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Original Research Article

Hearing loss in tympanic membrane perforations: an analytic study

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ABSTRACT

Background: Tympanic membrane perforations are common cause of hearing loss. There are very few systematic studies that have evaluated the size and location of a perforation to the degree of hearing loss, this study correlates the size and location of tympanic membrane perforation to the pattern of hearing loss.
Methods: The study design was based on cross sectional study. Ninety-six ears of dry tympanic membrane perforation of CSOM mucosal type were selected. Photographs of the tympanic membrane perforations were taken and size measured using the "Image J" software. The area of perforation was compared to hearing loss measured by pure tone audiometry.
Results: Ninety-six patients, aged 15-60 years with perforated eardrums were studied. Size of tympanic membrane perforation showed moderate level of correlation with hearing loss (Pearson r value=0.463). The various locations of perforations were: posterior (23 ears with Mean hearing loss 28.6±7.7 dB), anterior (31 ears with Mean hearing loss 26.5±7.8dB), subtotal (42 ears with Mean hearing loss 34.2±8.2 dB).
Conclusions: The hearing loss is frequency dependent, with maximum hearing loss at lower frequencies. Irrespective of size of perforation the hearing loss was the least for frequency of 2000Hz. Magnitude of hearing loss increases with increase in size of tympanic membrane perforation. Perforation posterior to handle of malleus resulted in more hearing loss than perforations involving anterior to the handle of malleus.

Keywords: Hearing loss, Tympanic membrane perforation, CSOM

INTRODUCTION

Hearing loss is one of the major reasons for disability and social anxiety in a person's life. Permanent perforation of tympanic membrane (TM) in chronic otitis media (CSOM) is the commonest cause for correctable hearing loss in society.[1] According to a recent WHO study-CSOM prevalent in 6% of the world's population with a higher incidence in countries with low socio-economic conditions.[2]

Reduced effective surface area of TM in perforation leads to ineffective sound transmission. Difference of opinion exists regarding effect on hearing loss due to perforation in literature. Glasscock and Shambough found differential hearing losses in ears with similar size and location of perforation.[3] Zhang et al in their study on the effect of small tympanic membrane perforations in inferior quadrant on manubrium vibrations in guinea pig suggested that loss in vibration velocity of manubrium in perforations were dependent on the frequency of sound and more loss will be at a lower frequency.[4] Vaidya et al reported greater degree of hearing loss in posterior perforations.[5] Saliba et al concluded that conductive hearing loss resulting due to perforation of TM is frequency dependent; with the greatest loss occurring at the lowest sound frequencies.[6] Hearing loss in their study was not dependent on the location of perforation

This study aims to provide more insight into the sound transmission mechanism by tympanic membrane by evaluation of quantitative hearing loss after perforation of the tympanic membrane. The aim of this study is to validate the suppositions available in the literature regarding hearing loss after tympanic membrane perforation and to fill lacunae of scientific research in this area providing the information in regard to avoiding hearing loss in the community due to tympanic membrane perforation by appropriate mode of interventions.

METHODS

This was a hospital-based cross-sectional study conducted in outpatient department of ENT in JIPMER (institute of national importance), Puducherry from august 2014 to august 2016. A total of 96 patients with CSOM with dry TM perforation involving pars tensa, attending OPD at a tertiary care centre in Puducherry, South India were included in the study. Ethical approval was obtained from JIPMER Human Ethics Committee (IEC/SC/2014/8/615). The study protocol conformed to the ethical guidelines of the Declaration of Helsinki and written informed consent was obtained from all study subjects.

Sample size estimation

Sample size was estimated based on the previous study by Nahata et al, using the "Stats to Do" program for estimating the population means.[7] The sample size was estimated with an expected maximum S.D in the level of hearing loss among the patients with tympanic membrane perforation as 25. At 5% level of significance and 5% absolute precision we require sample size 96 using "Stats to Do" program.

Study population and work-up

Patients with CSOM Tubotympanic disease with a dry central perforation aged between 15 to 60 years were recruited for the study. After a detailed clinical history and ENT examination, these patients underwent pure tone audiometry. A calibrated diagnostic audiometer (GSI 61) was used for measuring the pure tone thresholds. The modified Hughson and Westlake procedure was used for estimating the thresholds for air and bone conduction. Frequencies from 250 Hz to 4000Hz and were tested. The patients were asked to indicate whenever they perceived the given tone by raising their finger each time. The lowest intensity level at which the patients were able to hear 50% of the time was considered as the threshold for that particular frequency. Patients with a sensory neural hearing loss along with a conductive hearing loss were excluded. A patch test using a piece of aluminum foil was done on patients with hearing loss more than 40 decibels to rule out ossicular discontinuity. An aluminum foil of thickness of about 0.1 mm with approximate size of tympanic membrane perforation was placed onto the tympanic membrane by applying ointment onto the foil using oto-endoscopy. Audiogram was repeated. Patients having no improvement or worsened hearing loss on repeat audiogram were excluded from study.

Digital photographs of the perforated tympanic membrane were taken using otoendoscope. The site of the perforation was documented as anterior to the handle of Malleus, Posterior to handle of Malleus and Sub-total if it included both the anterior and posterior halves of the tympanic membrane. The size of the perforation and total size of tympanic membrane were measured using the "Image J version 1.49 d" software by analysing the photograph of the tympanic membrane in terms of pixels. The ratio of the area of the perforation to the area of the tympanic membrane was calculated.

Statistical analysis

Statistical analysis was performed using IBM SPSS statistics version 20 for Windows. Baseline characteristics of all study subjects were analyzed using descriptive statistics. The normality of continuous data was assessed by the Shapiro-Wilk test. The data were described as mean±standard deviation (SD). Correlation of area of perforation with hearing loss will be tested using the Pearson correlation and to compare average hearing loss at different location independent t-test was used. A regression analysis was done to predict hearing loss based on area of perforation

All statistical analysis was carried out at 5% level of significance and $p<0.05$ was considered as significant.

RESULTS

96 cases of TM perforations and its effect on hearing loss has been studied and analysed following observation noted.

Socio demographic profile

The mean age of subjects found to be 34.1 with maximum participants were between 21 to 40 years with a standard deviation of 11.7 and a majority were female (58). This study had most participants symptomatic for 6 to 12 months (51%). Maximum patients found to be symptomatic from 6 to 12 months of age and duration of dry ear found be less than 3 months in most of cases (59.4%) (Table 1).

Mean average air conduction threshold among 96 study participants found to be 30.4dB with standard deviation of 8.6dB with minimum air conduction threshold value of 13.3dB and maximum of 53.3dB.

Table 1: Demographic profile of study participants.

Parameters	Observation	Interpretation
Age	Maximum patients in age group 21-40 years (n=57) (mean age=34.1 years)	CSOM more common in younger and adult group
Gender	Male n=38 ; Female n=58	Female are more common
Duration of disease	Maximum patients between 6 months to 12 months n=49	
Duration of dry ear	Maximum patients since past 3 months n=57	

Table 2: Average air conduction threshold in relation to size of perforation of tympanic membrane N=96.

Percentage area of tympanic membrane perforated	Frequency n (%)	Average air conduction hearing loss in dB Mean (SD)
25	46	27.2(7.5)
25 to 50	42	31.9 (8.0)
50-75	8	40.4 (8.2)

Table 3: Distribution of perforation based on location of perforation with average air conduction threshold, N=96.

Location of perforation	Frequency n (%)	Area of perforation Mean (SD)	Average air conduction threshold (dB) Mean (SD)
Posterior	23 (24.0)	0.2 (0.1)	28.6 (7.7)
Anterior	31 (32.3)	0.2(0.1)	26.5 (7.8)
Subtotal	42 (43.8)	0.4 (0.1)	34.2 (8.2)

Table 4: Pearson correlation of ratio with air conduction threshold at each frequency with area of TM perforation.

Pair	r value	P value
Area of tympanic membrane perforation vs air conduction threshold at 250Hz	0.431	<0.001**
Area of tympanic membrane perforation vs air conduction threshold at 500Hz	0.433	<0.001**
Area of tympanic membrane perforation vs air conduction threshold at 1000Hz	0.402	<0.001**
Area of tympanic membrane perforation vs air conduction threshold at 2000Hz	0.321	0.001**
Area of tympanic membrane perforation vs air conduction threshold at 4000Hz	0.289	0.004**
Area of tympanic membrane perforation vs air conduction threshold at 8000Hz	0.082	0.428

Distribution of area of TM perforation and effect on hearing loss

Based on area 3 groups were made by calculating percentage of tympanic membrane perforated (table 2).Maximum cases belong to group 1 (n=46).maximum hearing loss seen in group 3 (mean=40.4dB).

ANOVA test showed a significant difference between the mean hearing loss (in decibels) across the three categories of the perforation of tympanic membrane, F=11.219 and p<0.001.

The post hoc analysis done using Bonferroni test showed that there was significant difference in the mean hearing loss across any of the two of the three groups of tympanic membrane perforation.

Thus, there is a significant increase in the mean hearing loss from the small perforation to the medium perforation and most in the large perforation

Correlation study showed moderate level correlation according to Pearson's product moment correlation coefficient (0.46) between area of tympanic membrane perforation and average air conduction threshold

Distribution of perforation based on Location of perforation and effect on hearing loss

Tympanic membrane perforation in posterior quadrant perforation group is equal to anterior perforation group (0.2) but subtotal perforation group has higher value (0.4). Since, above observations showed more magnitude of hearing loss in larger size of perforation it is not possible to compare subtotal perforation group to other two groups.

However, posterior quadrant perforation have higher mean hearing loss than anteriorly located perforations but values were not statistically significant (p=0.327) (Table 3).

Frequency of sound affected to area of perforation of tympanic membrane and location of perforation on tympanic membrane

Correlation study between air conduction threshold at each frequency with area of tympanic membrane perforation shows there is moderately good correlation at lower frequency which is statistically significant and relatively weak correlation at 4000Hz and 8000Hz (Table 4).

There is weak correlation with respect to frequency specific hearing loss according to location of tympanic membrane perforation. However there is statistical significant moderate level correlation at 500Hz and 1000Hz in anterior perforation group, at 250 Hz in subtotal perforation group (Table 5).

Table 5: Correlation of ratio with air conduction threshold at each frequency with area of tympanic perforation among location based tympanic membrane perforation group.

Correlation of area of perforation to hearing loss at different frequencies	Posterior		Anterior		Subtotal	
	r value	P value	r value	P value	r value	P value
250Hz	0.252	0.246	0.309	0.091+	0.359	0.020*
500Hz	0.114	0.605	0.378	0.036*	0.238	0.129
1000Hz	0.121	0.583	0.452	0.011*	0.259	0.098+
2000Hz	0.327	0.128	0.210	0.257	0.103	0.517
t4000Hz	0.350	0.101	0.215	0.245	0.026	0.871
8000Hz	0.265	0.222	-0.115	0.539	-0.008	0.960

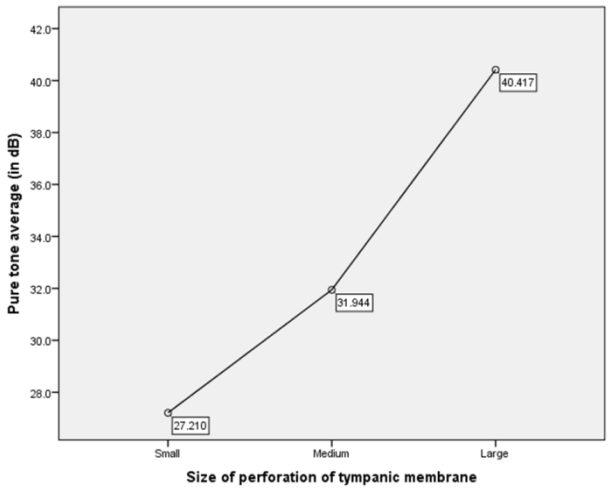

Figure 1: Shows distribution of perforation according to the area of tympanic membrane perforated to the mean hearing loss.

Small= Less than 25%, Medium=25-50%, Large=50-75%.

Regression analysis

1. Linear regression showed significant change in mean hearing loss with unit change in tympanic membrane perforation (B=0.236, SE=0.047, 95% CI: 0.142–0.330, p<0.001)
2. Linear regression showed significant change in mean hearing loss at 250 Hz with unit change in tympanic membrane perforation (B=0.355, SE=0.74, 95% CI: 0.208–0.502, p<0.001)
3. Linear regression showed significant change in mean hearing loss at 500 Hz with unit change in tympanic membrane perforation (B=0.285, SE=0.61, 95% CI: 0.164–0.407, p<0.001)
4. Linear regression showed significant change in mean hearing loss at 1000 Hz with unit change in tympanic membrane perforation (B=0.239, SE=0.057, 95% CI: 0.126–0.352, p<0.001)
5. Linear regression showed significant change in mean hearing loss at 2000 Hz with unit change in tympanic membrane perforation (B=0.183, SE=0.058, 95% CI: 0.069–0.298, p 0.002)
6. Linear regression showed significant change in mean hearing loss at 4000 Hz with unit change in tympanic membrane perforation (B=0.234, SE=0.083, 95% CI: 0.070–0.398, p 0.006).

DISCUSSION

Oto-endoscopic examination with details on perforation size and location enabled us to predict hearing loss pattern in those patients. We did a correlation study on the effect of size and site of tympanic membrane perforation on hearing loss in terms of average air conduction threshold and frequency-specific hearing thresholds measured by pure tone audiometry.

The study showed moderate correlation (Pearson r value 0.463) of hearing loss with area of tympanic membrane perforation. Hearing loss was found to be more at lower frequencies than at higher frequencies with the lowest hearing loss at 2000Hz. There was a significant increase in mean hearing loss as we compared hearing loss in anterior and posterior perforations to subtotal perforations. But this study showed there was no relation between locations of perforation to the frequency specific hearing loss.

The methodology used in this study was to record tympanic membrane pictures using a zero-degree otoendoscope, as demonstrated by Nahata et al.[7] "Image j

software" was used for measuring the area of TM area of perforation in pixels which is used previously by Nahatha et al and Ibweke et al.[7,8]

Another studies by Hsu et al used a computer program designed by them to calculate the size of tympanic membrane perforation. They concluded that the program is an accessory and useful to evaluate the size of tympanic membrane perforation as the difference in visual estimation can be very huge and variations can be large for different individuals, even for experienced otologists.[9]

Mehta et al used oto-microscopy and size of perforation measured by a 1 mm hook.[10] Kumar and Bhat in their study used an operating microscope with a graduated right angled fine aural probe.[11]

Ahmed et al measured tympanic membrane perforation diameter using a tape with a 0.5 mm scale and classified perforations into 4 categories based on the area of tympanic membrane perforations.[12]

Among all the various methods to measure the size of the tympanic membrane described the use of the "Image J" software is the most precise and also the easiest to perform. The software being freely available in the NML website is an added bonus as this does not add any financial burden on the research team.[13] As the tympanic membranes are photographed digitally and then analyzed the results can be cross-checked by a second investigator so as to remove any errors or bias. Thus this method of documentation will become a standard of care for all future studies and will also help archive pre-operative finding for possible medico legal uses.

To rule out ossicular discontinuity we did the "patch test". An Aluminium foil was used as a patch to cover the tympanic membrane perforation. A Similar method was used in a study by Kumar and Bhat, Nahata et al.[7,11] However, Anthony et al in their study on the effect of tympanic membrane perforations on audiogram chose only those cases whose air-bone gap was closed by myringoplasty, thereby controlling the variability of ossicular chain pathology.[14]

Socio-demographic characteristics of study

This study was conducted in a tertiary care hospital. Most of the patients visiting the hospital were referred from peripheral hospitals for surgical intervention. Pediatric age group of lesser than 15 years were excluded from this study due to the inconsistent PTA response. The mean age of subjects found to be 34.1 with maximum participants were between 21 to 40 years with a standard deviation of 11.7 and a majority were female (58). These observations were similar to a study on CSOM patients by Parida et al in the same hospital.[15] However, studies done by Sing et al and Afolabi et al had a male preponderance.[16,17] This observation is due to increased awareness among the patients about their disease and need for surgical intervention due to social and occupational needs during their younger age.

This study had most participants symptomatic for 6 to 12 months (51%). Hearing loss was found to be more with patients having symptoms for a longer duration but values were not statistically significant. A study done by Pannu et al showed similar observation of an increase in average hearing loss as the duration of disease increased.[18] Most patients had a dry ear for less than 3 months (57%).

Hearing loss according to size of tympanic membrane perforation

There was a significant difference between the mean hearing loss (in decibels) across the three groups (shown in Table 2). The post hoc analysis done using Bonferroni test showed that there was a significant difference in the mean hearing loss across any of the two of the three groups of tympanic membrane perforation.[19] This suggested that as the size of perforation increases hearing loss increased.

Correlation study between average hearing loss and area of TM perforation showed moderate strength of Correlation with Pearson correlation coefficient value of 0.463 and P value less than 0.001. In practical terms this suggests that with increasing area of tympanic membrane perforation the hearing loss increases but increase is nonlinear. This can probably explained by the fact that with increasing size of the perforation the ability of the remaining pars tensa to continue to vibrate becomes less efficient. The pars tensa is normally stretched due to the arrangement of fibres in the middle layer of the tympanic membrane and this is lost due to a perforation. This stretched and pre-stressed nature of the pars tensa contributes to the efficiency of the pars tensa in vibration and any perforation leads to a nonlinear loss of efficiency. Thus a perforation not only causes loss of vibrating surface it also reduces the efficiency of the remaining tympanic membrane to vibrate thus explaining the nonlinear hearing loss with increasing area of tympanic membrane perforation.

Linear regression showed a significant change in mean hearing loss with unit change in tympanic membrane perforation. Suggesting each 0.1 increase in area of perforation audiometry which was statistically significant.

This study further showed that perforation induced hearing loss was more at low frequencies than high frequency. Regression analysis showed for every 0.1 increase in area of TM perforation hearing loss will increase by 0.35, 0.28, 0.24, 0.18 and 0.23 at 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz respectively. Lowest hearing loss at 2000Hz

This study showed similar results to a study by Ahmed and Ramani that increasing hearing loss with increasing area of tympanic membrane perforations.[12] They attributed this finding to "Areal Ratio" and suggested that hydraulic action due to difference in the surface area of vibrating part of tympanic membrane and stapes footplate is the main factor in impedance mechanism of middle ear. Similar results were noted in studies done by McArdle and Tanndorf, Nahatha et al and Bigelow et al.[20,7,21]

Frequency dependent hearing loss was found to be lowest at the 2000 Hz.This can be explained by the fact that the fundamental frequency of vibration of the human Tympanic membrane is 2000 Hz thus there will be a maximum vibration of the tympanic membrane at this frequency leading to effective transfer of sound power to ossicular chain at its maximum capacity. Furthermore the hearing loss was found to be more at lower frequencies similar to results published by Nahata et al and Lerut et al.[7,22]

Hearing loss in relation to location of perforation

We found hearing loss in subtotal group more than posterior and anterior group. However this observation is a result of the increased area of perforations rather than the result of the location. Hence the subtotal perforation group was not compared with anterior and posterior group of perforations.

The average hearing loss for posterior and anterior perforation were compared and it was seen that mean air conduction hearing loss was found to be more in posterior perforations than in anterior perforations but results were not statistically significant (p=0.327 Refer Table 3). This result may be because of a small sample size for the subgroup analysis. Future studies with larger sample sizes are necessary to correlate hearing loss with location. It is traditionally believed that posterior perforations caused significantly higher amounts of hearing loss when compared to the perforations of similar size in the anterior quadrant. It was explained that this was a result of the loss of the round window shielding effect of the tympanic membrane in posterior perforations leading to loss of preferential sound transmission to the oval window. Apart from a small sample size there may be other reasons to explain this anomaly. Most studies on hearing have been in animals like rats and chinchilla.[23,24] The human round window is located in a deep niche and the round window is not directly in line with the opening of the niche. This is been used to explained the lower incidence of ototoxicity in human ears when using ototoxic drugs for perforated tympanic membrane when compared to animal models.[25] Thus the basic anatomical design of the round window also helps provide some shielding and may explain the not so significant hearing loss in posterior perforations when compared to anterior perforations of a similar size.

This study also showed correlation between area of perforation in each subgroup of location of perforations of tympanic membrane with frequency specific hearing loss were statistically insignificant at all frequencies except significant moderate level correlation noticed at 500Hz, 1000Hz in anterior perforations and at 250hz in subtotal perforations

This findings also conforms to the historic statement by Bekesy, Payne and Gither that location of perforation on tympanic membrane has its effect on magnitude of hearing loss.[26,27] Similar findings were noticed in studies of Ahmed and Ramani, Bianca et al and Malik et al.[12,28,29]

There are not many studies available in literature comparing magnitude of hearing loss at various frequencies according to location of perforation. The study done by Mehta et al noted that there was statistical insignificant but a small difference in air bone gap at various frequency between anterior and posterior perforation but they stated that this finding lacked sufficient power to distinguish between no effect and a small effect.[10] Our study also showed no correlation between magnitude of hearing loss at each frequency and location of perforation. However we need further studies in this area with larger sample sizes to find out statistical significance for this finding.

CONCLUSION

This observational clinical study of ears with tympanic membrane perforations showed that

1. The hearing loss in frequency dependent, with maximum hearing loss at lower frequencies
2. Irrespective of size of perforation the hearing loss was the least for frequency of 2000Hz
3. Magnitude of hearing loss increases with increase in size of tympanic membrane perforation
4. Perforation involving posterior to handle of malleus result in more hearing loss than perforations involving anterior to the handle of malleus
5. Location of perforation does not have effect on frequency specific hearing loss.

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