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ORIGINAL ARTICLE

Observations on Tympanic Membrane Perforations (Safe Type) and Hearing Loss

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Abstract The most commonly observed clinical findings in otological practice is discharging ear in which perforation of the tympanic membrane is the commonest, yet the patients hardly ever seek advice for deafness as the presenting symptom. In patients with the symptoms of ear ache or ear discharge when relieved seldom present for follow up and are not very much concerned about the hearing loss present there. There is a different correlation between surface area of tympanic membrane and amplification of sound. Conductive hearing loss is seen in lower tones than higher tones. When the surface area of tympanic membrane is reduced in case of perforations there is decreased in amplification of sound waves. Hearing loss is less in smaller perforations than in larger ones and more for lower tones than for higher tones. A perforation has more serious effect on hearing when it is located in the vicinity of the attachment of malleus. Perforations situated in the postero-inferior quadrant will cause more hearing loss than in other quadrants. The aim of the study is to know the exact location and exact size of perforation and to make a comparative study on the amount of hearing loss produced respectively—in cases of central perforations. Data of 100 patients was collected and studied from May 2015 to April 2016. Hearing loss is related to site and size of perforation with postero-inferior quadrant perforations caising more degree of hearing loss. It varies between 2 and 25 dB more at lower 2 frequencies. Hearing loss is related to size and site of perforation. Small perforation in the postero-inferior quadrant cause more hearing loss than a perforation of same size in other quadrants. Similarly the size of perforation also affects the amount of hearing loss.

Keywords Hearing loss · Tympanic membrane perforation · Site and size of perforation

Introduction

The most commonly observed clinical findings in otological practice is discharging ear in which perforation of the tympanic membrane is the commonest, yet the patients hardly ever seek advice for deafness as the presenting symptom. In patients with the symptoms of ear ache or ear discharge when relieved seldom present for follow up.

The absence of any appreciable disturbance of hearing is encountered when free field tests are carried out on the patients and later on perforations are detected. Surface area of tympanic membrane is 64.3 mm^2 which is responsible for amplification of sound by 18.3. Therefore decrease in the surface area of tympanic membrane leads to loss of or decrease in amplification. This also means that the size of perforation is directly proportional to the hearing loss. Site of perforation is also important as a perforation located in the vicinity of attachment of malleus or in the postero-inferior quadrant will cause more hearing loss than in other quadrants.

Surface area—When the surface area of tympanic membrane is reduced in case of perforations there is decreased in amplification of sound waves. Size–Hearing loss is less in smaller perforations than in larger ones and more for lower tones than for higher tones. A perforation has more serious effect on hearing when it is located in the vicinity of the attachment of malleus. Site–perforations

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situated in the postero-inferior quadrant will cause more hearing loss than in other quadrants.

Effects of Perforation

A number of writers have expressed the view that a simple perforation has no effect on hearing while others have found that the low tones are only affected [1]. Bordley and Hardy [2] in a study of audiograms of two persons having traumatic perforations without secondary infection found that hearing was diminished by an average of 12 dB over the frequency ranging from 256 to 4096 Hz which they tested. The losses varied with the site of perforation but in any location were fairly uniform over the frequency range.

Mawson [3] stated that impairment of the tympanic membrane is inseparable from same impairment of auditory function and also that the degree of impairment will not be a simple function of the size of the perforation but will depend upon the position of the defect.

Simpson et al. [4] believed that the degree of deafness in the presence of a perforation is variable. In central perforations with intact ossicular chain the hearing loss may average between 10 and 30 dB, is greater if the perforation is large. The anterior small perforations cause less deafness than large central ones.

Thorburn [5] stated that the average hearing loss for speech frequencies 500, 1000, 2000 Hz varies between 20 and 45 dB is in proportion to the size of the defect and tends to be slight with an anterior perforation but greater with a posterior extension due to loss of sound protection of round window.

Antony and Harrison [6] studied the audiograms of 103 patients with simple perforations who had been subjected to myringoplasty with return of hearing to normal and thus having no other cause of hearing loss. They studied the loss for frequencies from 250 to 4000 Hz. The average of all types of perforations showed the maximum loss of 25 dB at 250 Hz, gradually decreasing to 13 dB at 4000 Hz. The average hearing loss in all types of perforations of less than 2 mm diameter (12 cases) was between 19 to 8 dB, the higher loss being up to 1000 Hz, and the smallest at 2 and 4 kHz. The average loss in all types of perforation of more than 2 mm diameter (91 cases) also showed the same trend of being more at low frequencies but was greater in magnitude than the smaller perforations the maximum being 27 dB (at 250 and 500 Hz) and minimum 13 dB at 4 kHz. They also studied the effects of location of perforations comparing the central (those touching the manubrium) with the peripheral (those not touching the manubrium). In the group of small perforations (up to 2 mm diameter) the hearing loss in central ones (7 cases) was more in the mid frequencies 500–2000 Hz, while in the peripheral ones (5 cases) the relation was reversed, the maximum (25 dB) being for 250 Hz. Large more than 2 mm diameter central perforation (30 cases) had 10 dB more average loss at low frequencies but only about 5 dB more loss for high tones. Comparing the average of all perforations of anterior inferior quadrant with those of postero-inferior quadrant they found the loss in former to be 16 dB less than that in the later at 250 Hz but 2–4 dB more at mid frequencies (equal to 4000 Hz).

Glasscock and Shambaugh [7] observed that "seemingly identical perforations in size and location produce different degrees of hearing loss. The reasons for the variations in the hearing effects of simple perforations are not easily defined".

Materials and Methods

Study Design

A cross-sectional prospective study of 100 patients with perforated tympanic membrane conducted in the ENT OPD of Santosh Medical College and Hospital Ghaziabad from May 2015-April 2016. Instruments used for data collection/processing include questionnaires, micro-otoscopy, pure tone audiometry, tympanometry.

Inclusion Criteria

1. Presence of dry central perforation in pars tensa (safe type).
2. Patent Eustachian tube.

Exclusion Criteria

1. Presence of any ear discharge.
2. Presence of calcareous deposits over tympanic membrane remnants, polypi, granulation or cholesteatoma.
3. Presence of any mucosal oedema, microscopic granulation, polypi cholesteatoma in the middle ear.
4. Presence of any ossicular chain disruption or fixation.
5. Presence of adenoid vegetations, tonsillar hypertrophy and sepsis, gross septal deviation, nasal polypi or sinusitis.
6. Presence of meatal stenosis or exostosis.
7. Presence of any sensorineural hearing loss.

Observations

100 cases of simple tympanic membrane perforations and its effect on hearing loss has been studied and analysed. For each of the frequency the average hearing loss in decibels

has been calculated on the basis of site and size of perforation. The average hearing loss in each frequency has been charted like audiogram in graph paper, the scale being 2 mm on the ordinate representing dB.

The average maximum hearing loss was seen in 125 Hz that is about 25 dB. But hearing loss gradually decreased as the frequencies increased. The minimum average hearing loss at 8000 Hz is 7.5 dB. The average hearing loss is almost uniform at 2000–4000 Hz. For all large perforations the average hearing loss is 29.5 dB at 125 Hz which is maximum. Then the hearing loss gradually decreasing to a minimum of 7.5 dB at 8000 Hz as it has been in graph no.1 and table no. 1.

According to size of perforation that is percentage of tympanic membrane area lost is calculated and categorised into 4 groups:–

1. Up to 10 %.
2. Above 10 % but up to 20 %.
3. Above 20 % but up to 40 %.
4. Above 40 %.

Comparatively large central perforations had shown more hearing loss than small central perforations, the difference being about 15 dB average hearing loss at 125 Hz. But at mid-frequencies it is 11–9 dB and at higher frequencies it varies between 7 and 5 dB hearing loss.

Study shows hearing loss for the large antero-inferior perforations comparatively more than small antero-inferior perforations, the difference in hearing being maximum 10 dB in frequencies up to 3000 Hz. Thereafter both types show almost same amount of hearing loss.

All postero-inferior perforations show less hearing loss than large postero-inferior perforations, the difference of hearing loss being round about 12 dB up to frequencies 3000 Hz but for higher frequencies the difference is reduced gradually.

Average hearing loss in postero-inferior perforations were more than in antero-inferior perforations. The hearing loss varies between 7 and 8 dB in frequencies from 125 to 1000 Hz at 1500 Hz it is 5 dB and maintained 3–5 dB hearing loss for rest of the frequencies.

In the group of perforations having area more than 20 % but less than 40 %, 10 were central postero-inferior perforations and 10 were central antero-inferior perforations. The hearing loss in these two sub groups the postero-inferior located perforations show 11–7 dB hearing loss in frequencies up to 3000 Hz.

In the group of perforations having area more than 40 % that of the tympanic membrane 6 were located postero-inferiorly and 6 were antero-inferiorly. The postero-inferior perforations show more hearing loss than antero-inferior average being 5 dB hearing loss in all frequencies but midfrequencies 2000 Hz they were equal.

Discussion

Effects of Size of Perforation

Simpson et al. [4] observed that the hearing loss varied between 10 to 30 dB. Thorburn [5] estimated hearing loss over speech frequencies 500, 1000, and 2000 Hz and his range was between 20 and 45 dB.

Anthony and Harrison [6] in a study of audiograms of patients having undergone myringoplasty with almost complete closure of air bone gap compared the hearing loss for perforations of varying sizes and locations. They studied the average hearing loss for frequencies between 250 and 4000 Hz and detailed findings were charted in Table 1 given below.

In their study perforations having a diameter of up to 2 mm have been grouped as “small” while those with a diameter of more than 2 mm have been termed as “large”, perforations touching the malleus handle have been termed “central” and those not in contact with malleus handle termed peripheral.

Average Hearing Loss for Various Types of Perforations Anthony and Harrison [6]

In the present study the average hearing loss for all sizes of perforation is shown in graph -1.

Maximum loss of 25 dB is seen at 125 Hz decreasing gradually to about 10 dB at 4000 Hz and then to the minimum of 6.2 dB at 8000 Hz.

Between the frequency 250 to 4000 Hz the loss ranges between 22.6 and 10 dB.

For the same frequency range Anthoney and Harrison [6] the figures vary from 25 to 13 dB.

The average of hearing losses for frequencies 125 to 4000 Hz comes to 16.9 dB when compared to the figures of Bordley and Hardy [2] this is 4.9 dB more. This variation to higher side of this study might be due to many number of patients than Bordley and Hardy. But when compared to the figures of Simpson et al. [4], present study results are somewhat within the range, and at the same time when compared to the figures of Thorburn [5] loss being 20–45 dB, and the present study shows loss of 10–25 dB which seems to be much differed almost half of the Thorburn result.

For small perforations up to 2 mm diameter the hearing loss is 17.3 dB at 125 Hz gradually decreasing to 6 dB at 8000 Hz when compared to the findings of Anthony and Harrison present study results are 1.7 dB less at 250 Hz, 3.7 dB less at 500 Hz, 5 dB less at 1000 Hz, 0.4 dB less at 2000 Hz and 2 dB less at 4000 Hz. These small differences as shown in the table given below might be due to the

Table 1 Comparison of hearing loss in relation to site and size of perforation

Type of perforation	Average hearing loss in dB for each frequency				
	250	500	1000	2000	4000
All perforations	25	22	17	17	13
All large perforations	27	27	17	17	13
Large central perforations	28	25	17	18	13
Large peripheral perforations	18	18	14	9	11
All small perforations	19	18	17	8	8
Small central perforations	16	23	21	19	9
Small peripheral perforations	25	11	12	19	18
All antero-inferior perforations	22	23	17	17	13
All posteroinferior perforations	38	20	13	15	13

variation in the size of perforation and mechanical error of the instrument.

	Frequency in Hz				
	250	500	1000	2000	4000
Present study	17.3	14.3	12	7.6	6
Anthony and Harrison	19	18	17	8	8
Difference	1.7 dB	3.7 dB	5 dB	0.4 dB	2 dB

In large perforations more than 2 mm in diameter maximum loss of 29.5 dB seen at 125 Hz and the maximum of 7.5 dB at 8000 Hz when compared to Anthony and Harrison findings at 250 Hz there is only 0.5 dB less, difference at 500 Hz is 2.5 dB more. Here the results are almost tallying with those of Anthony and Harrison except at 500 Hz and 1000 Hz as shown in table below.

	Frequency in Hz				
	250	500	1000	2000	4000
Present study	26.5	24.5	22.2	16.5	14.5
Anthony and Harrison	27	27	17	17	13
Difference	0.5 dB	2.5 dB	5.2 dB	0.5 dB	1.5 dB

In this study hearing loss for large and small perforations was between 10.2 and 8.5 dB over frequencies 250–4000 Hz whereas Anthony and Harrison 6 dB at 250 Hz, 9 dB at 500 Hz, no difference at 1000 Hz, 9 dB at 2000 Hz and 5 dB at 4000 Hz, that is range between 5 and 9 dB as shown in the table below.

	Frequency in Hz				
	250	500	1000	2000	4000
Present study	9.2	10.2	10.2	8.9	8.5
Anthony and Harrison	6	9	0	9	5
Difference	3.2 dB	1.2 dB	5.2 dB	0.1 dB	3.5 dB

In present study the loss is seen to be gradually decreasing up to 1500 Hz and then being more or less uniform up to 4000 Hz then there is some gain at higher frequencies. Like their study present study also shows increasing loss with increasing size of perforation but the only difference is the larger amount of hearing loss and gradual decrease of hearing loss from 125 to 2000 Hz. Most probable explanation of this difference in observation may be that Payne and Githler had got results from experimental studies on cats but where aas this present study is on humans.

In the present study it has also been possible to compare the variation in hearing loss due to variation in the size of perforation even when their locations are identical. The hearing loss for "small central perforations" is less than that for "large central perforations". The loss for "small peripheral perforation" is also less than that for "large peripheral perforations" at all frequencies. About the perforations located in anteroinferior quadrant small perforations show less hearing loss than large perforations. Similarly, in the posteroinferior quadrant the hearing loss for small perforations is less than that for larger ones at all frequencies.

It is, thus observed that in all locations the small perforations having up to 2 mm diameter cause less hearing loss than the larger perforations having more than 2 mm diameter.

This present study shows that in simple perforations there is hearing loss in all frequencies. The loss is more at lower frequencies but gradually decreasing towards higher frequencies almost nill towards 6000 and 8000 Hz. The hearing loss increases with the increase in size of perforations. This is in agreement with the findings of Bordley and Hardy [2], Payne and Githler [1] and Anthony and Harrison [6], Wever and Lawrence [8] and also accept the same view and explain these by simple mechanical and physiological principles. The primary effect of a perforation of the tympanic membrane is reduction of the surface on which the sound pressure is exerted.

They state that this effect is simply proportional to the size of the perforation and therefore the hearing loss will be more when the perforation is larger. The explanation put forward for the greater hearing loss at lower frequencies. They observed that a perforation permits the sound to pass through the opening and exert a back pressure in opposition to the primary pressure. In a small perforation the edges of the perforation present a certain amount of frictional resistance to the passage of sound ant this friction increases with increase in frequency. Thus, in smaller perforation less sound will pass through and nullify the primary pressure and still less sound of higher frequency will pass through. Therefore, the hearing loss is less in smaller perforations than in larger ones and more for lower frequencies than for higher frequencies.

Effect of Realtion of Perforation to Handle of Malleus

Wever and Lawrence [8] told that a perforation causes more less if it is in the vicinity of the attachment of the tympanic membrane with manubrium of the malleus.

Anthony and Harrison found that the hearing loss for all large central perforations varied, 28 dB at 250 Hz to 13 dB at 4000 Hz and for all large peripheral perforations was between 18 and 9 dB. The difference was 10 dB at 250 Hz; 7 dB at 500 Hz; 3 dB at 1000 Hz; 9 dB at 2000 Hz and 2 dB at 4000 Hz.

In the present study the average hearing loss for “large central perforation” was 35 dB at 125 Hz and gradually decreased to 10 dB at 8000 Hz. The value were 2 dB more than that of Anthony and Harrison at 250 Hz, 1 dB at 500 Hz, 6 dB in 1000 Hz and in rest of frequencies it was only 1 dB more less.

For large peripheral perforations the present study shows value between 30 and 5 dB hearing loss, when compared to results of Anthony and Harrison the results varied between 12 and 6 dB more hearing loss. But on the whole the present study shows more hearing loss for central perforations than the peripheral perforations at all frequencies. The difference varies between 5 and 2 dB more.

In the group of small perforations Anthony and Harrison did not find the same consistent relation. At 250 Hz the hearing loss in central perforation was 9 dB less than that of peripheral perforation. But at frequencies 2000 Hz and 4000 Hz loss was equal. In the present study the hearing loss was seen 1 dB more in small central perforations at 125 Hz, 2 dB more hearing loss in 250 Hz, equal at 500 Hz again, 1 dB more in 1000 Hz and 1500 dB, the rest of the frequencies shows no difference.

When summing up hearing loss in all central and peripheral perforations the present study shows more hearing loss in all central perforations than peripheral perforations, that is difference of more hearing loss 4 dB more at 125 Hz in central perforations and 5 dB at 250 Hz, 2 dB at 500 Hz, equal at 1000 Hz again 3 dB more at 1500 Hz and in rest of frequencies it is almost equal.

The range of difference varies between 5 dB to equal. By analysing the above results it can thus be concluded that central or malleolar perforations cause more hearing loss than peripheral or non malleolar perforations, results being same as published by Anthony and Harrison. Wever and Lawrence [8] explained the above phenomena as because the tympanic membrane is effective only in so far as it communicates its motions through its attachment to the manubrium so it follows that a perforation is particularly serious when it is in the vicinity of this attachment. Thus the greater hearing loss observed for central perforations in conformity with this physiological explanation.

Effect of Location of Perforation

Mawson [3] stated that the impairment of auditory function will depend also upon the position (in relation to the four quadrants of tympanic membrane).

Simpson et al. [4] observed that anterior small perforations cause less deafness than large central ones.

Thorburn [5] has stated that hearing loss tends to be slight with an anterior perforation but greater with a posterior extension due to loss of sound protection of round window.

Anthony and Harrison [6] have made a comparative study of hearing loss in perforations of all anterior inferior and posterior inferior quadrants of pars tensa. In perforations of the posterior inferior quadrant the hearing loss was 16 dB more at 250 Hz, but equal at 4000 Hz. However at the intermediate frequencies 500, 1000, 2000 Hz the hearing loss was more in anterior inferior quadrant.

In the present study the hearing loss of all sizes of peripheral and central perforations situated in the posterior-inferior quadrant was more than that for antero-inferior quadrant. The maximum difference in 4 dB more at

125 Hz, 6 dB at 250 Hz, 4 dB at 500 Hz, 1000 Hz, equal at 1500 Hz, 2 dB loss at 2000 Hz, 1 dB at 3000 Hz, in postero-inferior quadrant perforation and in the rest of frequencies the hearing loss was equal.

In the group of small peforations, postero-inferior quadrant perforation shows more hearing loss than antero-inferior quadrant perforation, the maximum hearing loss being of 5 dB more in 250 Hz. In the rest of frequencies the difference varied between 3 and 0 dB.

In the group of large perforations also postero-inferior quadrant perforations showed more hearing loss than antero-inferior quadrant perforations. The difference was between 1 and 8 dB more hearing loss in potero-inferior perforations.

At frequencies 250 Hz difference in hearing loss is 8 dB.

500 Hz	4 db
1000 Hz	5 db
2000 Hz	2 db
4000 Hz	1 db

In this, it has also been seen that the hearing loss was more in antero-inferior perforations than antero-superior perforations.

It was seen that the hearing loss is more when the perforation is in the vicinity of postero-inferior quadrant. This was due to the loss of sound protection of the round window [5]. In these situations the perforation permits more of the sound to enter the middle ear and cause a cancellation effect by their pressure on the round widow. For this reason the observation is more clearly noticed for large sized perforations through which large number of sound waves can pass through to act upon the round window.

In very large perforations about 50 % of the size of the tympanic membrane will permit same loss of sound protection even when their situation is more anterior than posterior.

Conclusions

- Simple perforations of tympanic membrane causes a conductive deafness varying from 2 to 25 dB.
- Smaller perforations cause less hearing loss than larger ones.
- The hearing loss increases with the increase in the size of perforations.
- The hearing loss is more at lower frequencies than at higher frequencies.
- The perforations in relation to the handle of malleus cause more hearing loss than those situated away from the handle of malleus.
- Perforations in postero-inferior quadrant cause more hearing loss than those situated in antero-inferior quadrant.
- Antero-superior perforations cause less hearing loss than the antero-inferior ones.
- Perforations of 2 mm or less diameter do not show any definitive effect of their location on any of the quadrants.

Compliance with Ethical Standards

Conflict of interest None.

Ethical Standard With prior approval and permissions from ethical and research committee.

Informed Consent Written informed consent from every patient was taken before the test was performed.

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