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ORIGINAL STUDY

INFLUENCE OF PERFORATION CHARACTERISTICS OF THE TYMPANIC MEMBRANE ON HEARING LOSS

Bianca Niculescu[1], Doina Vesa[2], Ermil Tomescu[3]

[1] ENT Clinic, Emergency Clinic Hospital Galați
[2] Department of Otolaryngology, Faculty of Medicine and Pharmacy, University "Dunarea de Jos" Galati
[3] University of Medicine and Pharmacy, Cluj-Napoca

niculescu_bianca13@yahoo.com

ABSTRACT

Tympanic membrane perforations result in a transmission hearing loss or mixed hearing loss predominant transmission up to 40 dB. Our study aimed to determine which characteristics of the tympanic membrane perforation is a key factor in hearing loss. The retrospective study was based on 151 perforated tympanic membranes that were identified by otoscopy were examined by means of liminal tonal audiograms to determine the hearing loss in decibels on different frequencies. Images of the perforations were captured by video otoscopy and their surfaces were calculated as a percentage of the tympanic membrane surface. Perforation sizes and locations were correlated with hearing loss in decibels on different frequencies.Hearing losses in sound transmission are frequency dependent, with most severe losses on lower frequencies. Hearing loss intensifies as the size of the perforation increases in the case of all perforations under consideration being similarly located, either anterior or posterior. On high frequencies hearing losses are less serious. When comparing perforations of similar size, it turns out that posterior perforations cause more serious hearing loss.In anticipation of a hearing loss caused by a tympanic membrane perforation both the location and the size of the perforation should be considered as they both closely influence hearing loss.

KEYWORDS*: hearing loss, tympanic membrane, audiogram, video-otoscopy*

1. Introduction

Tympanic membrane perforations may be caused by middle ear diseases and trauma (including iatrogenic). These perforations appear in a wide variety of shapes, sizes and locations, and are more or less recent [1]. The characteristics of perforations are closely related to the transmission of sound through the middle ear to the inner ear, hence the hearing loss. Also these features are key factors as regards symptoms, clinical signs, complications and treatment methods. For example, marginally located perforations are associated more frequently with complications than centrally located ones; some small perforations heal spontaneously, while larger ones require surgical treatment [2].

Audiometric examination of the middle ear in the case of perforated eardrums reveals transmission hearing loss or mixed hearing loss predominant transmission, ranging between 10 and 40 dB. When besides the perforation there is also an osicular chain injury or other disorders of the middle, the hearing loss is even more severe.[3]

Studies conducted so far to determine to what degree the characteristics of perforations influence hearing loss have been carried out on animals [4,5], temporal bones taken from cadavers [2,6,7] and there have been clinical studies [8]. The conclusions from animal studies and those conducted on temporal bones were conflicting because of the differences between animal and human auditory system and because of the differences of sound transmission in vitro and vivo [2].

Clinical trials are difficult to conduct for many reasons including the following:

- Additional effects of other middle ear disorders (other than perforation of tympanic membrane)
- Difficulties in measuring the perforation [7].

To avoid these problems we have included in the study only patients whose disorder is only the tympanic membrane perforation (below 40 dB hearing loss), and to ensure the accuracy of perforations measurements a computer program was used to measure images obtained by means of video-otoscopy. This size of the perforation was thus accurately calculated and compared with the size of the tympanic membrane (perforation surface area expressed as a percentage of the eardrum surface). Then the perforation sizes and locations were statistically correlated with the hearing loss in dB on different frequencies.

2. Material and methods

This paper is a retrospective study conducted at the ENT Department Emergency County Hospital St. Apostol Andrei "Galați, within 2 years (04/01/2009 to 03/31/2011).

We observed 183 tympanic membranes with one or two perforations identified by means of otoscopy in a group of 177 patients. A review was conducted for each case establishing the cause and duration of perforations and a liminal tone audiogram was performed with an audiometer from GN OTOMETRICS ITERA II.

Of the initial group of 177 patients were excluded from the study patients with hearing loss exceeding 40 dB to avoid hearing loss data caused by other middle ear disorders. Thus the final study was conducted on 151perforated tympanic membranes on 147 patients aged between 14 and 70. 48.39% of patients were male and 51.61% female (calculating $\chi 2$ the value 0.16, $p > 0.05$ is obtained, hence the patient sex does not influence the occurrence of tympanic perforation). The duration of the perforation was between 1 day and 7310 days (20 years), the causes were traumatic, 74.18% and resulting from otitis, 25.82% .

To accurately emphasize the correlations between perforation size and variation of hearing loss, five groups were established:

- with a perforation smaller than 2% of the eardrum surface,
- with a perforation between 2% and 5% of the eardrum surface,
- with a perforation between 5% and 10% of the eardrum surface,
- with a perforation between 10% and 15% of the eardrum surface, with a perforation of more than 15% of the eardrum surface (a quadrant).

Then there were images of perforated tympanic membranes by means of video-otoscopy with MDSCOPE MS101. All images were recorded on a computer and using the Universal Desktop Ruler v.3.5.3364 the area of perforation was calculated as a percentage of the tympanic membrane area according to the following formula:

$$\frac{P}{T} \text{ x } 100\% = \text{percentage of perforation, where:}$$

P = perforation area (in pixels)
T = total area (in pixels) of the entire eardrum including perforation.

Statistical analysis was performed using a personal database obtained by means of SPSS program(Statistical Package for Social Sciences). Determining the association (correlation) among different variables studied (perforation size, perforation location, hearing loss in decibels on different frequencies) was performed under the firm of contingency tables with two entries, which is specific to associations among discrete variables, or by calculating the Pearson correlation coefficient, which is specific to continuous variables. For continuous data the usual statistical indicators were calculated: the arithmetic mean, the standard deviation, the standard error margin of the mean, etc. The standard deviation was calculated by applying the formula:

$$s = \sqrt{\frac{\sum x^2}{N}}\ .$$

Testing the significance of an association was obtained by using χ^2 test (for frequency tables) and the "t" test (for correlation coefficients).

For discrete data the absolute and relative frequencies were calculated, which provide adequate information about the distribution of the cases studied according to the respective variable categories. The χ^2 adjustment test aimed to compare the numbers of a single variable, either with other observed numbers or with theoretical numbers that can be calculated starting from a hypothesis, usually the null hypothesis. In this first case, we could verify that a subset (taken in the analysis) has the same known characteristics of the general group (eg. the sex category, the social origin).

The following formula was used to calculate the χ^2 test:

$$\chi^2 = \sum \frac{(fo - ft)^2}{ft}$$

in which the f_o stands for the examined numbers while f_t stands for theoretical numbers or other examined numbers.

The deviation between the examined or real number and the theoretical number (f_o-f_t) is raised to the square to avoid the cancellation of the algebraic sum. So χ^2 can only have a positive value, which places it among the tests with only one exit (which requires a single alternative for comparison). Bravais-Pearson correlation coefficient was used because it is more reliable as regards the accuracy of results. During the study we followed the different trends of the variables analyzed. Significances were calculated by means of Student's tables "t" or by means of Bravais-Pearson's "r" law tables. Another table used in the study was "Fisher's Table of χ^2 values.

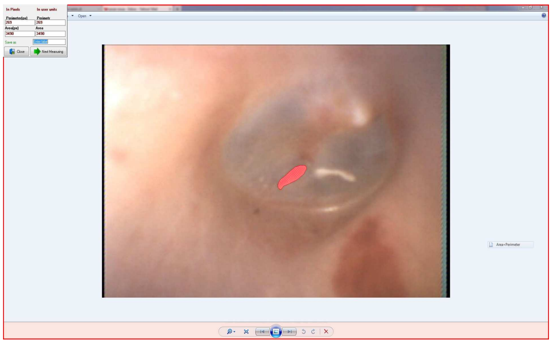

Figure 1. *Measuring the area of tympanic membrane perforation in the posteroinferior quadrant (right ear)*

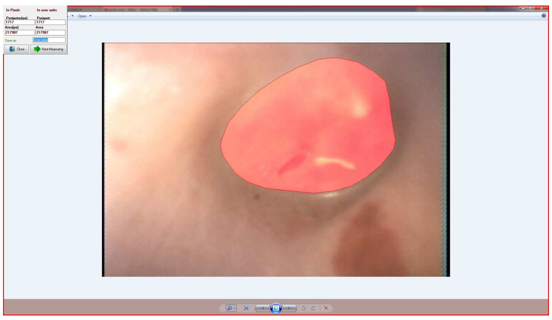

Figure 2. *Measuring the entire tympanic membrane area including the perforation (right ear)*

3. Results and discussions

After analyzing the hearing loss in dB on frequencies in patients divided into five groups according to perforation size we obtained the following results (table I, II):

Table I. *Average of hearing loss in dB on frequencies*

Frequencies / Perforation	125 Hz	250Hz	500 Hz	1000Hz	peste 1000Hz
0-2%	25 dB	20,5 dB	19,7 dB	17,5 dB	15,06 dB
2-5%	21 dB	20 dB	19 dB	18,3 dB	15,79 dB
5-10%	28,05 dB	20,27 dB	19,9 dB	19,5 dB	16,32 dB
10-15%	31,36 dB	22,72 dB	21,34 dB	20,14 dB	16,87 dB
over 15%	28,8 dB	25,37 dB	24,59 dB	22,23 dB	17,32 dB

Table II. *Standard deviation of hearing loss in dB on frequencies*

Frequencies / Perforation	125 Hz	250Hz	500 Hz	1000Hz	peste 1000Hz
0-2%	± 6,04 dB	± 6,15 dB	± 4,62 dB	± 4,12 dB	± 3,18 dB
2-5%	± 7,26 dB	± 4,87 dB	± 3,18 dB	± 5,67 dB	± 4,76 dB
5-10%	± 4,32 dB	± 6,73 dB	± 4,29 dB	± 3,29 dB	± 5,07 dB
10-15%	± 8,56 dB	± 5,71 dB	± 6,37 dB	± 6,89 dB	± 3,19 dB
over 15%	± 7,32 dB	± 8,12 dB	± 7,82 dB	± 5,22 dB	± 2,96 dB

We notice that sound transmission loss in the case of perforated eardrums is frequency dependent with most serious losses on low frequencies (125 Hz, 250 Hz and 500 Hz), 31.36 dB on average. This is consistent with the literature studies conducted so far:

- on animals, when cochlear potentials in cats with perforated eardrums were recorded as well as the velocity of the tympanic membrane around umbo in rats with the same disorder [4,5].
- on temporal bones from cadavers, with perforated eardrums [2,6,7].
- in clinical cases, on eardrums with tympanostomy tubes [8].

On low frequencies hearing loss does not intensify along with the size of the perforation, so that we cannot draw a rising line for hearing losses between 125 and 500 Hz in accordance with a decrease in the actual area of the eardrum as expected according to the results of studies in literature. We assumed this disagreement is due to the fact that the perforation surface measurements made by us are more accurate. Moreover, the other authors do not specify how they measured the perforations.

Estimation accuracy of the perforation size by means of standard otoscopy is not only limited to errors of observation but also to the fact that the edges of the perforation are not uniformly round. Thus their areas are not easily assessed by simple observation or calculated based on the diameter of the tympanic membrane [9].

A computerized system of measurement by video-otoscopy [10] can calculate more accurately a perforation size expressing it as a percentage of the surface of the eardrum [11,12].

On high frequencies (1000 Hz, over 1000 Hz) dB losses increase along with the size of the perforations, but are much less significantly than on low frequencies, below 20 dB on average, sometimes turning towards 0.

Thus for the frequency of 125 Hz, correlating values of decibel loss for perforations with a size between 0 and 2% of the tympanic membrane is obtained by calculating the Pearson correlation coefficient, r = 0.613 (r - correlation coefficient) and p = 0 , 07.

Since p> 0.05 we can say that there is no link between the two variables analyzed (size of the tympanic perforation and hearing loss), in other words the two variables do not influence each other, the increase in one not causing changes in the second variable (figura 3).

The correlation coefficients were calculated as follows (table III):

Table III. *Calculation of correlation coefficients*

p / Perforation	p for 125 Hz	p for 250Hz	p for 500 Hz	p for 1000Hz	p for over 1000Hz
0-2%	> 0,05	> 0,05	> 0,05	< 0,05	< 0,05
2-5%	> 0,05	> 0,05	< 0,05	< 0,05	< 0,05
5-10%	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05
10-15%	> 0,05	0,012	< 0,05	< 0,05	< 0,05
over 15%	> 0,05	< 0,05	< 0,05	< 0,05	< 0,05

For values of p <0.05 the *research hypothesis* was accepted, namely that the *variable size of the perforation* affects *hearing loss.*

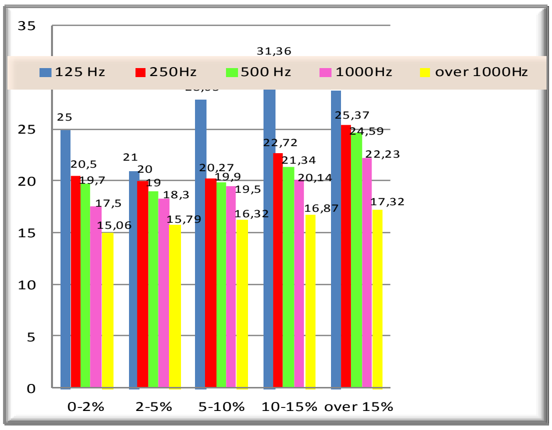

Figure 3. *Dependence of hearing loss on perforation size*

We further analyzed hearing loss in decibels on frequencies according to the perforation location in the anterior quadrants (upper and lower) and posterior quadrants (upper and lower) (table IV).

Table IV. *Review hearing in decibels lower frequencies depending on the location of perforation*

Frequency / Perforation	125 Hz	250Hz	500 Hz	1000Hz	over 1000Hz
Anterior	25,74 dB	21,43 dB	19,17 dB	17,6 dB	15,82 dB
Posterior	30,23 dB	23,23 dB	22,42 dB	21,67 dB	18,97 dB

The results showed that posterior perforations cause a more serious hearing loss than anterior perforations. This result is also inconsistent with the results of existing studies in literature, which shows that the differences observed between decibel losses associated with anterior and posterior perforations cannot be systematized in valid conclusions [2].

We assumed that this discrepancy comes from the fact that the perforations in our group of patients are located in the posterior quadrants, responsible for more serious hearing loss were larger than the anterior perforations. Furthermore it is known that due to the anatomical position of the eardrum and external ear canal curvatures, the mid-posterior and especially the posterior-inferior quadrant is more accessible to trauma factors (75% of perforations are posttraumatic). Also, due to inhomogeneous distribution of the fibers entering the histological structure of the tympanic membrane, the posterior-inferior area is the thinnest and has low resistance therefore it is prone to large perforations (figura 4) [13].

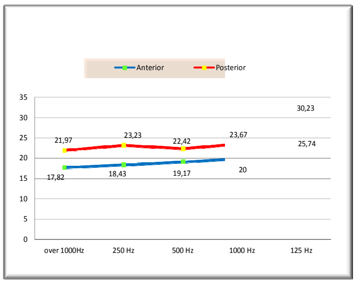

Figure 4. *Dependence of hearing loss on perforation location*

In literature, there are no clinical studies to correlate the two parameters characterizing the perforations (size and location) with hearing loss, but only separate correlations: between size and hearing loss and between location and hearing loss.

Given that our results were largely inconsistent with the existing data we concluded that a more accurate assessment of the variations in hearing loss should considered both the size and the location of a perforation.

This is the reason why we observed hearing loss on different frequencies in perforations of similar size but differently located.

Table V (a. and b). *Decreased hearing on different frecquencies for perforation of the same size but with differen location*

Frequency / Perforation	125 Hz		250 Hz	
	Anterior	Posterior	Anterir	Posterior
0-2%	21,42 dB	26,33 dB	21,04 dB	25,94 dB
2-5%	23,84 dB	28,36 dB	22,18 dB	27,49 dB
5-10%	24,11 dB	32,22 dB	23,89 dB	31,17 dB
10-15%	26,25 dB	33,25 dB	25,43 dB	32,04 dB
Over 15%	28,75 dB	40 dB	27,32 dB	38,14 dB

a.

Frequency / Perforation	500 Hz		over 1000 Hz	
	Anterir	Posterior	Anterior	Posterior
0-2%	19 dB	24,13 dB	18,1 dB	22,57 dB
2-5%	21,07 dB	26,32 dB	19,7 dB	25,68 dB
5-10%	23,19 dB	28,1 dB	21,54 dB	27,3 dB
10-15%	24,7 dB	29,67 dB	22,3 dB	28,14 dB
over 15%	26,51 dB	36,54 dB	25,81 dB	32,8 dB

b.

The results presented in Table V (a. and b.) showed that both on low and high frequencies hearing losses caused by anterior eardrum perforations intensifies as perforation size increases. This is also true for posterior perforations. Our hypothesis regarding posterior perforations that cause a more serious hearing loss than anterior perforations, even if of similar size, is further confirmed.

5. Conclusions

Assessing hearing variations caused by tympanic membrane perforations should consider both size and location of perforation, because a small perforation located in a more mobile and sensitive area of the eardrum or above the round window can cause a more serious hearing loss than a large perforation in a less important area (in terms of transmission of sound) of the eardrum.

Perforation size must be calculated as accurately as possible by means of computerized methods (not by a simple visual assessment that is subject to error) and should be expressed as a percentage of the tympanic membrane surface (not in comparison with other parts of the eardrum that may be vary from patient to patient or can be modified).

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