnitus at 8000 Hz or above. Reed (1960) and Vernon (1987) found that most of the patients have their pitch match frequency around and above 3000 Hz. Stouffer and Tyler (1990) observed that patients typically rated their tinnitus as being high pitched. Meikle (1995) reported that the pitch match frequency in 33% patients was between 3500 and 6499 Hz.³ Meikle et al 2003 reported that 75% of the patients matched their tinnitus pitch at or above 4000 Hz. The median pitch for the entire group of 1519 patients was 6000 Hz.²⁰ Our finding is in agreement with all the previous studies. Pitch matching

may differ based on type and perspective of tinnitus but different types of tinnitus was not considered in our study and hence no comment is possible in this regard.

In our study, we calculated the sensation level in dB of the tinnitus and found that most cases had tinnitus in SL 15 dB (20% on right and 25% on left) followed by 20 dB (11.7% on right and 13.3% on left). Meikle et al (2003) reported 70% of the loudness matches are at or below 6 dB SL, and 84% are below 9 dB SL. Reed F George et al (1960) reported that in their study 69% of cases were below 10 dB SL.

In cases with right ear tinnitus, it was found that 100% cases had a definite relation between tinnitus pitch match and frequency at which maximum hearing loss is seen at frequencies 250 Hz, 1000 Hz and 4000 Hz. At 6000 Hz, in 63.6% cases relation was observed. At 8000 Hz, in 80% cases relation was observed. The p value calculated to be <0.001 . In cases with left ear tinnitus, the relation between tinnitus pitch and frequency of maximum hearing loss is seen to be 100% at 250 Hz, 66.7% at 500 Hz, 40% at 1000 Hz, 71.4% at 4000 Hz, 66.7% at 6000 Hz, 33.3% at 8000 Hz. The 'P' value calculated to be <0.001 . Konig et al (2006) studied 71 patients who had moderate to severe high frequency noise induced hearing loss. They found that there was association between tinnitus and edge frequency of audiogram.³

In our study, we made an attempt to find a relation between tinnitus loudness and highest hearing loss in the same ear. We found that relative coefficient, 'r' being 0.309 on right side and 0.270 on left side. 'P' value on right is 0.097 and on left is 0.117, showing insignificant relation. Reed F George (1960) also stated in his study that objectively determined loudness of the patients' tinnitus had no apparent relation to the amount of audiometrically determined hearing loss or deafness.¹²

Conclusion

Since most of the cases of tinnitus also complaints of hearing loss, so it is necessary to identify a relation between the two. If a relation between tinnitus and hearing loss can be identified, it helps to identify the

pathophysiology, which will further be helpful to plan the line of management. There have been a very few studies before in this field, but the results have been varied. The treatment of chronic tinnitus is multimodal. Along with different sound therapy, different physical interventions like TENS, Laser therapy, Acupuncture therapy, TMD treatment, biofeedback etc are also being practised to improve tinnitus. But sound therapy with tinnitus masking or tinnitus retraining therapy alone is currently an advanced and effective treatment for subjective tinnitus. Our study concludes that there is a definite relation between maximum hearing loss pitch and tinnitus matching pitch though there is no statistically significant correlation found between tinnitus sensation level and highest hearing loss in the same ear.

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