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Original Research Article

Relationship between tympanic membrane perforation and conductive hearing loss in patients with chronic otitis media

Amjed H. Ali*, Isam M. Alshareda

Department of Otorhinolaryngology, Basra General Hospital, Basra, Iraq

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***Correspondence:**
Dr. Amjed H. Ali,
E-mail: amjedali_81@yahoo.com

ABSTRACT

Background: Study performed to evaluate relationship between surface area of tympanic membrane perforation and degree of hearing loss and to the effect of perforation site on that relationship in patients with chronic otitis media.
Methods: Seventy-five perforated tympanic membranes from 63 patients aged between 14-45 years with inactive mucosal chronic otitis media included in this study. Rigid endoscope (0 degree) used to take an image for each perforation that analyzed by Autodesk Design Review 2013 program. Degree of hearing loss assessed by pure tone audiometry. Surface area of perforation classified into four groups according to its percentage. Perforation site categorized into three groups regarding its relation to handle of malleus. Data analysis carried out with SPSS program version 17.
Results: We studied 34 females and 29 males with different surface area and site of perforations. It observed that with increment of surface area of tympanic membrane perforation, the degree of conductive hearing loss increases (P value=0.000). This relationship expressed in a logarithmic equation. The mean hearing loss of posterior perforation was 1.7±0.5 dB for each 1% of perforation but in anterior perforation was 1.5±0.6 dB for each 1% of perforation (p value 0.185).
Conclusions: In chronic otitis media, there is a quantitative logarithmic relationship between surface area of tympanic membrane perforation and degree of conductive hearing loss. The site of perforation does not play a significant role in determining degree of conductive hearing loss.

Keywords: Site of tympanic membrane perforation, Size of tympanic membrane perforation, Degree of hearing loss in CSOM, Measurement of size of perforation

INTRODUCTION

There is high incidence of conductive hearing loss caused by perforations of tympanic membrane in chronic otitis media. The results of studies regarding the effect of the size and the site of perforations on the degree of hearing loss conflicting.

Some studies show a correlation between degree of hearing loss and the size of tympanic membrane perforation that larger perforation causes larger hearing loss.[1-4] The weak point of these studies is the crude estimation of the size of tympanic membrane perforation. In our study, we use a program enable us to calculate the surface area of perforation precisely and designing a logarithmic equation between degree of hearing loss and surface area of perforation.

The results of articles were conflicting about the effect of perforation site on the degree of hearing loss. The present studies depend on comparing the mean of the degree of hearing loss of different site of perforation irrespective to the surface area of perforation.[1,3] There is a great bias in the above method because the result affected by the different surface area of perforation among these sites. We design a specific equation in order to overcome the above problem as shown in our study.

METHODS

A prospective study carried out at otolaryngology department of Basra General Hospital from January 2014 to January 2015. Seventy-five perforated tympanic membranes from sixty-three patients of both gender with the following criteria were included.

- Age between 14 to 45 years old.
- Inactive mucosal chronic otitis media.

Exclusion criteria

- Inactive or active squamous epithelial chronic otitis media.
- Active mucosal chronic otitis media.
- Previous myringoplasty with re-perforation of tympanic membrane.
- Mixed or sensorineural hearing loss.
- Conductive hearing loss with threshold of 50 dB or more for any frequency to exclude complete ossicular discontinuity or fixation.

History and ENT examination carried out for patients. Microscopic ear examination performed by using Entermed Holland 103322019 diagnostic microscope in order to ascertain the state of ear whether it was active or not, determine the site of perforation and exclude the presence of cholestetomas and granulation tissues.

An image taken for each perforation by using (Entermed Holland 174009ES rigid nasendoscopy 0 degree) and analyzed by Autodesk Design Review 2013 program to calculate the surface area of tympanic membrane perforation (Figure 1).

Figure 1: Measurement of the surface area of tympanic membrane perforation by Autodesk Design Review 2013 program.

The surface area of tympanic membrane perforation calculated in percentage and not in millimeter to overcome the mathematical effect of the difference in the surface area of tympanic membrane among subjects.

The following equation adopted to calculate the surface area of tympanic membrane perforation:

$$(SA\%) = \frac{P}{T} \times 100\%.$$

SA%: Percentage of surface area of tympanic membrane perforation to surface area of the whole tympanic membrane of same ear.

(P): surface area of tympanic membrane perforation.

(T): surface area of the whole tympanic membrane of same ear.

Pure tone audiometry was done by using an AA222 diagnostic audiometer at frequencies of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Hearing loss for each ear was calculated through the average of air – bone gap taken at 500 Hz, 1000 Hz and 2000 Hz.

Being that parstensa can be divided anatomically into four quadrants and percentages are preferred to nondefined terms such as small, large and subtotal to record the proportion of parstensa involved by a specific condition , surface area of tympanic membrane perforations were classified into four groups as the following:

- Group I: (SA%) 25% and less.
- Group II: (SA%) ranging from 26% to 50%.
- Group III: (SA%) ranging from 51% to 75%.
- Group IV: (SA%) 76% and above.

Tympanic membrane perforations divided into the following categories based on their location on the parstensa in relation to the imaginary line passing along the handle of the malleus [6]:

- Anteriorly located perforations: any perforation located anterior to the imaginary line that passing along the handle of malleus on parstensa.
- Posteriorly located perforations: any perforation located posterior to the imaginary line that passing along the handle of malleus on parstensa.
- Centraly located perforations: any perforation located on both side of the imaginary line that passing along the handle of malleus on parstensa.

In order to determine the effect of perforation site on degree of hearing loss, the following equation suggested:

$$R = D/S$$

R: the ratio of the mean of average hearing loss to the mean of (SA %) at specific site of perforation in (dB per 1% of perforation).

D: the mean of average hearing loss at that site of perforation in (dB).

S: the mean of (SA%) at that site of perforation in (percentage).

The following points can explain the fact behind the adoption of the above equation.

- The results of articles were conflicting whether different sites of tympanic membrane perforation give different degree of hearing loss or not.
- According to the results of most articles, the surface area of perforation plays a significant role in determining the degree of hearing loss.
- Method that generally adopted by other articles to decide whether the site has a significant effect on the degree of hearing loss or not was depending on comparing the mean of the degree of hearing loss of different site of perforation irrespective to the surface area of perforation.
- There is a major problem in the above method that when they decide a certain site of perforation gives more degree of hearing loss than the others, the result affected by the different surface area of perforation among these sites.
- In order to overcome the above problem, we should take in account the surface area of tympanic membrane perforation to elucidate the effect of the site on the degree of hearing loss as shown in our equation.

The degree of hearing loss classified into the following grades according to WHO grades of hearing impairment:

- Grade 0 (No impairment): 25 dB or better.
- Grade 1 (mild impairment): 26-40 dB
- Grade 2 (moderate impairment):41-60 dB
- Grade 3 (severe impairment): 61-80 dB
- Grade 4 (profound impairment): 81 dB or greater.

Data processing and analysis carried out with computer software Statistical Package for Social Sciences (SPSS) version 17. The p value <0.05 was considered statistically significant.

RESULTS

Sixty-three patients with 75 perforated eardrums were included in the study. The results of the study shown in the following:

Age and gender distribution: The age of studied group ranged from 14 to 45 years (mean 28±9 years). The most common age group studied 21-30 years (39.7%) followed by 31-40 years (25.39%), 10-20 years (23.81%), then 41-50 years (11.1%).There was unequal male and female distribution; 34 patients (54%) were female and 29 patients (46%) were male (Table 1).

Table 1: Age and gender distribution.

Age (year)	Male no.	Male (%)	Female no.	Female (%)	Total no.	Total (%)
10-20	8	12.7	7	11.11	18	23.81
21-30	11	17.43	14	22.27	22	39.7
31-40	7	11.11	9	14.28	13	25.39
41-50	3	4.76	4	6.34	10	11.1
Total	29	46	34	54	63	100

Side distribution: Tympanic membrane perforation most commonly seen in the left side, which found in 34 patients (54%). Right-sided perforation seen in 17 patients (27%). bilateral perforation was evident in 12 patients (19%) (Figure 2).

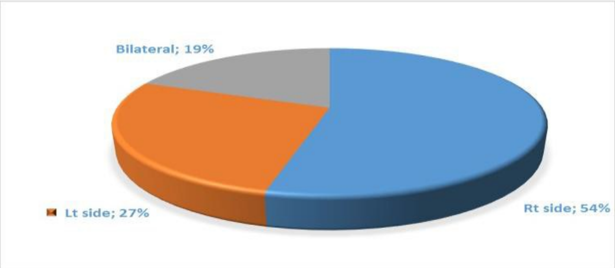

Figure 2: Distribution of the side of tympanic membrane perforation.

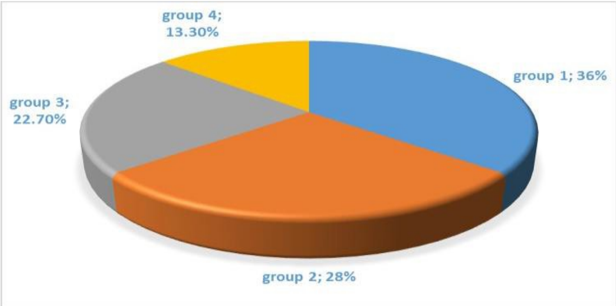

Figure 3: Distribution of percentage of surface area of tympanic membrane perforation (SA%).

Percentage of surface area of tympanic membrane perforation (SA %) distribution: The percentage of surface area of tympanic membrane perforation (SA %) ranged from 10% to 82% (mean 42.2±28.8 percentage).

The majority of ears seen in Group I; 27 ears (36%), Group II; 21 ears (28%), Group III; 17 ears (22.7%) and Group IV; 10 ears (13.3%) (Figure 3).

Site distribution: The majority of ears seen with central perforation; 47 ears (62.7%) then anterior perforation; 15 ears (20%) finally posterior perforation; 13 ears (17.3%) (Figure 4).

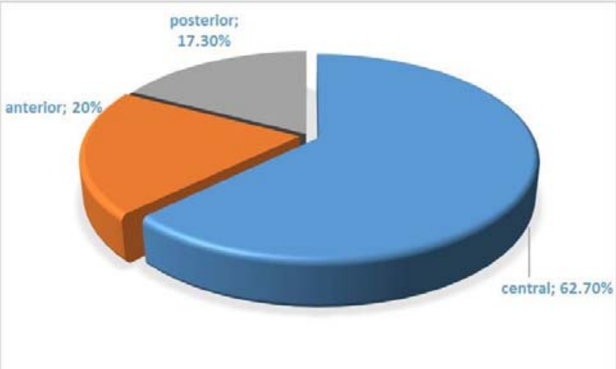

Figure 4: Distribution of the site of tympanic membrane perforations.

Hearing loss distribution: The degree of average hearing loss of speech frequencies ranged from 13.3 dB to 45 dB. The majority of ears shown to have a mild hearing impairment with 45 ears (60%). Normal hearing observed in 16 ears (21.3%) and only 14 ears (18.7%) had a moderate hearing impairment. The degree of hearing loss shown to be greatest at the frequency of 500 Hz (34.3±8.7) and lowest at the frequency of 4000 Hz (30.6±8) with p value equal to 0.157 (Table 2).

SA% and hearing loss: There is an increment in the degree of hearing loss as SA% increases. Average air-bone of speech frequencies for each group was as follows; Group I: 24.67±4.7 dB, Group II: 33.36±5.8 dB, Group III: 38.5±3.9 dB and Group IV: 42.6±2.1 dB (Table 3). P value was 0.000.

The relationship between (SA%) and degree of hearing loss can be expressed in a curve (Graph 1). The curve interpreted by the following logarithmic equation:

HL (dB) = 9.707(dB)×Ln (SA%×100)–1.508 (dB)

HL: average hearing loss of speech frequencies in (dB); *Ln:* natural logarithm.

Example:

If SA% = 40% Then:

HL (dB) = 9.707 (dB) × Ln (40% ×100) – 1.508(dB)

HL (dB) = 9.707 (dB) × 3.6888 – 1.508 (dB)

HL (dB) = 34.29 dB.

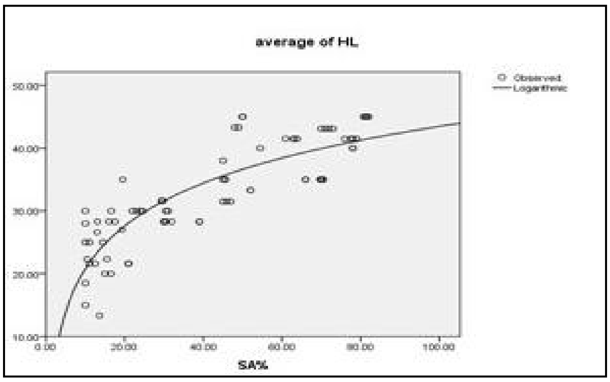

Figure 5: Curve represents the logarithmic relationship between SA% and average hearing loss.

Site of perforation and hearing loss: Tympanic membrane perforations divided into three groups based on their location on the parstensa in relation to the handle of malleus. According to average hearing loss of speech frequencies, the maximum degree of hearing loss was observed in the centrally located perforation (37±6 dB), followed by posteriorly located perforation (25.6±5 dB) then anteriorly located perforation (24.8±5 dB) (Table 4). There was a significant difference in degree of hearing loss between centrally located perforation and that of anterior or posterior one (p value 0.000). The difference was insignificant between posterior and anterior perforation (p value 0.441).

Table 2: Grades and mean of hearing loss according to different frequencies.

Hearing frequency	No. of ears with normal hearing	No. of ears with mild HL	No. of ears with moderate HL	Mean of hearing loss (dB)
500 Hz	15	39	21	34.3±8.7
1000 Hz	24	43	8	31.5±8.2
2000 Hz	19	44	12	32.1±8.3
Average frq.	16	45	14	32.6±8.1
4000Hz	17	48	10	30.6±8

According to R ratio, the maximum degree of hearing loss was observed in posterior perforation (R ratio 1.7±0.5 dB/%), anterior perforation (R ratio 1.5±0.6 dB/%) and centrally located perforation (R ratio 0.8±0.4

dB/%) (Table 4). There was insignificant difference between the mean of (R ratio) of posterior perforation and that of anterior one (p value 0.185), while a significant difference between mean of (R ratio) of centrally located perforation and that of anterior or posterior one was seen (p value 0.002).

Table 3: SA% and hearing loss.

SA%	Hearing threshold at 500 HZ	Hearing threshold at 1000 HZ	Hearing threshold at 2000 HZ	Average hearin	Hearing threshold at 4000 HZ
Group I (1-25%)	25.2±5	24.5±5.4	23.9±4.8	24.67±4.7	24±6
Group II (26-50%)	35.7±5.7	31.1±6.6	33.3±5.9	33.36±5.8	31.3±6
Group III (51-75%)	41.1±4.1	35.8±4.7	38.2±4.9	38.5±3.9	35.5±3
Group IV (76-100%)	44±2	43±2.5	41±3.9	42.6±2.1	42±2.5

Table 4: Site of perforation and hearing loss.

Site	Hearing loss at 500 HZ	Hearing loss at 1000HZ	Hearing loss at 2000H	Average Hearing loss	Hearing loss at 4000HZ	R ratio (dB/%)
Anterior	26±5	24±5	24.3±5	24.8±5	23.3±6	1.5±0.6
Posterior	26.1±5	24.9±5	25.7±5	25.6±5	24.7±5	1.7±0.5
Central	39±6	35.6±6	36.3±6	37±6	35.8±5	0.8±0.4

DISCUSSION

Age and gender distribution: The most commonly affected age group was 21-30 years (39.7%) (Table 1). Our observation differed from the studies of Nahata et al and Bhusal et al and where the most common age group was 15-24 years.[1,7]

We found a slight female preponderance (male: female ratio was 1:1.17) (Table 1). Our finding was similar to that of Nahata et al, Maharjan et al and Ibekwe et al where female preponderance seen but differed from the findings of Pannu et al and Nepal et al where there was male preponderance.[1-4,8]

Side distribution: Left ear found to be mostly affected (54%) (Figure 1).This finding was consistent with that of Maharjan et al, Pannu et al and Ibekwe et al and Ribeiro et al.[2,3,8,9] Nahata et al showed that bilateral ear involvement was more common.[1]

(SA%) distribution: (SA%) was divided into four groups as stated previously. The highest number of ears was seen in group I (36%), while the lowest number was seen in group IV (13.3%) (Figure 2). Nahata et al found that group III was most commonly involved (43%), while group I was most commonly involved (47%) in the study of Pannu et al.[1,3]

Site distribution: The site of tympanic membrane perforation divided into three categories according to its relation to the handle of malleus. Most of perforations were located centrally (62.7%) (Figure 3). This finding was similar to that of Bhusal et al (34%), Nahata et al (69%), Maharjan et al (60.5%) and Ibekwe et al (77.9%), but differed from that of Pannu et al who found most of perforations situated anteriorly (38%).[1-3,8]

Hearing loss distribution: Most of ears had a mild degree hearing loss (Table 2) .This finding was similar to the study of Nahata et al, but differed from that of Maharjan et al because he found that most of ears had a moderate degree hearing loss.[1,2]

Low frequencies shown affected more than high frequencies. The highest degree of hearing loss observed at frequency of 500 Hz while the lowest one at frequency of 4000 Hz (Table 2).This difference in degree of hearing loss was insignificant (p value=0.157). Nahata et al, Maharjan et al and Nepal et al stated that lower frequencies affected more than higher frequencies but difference significant (p value <0.05).[1,2,4] Our result explained by presence of some ears that have partial ossicular defect that may be associated with an air-bone gap greater at high versus low frequencies. The mechanism of hearing loss probably related to a decrease in the rigidity within the ossicular chain .At low frequencies, a fibrous band seems to be tense enough to allow near-normal sound transmission. At higher frequencies, the fibrous band flexes such that motions of the tympanic membrane not readily coupled to the stapes.[10] This mechanism resulted in an increment in hearing loss in high frequencies that made the difference between them and low frequencies insignificant.

SA% and hearing loss: We observed that hearing loss increases with increasing SA% of perforation (Table 3).This increment was significant (p value =0.00). Our view supported by studies of Nahata et al, Maharjan et al, Pannu et al and Nepal et al.[1-4]

Ribeiro et al observed no significant relation between size of perforation and degree of hearing loss in patients with inactive chronic otitis media. His study included patients with inactive chronic otitis media who had a pure conductive hearing loss irrespective to state of the ossicles.[9]

The mechanism of conductive hearing loss due tympanic membrane perforation may explained by the effect of two factors.[10]

- Reduction in the ossicular coupling that is caused by a loss in the sound pressure difference across the inner and outer surface of tympanic membrane which decreases the phase differential between oval and round windows.
- Reduction in the surface area of tympanic membrane that is necessary for transmission of sound wave from the external auditory canal through the ossicles to the cochlea.

In the studies of Nahata et al and Pannu et al, the surface area of tympanic membrane perforation was classified into three groups as the following: group I (0-9 mm^2), group II (9-30 mm^2) and group III (more than 30 mm^2).[1,3] Nahata et al found that the degree of hearing loss in relation to the surface area of tympanic membrane perforation was 29.41±4.39 dB, 34.69±4.96 dB and 38.79±3.44 dB respectively.[1] They excluded the presence of ossicular abnormality by paper patch test. The results of Pannu et al were 31.43±11.59, 39.88±11.43 and 55.22±7.15 respectively.[3] They did not adopt any specific method to exclude the presence of ossicular abnormality.

The relation between the surface area of tympanic membrane perforation and degree of hearing loss formulated in a curve ruled by a logarithmic equation (Figure 5). By applying our equation, we can calculate the predictable degree of hearing loss that corresponds to a known surface area of tympanic membrane perforation. If the degree of hearing loss of an ear exceeds the predicted value for the corresponding surface area, the presence of ossicular affection confirmed. This logarithmic equation is a unique feature of our research; therefore, more researches needed to compare our finding.

Site of perforation and hearing loss: According to average hearing loss of speech frequencies, the maximum degree of hearing loss observed in centrally located perforations (37±6 dB). Posterior perforation caused hearing loss more than anterior one (25.6±5 dB: 24.8±5 dB respectively) (Table 4). There was a significant difference in the degree of hearing loss between centrally located perforation and that of anterior or posterior one (p value 0.000). The difference was insignificant between posterior and anterior perforation (p value 0.441).

Our result was consistent with the observation of Pannu et al because he found that central perforations involving multiple quadrants gives highest degree of hearing loss (40.29 dB) while posterior perforations gives (27.62 dB) and anterior perforations causes only (24.93 dB) with an insignificant difference between anterior and posterior perforation (p value >0.05).[3]

Our findings differed from that of Nahata et al who showed that posterior perforations had the greatest hearing loss (39.99±2.79 dB), followed by central perforations (35.64±5.31 dB) lastly anterior perforations (30.1±2.98 dB).[1] The difference was significant (P value 0.000). Bhusal et al found that the highest degree of hearing loss found in big central perforations (45±7.6 dB) then in posterior perforations (43.3±7 dB) and lowest in anterior perforations (31±3 dB).[7] The difference was insignificant between central and posterior perforations (p value > 0.05), but it was significant between anterior and that of central or posterior one (p value <0.05).

All the above studies compared the site of perforation to degree of hearing loss irrespective to the surface area of perforations. This method is inaccurate to elucidate the role of perforation site in determining degree of hearing loss. We generated (R ratio) from a specific equation as we mentioned previously to determine the role of the site of perforation according to perforation surface area. By application of R ratio, the maximum degree of hearing loss was shown in posterior perforation (R ratio 1.7±0.5 dB/%) followed by anterior perforation (R ratio 1.5±0.6 dB/%) then centrally located perforation (R ratio 0.8±0.4 dB/%) (Table 4). There was insignificant difference between the mean of (R ratio) of posterior perforation and that of anterior one (p value 0.185), while a significant difference between mean of (R ratio) of centrally located perforation and that of anterior or posterior one was seen (p value 0.002).

The difference between centrally located perforation and that of the other sites should be insignificant because centrally located perforation includes both anterior and posterior elements and the difference between anterior and posterior perforation was insignificant. Hence, we must ask a question; why did this difference appear significant? The answer is that this significant difference between central perforation and that of other sites is not due to the location itself, but due to the mechanic of the ear that illustrated in (Figure 5) which shows a regressive increment in the degree of hearing loss with increasing SA% of perforation in a form of logarithmic equation. The mean of surface area of central perforation situated in the middle part of the curve, therefore gave (R ratio=0.8±0.4 dB/%) while the mean of surface area of anterior and posterior perforation situated in the first part of the curve, hence they showed (R ratio: 1.5±0.6

dB/%,1.7±0.5 dB/%) respectively. Other researches should adopt our R ratio in their analysis to compare their results with us.

CONCLUSION

From this study it is concluded that there is a significant increment in degree of hearing loss in patients with inactive mucosal chronic otitis media with increasing the surface area of tympanic membrane perforation at different frequencies. There is a quantitative relationship between the surface area of perforation and degree of hearing loss from which we can judge whether the patients with inactive mucosal chronic otitis media have a middle ear pathology rather than perforated ear drum. This quantitative relationship ruled by a logarithmic equation as follows:

$$HL\ (dB) = 9.707(dB) \times \ln\ (SA\% \times 100) - 1.508(dB).$$

There is an insignificant difference in degree of hearing loss among different frequencies in patients with chronic otitis media irrespective to site and size of perforations. There is an insignificant effect of the site of tympanic membrane perforation on degree of hearing loss in patients with inactive mucosal chronic otitis media.

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