ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

DOI: 10.24179/kbbbbc.2019-65479

Effect of Small Tympanic Membrane Perforations on Hearing

Timpanik Membrandaki Küçük Perforasyonların İşitme Üzerine Etkisi

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Received: 12.02.2019
Received in revised form: 12.04.2019
Accepted: 12.04.2019
Available online: 16.04.2019

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ABSTRACT Objective: The effects of perforations on middle-ear sound transmission are not well defined because of middle ears with TM perforations generally have additional pathological changes. The aim of the study is to compare the hearing loses in tympanic membrane perforation of quadrants with exclusion of the possible middle and inner ear pathologies that may have resulted any hearing loss. **Material and Methods:** Patients who attended Otorhinolaringology-Head Neck Surgery Department, and underwent type 1 tympanoplasty between 2011 January and 2014 December were retrospectively analyzed. Size of perforation had been described in millimeter and location was grouped as anteroinferior (AI), anterosuperior (AS), posteroinferior (PI), posterosuperior (PS). **Results:** Sixty-five patients (65 ears) with isolated TM perforations were included in the study. Twenty-seven (41.5%) perforations were in PI, 8 (12.3%) perforations PS, 25 (38.4%) perforations AI, and 5 (7.7%) perforations AS-localized. There were not statistically significant differences between 4 groups at each frequency (0.5 kHz, 1 kHz, 2 kHz, and 4 kHz) for air-bone gap. Statistically significant decrease of bone conduction thresholds was observed in AI group when compared with other groups at higher frequencies (2 and 4 kHz, $p<0.05$) and between small and moderate perforation groups in all frequencies (500, 1000, 2000 ve 4000 Hz, p value: p=0.025, p=0.025, p=0.037, p=0.034 respectively). **Conclusion:** The results showed that the air-bone gap increases with increasing size of perforation. However, no statistically significant air-bone gap differences between tympanic membrane quadrants were determined.

Keywords: Ear drum perforation; hearing loss

ÖZET Amaç: Timpanik membran perforasyonlarının orta kulaktan ses iletimi üzerine olan etkisi tam olarak bilinmemektedir. Çünkü, çoğu zaman diğer orta kulak patolojileri de timpanik membran perforasyonlarına eşlik etmektedir. Bu çalışmanın amacı işitme kaybına neden olabilecek olası orta ve iç kulak patolojilerin dışlanmış olduğu hastalarda timpanik membran perforasyonu ile işitme kaybı arasındaki ilişkiyi araştırmaktır. **Gereç ve Yöntemler:** Ocak 2011 ile Aralık 2014 tarihleri arasında Başkent Üniversitesi Kulak Burun Boğaz ve Baş-Boyun Cerrahisi Ana Bilim Dalı'nda tip 1 timpanoplasti uygulanan hastalar retrospektif olarak incelendi. Perforasyon boyutu milimetre ile belirtildi. Hastalar perforasyonun lokalizasyonuna göre anteroinferior (AI), anterosüperior (AS), posteroinferior (PI), posterosüperior (PS) olarak 4 gruba ayrıldı. **Bulgular:** Çalışmaya basit kulak zarı perforasyonu olan 65 hasta (65 kulak) dahil edildi. Posteroinferior grupta 27 hasta (%41,5), posterosüperior grupta 8 hasta (%12,3) anteroinferior grupta 25 hasta (%38,4), anterosüperior grupta 5 hasta (%7,7) vardı. Her frekansta (0,5 kHz, 1 kHz, 2 kHz, 4kHz) 4 grup arasında hava-kemik aralığı açısından istatistiksel anlamlı farklılık saptanmadı. İki ve 4 kHz'te anteroinferior grupta diğer gruplar ile karşılaştırıldığında kemik yolu eşiklerinde istatistiksel olarak anlamlı düşüş tespit edildi ($p<0,05$). Orta ve küçük boy perforasyon grupları arasında hava-kemik aralığı açısından istatistiksel anlamlı fark tespit edildi ($p<0,05$). **Sonuç:** Sonuçlar, perforasyon boyutu arttıkca hava-kemik aralığının arttığını göstermektedir. Ancak, hava-kemik aralığı açısından timpanik membran kadranları arasında istatistiksel anlamlı farklılık saptanmadı.

Anahtar Kelimeler: Timpanik zar perforasyonu; işitme kaybı

Most common causes of tympanic membrane (TM) perforations are infection and trauma that lead to conductive hearing loss particularly affected by low frequencies and recurrent infections.[1-3] The effects of perforations on middle-ear sound transmission are not well defined because of middle ears with TM perforations generally have additional pathological changes. Previous experimental and clinical studies have shown that hearing loss due to TM perforation worsens with increasing perforation size and is greater at lower frequencies.[4-6] It has also been believed that there is correlation between hearing loss and site of TM perforation.[7,8] However, some cadaveric and clinic studies reported no relationship between sound transmission and site of TM perforation.[9-11] Additionally, there is no information about exclusion of the other middle and inner ear pathologies, which is resulted as conductive hearing loss in these studies.

The aim of the current study is to compare the hearing loses in TM perforation of anteroinferior (AI), anterosuperior (AS), posteroinferior (PI) and posterosuperior (PS) quadrants with exclusion of the possible middle and inner ear pathologies that may have resulted any hearing loss.

MATERIAL AND METHODS

This study was performed in compliance with the Declaration of Helsinki. Patients who attended otorhinolaryngology Department, and underwent type 1 tympanoplasty between 2011 January and 2014 December were retrospectively analyzed. Patients who had inflammatory and sclerotic changes in tympanic cavity, fixation and erosion of the ossicular chain, large perforation, cholesteatoma, semicircular canal dehiscence and otosclerosis were excluded. Patients who have dry-clean (no otorrhea or no history of otorrhea during the past 6 months) TM perforations due to chronic tubotympanic suppurative otitis media, post residual perforations as a result of ventilation tube insertion and simple traumatic perforations, clearly described location, shape and size of perforation, ruled out sclerotic and inflammatory tissues in tympanic cavity and had mobile and intact ossicular chain in operative report were selected. All the patients have preoperative high-resolution temporal bone computed tomography.

Tympanic membran is divided in four quadrants (AI, AS, PI, PS) with horizontal and vertical imaginary lines, one passing through the handle of malleus and another transverse line intersecting it at umbo Figure 1 that provides to grouping the pathologies. Size of perforation had been described with millimeter and location of perforation was grouped as mentioned above. Diameter of the TM is about 8-10 mm. It means that sizes of each quadrant is about 5 mm. Therefore, perforations larger than 5 mm diameters and have irregular shape excluded from the study. Additionally, all perforations are also divided as small perforation (1-2 mm) and moderate perforation (3-5 mm) groups, according to the diameter.

All patients had pure-tone audiometry. Audiologic tests were conducted using a Clinical Audiometer AC40 audiometric device (Interacoustics A/S, DK-5610, Assens, Denmark). To determination of frequency dependence on the perforation-related conductive hearing loss, air conduction threshold, bone conduction threshold, air-bone gaps measured at each frequency and were analyzed. The study was approved by Baskent University (project no: KA15/15, 28/01/2015) İnstitutional Review Board and supported by Baskent University Research Fund.

Datas were transfered to IBM SPSS Statistics for Windows, version 18.0 (IBM Corp., Armonk, N.Y., USA) and analyzed. Independent sample t test was used to compare the groups. Pearson's correlation was used to analyze the correlation between the location of the perforation and hearing

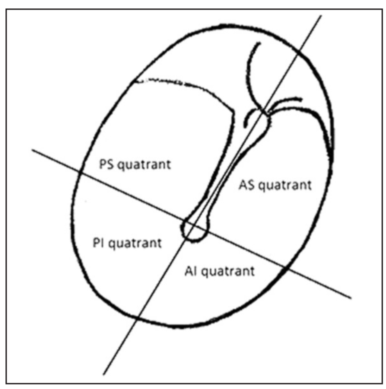

FIGURE 1: Schematic demonstration of the tympanic membrane quadrants. PS: Posterosuperior; AI: Anteroinferior; AS: Anterosuperior; PI: Posteroinferior.

loss. A value of p<0.05 was used to indicate statistical significance.

RESULTS

Total of 610 patients who underwent type 1 tympanoplasty were retrospectively analyzed. Sixty-five patients (36-males, 29-females) with isolated TM perforations were included in the study, ranging in age from 4 to 74 years (mean 36.9 years). The most common cause of the TM perforation was chronic tubotympanic suppurative otitis media among the patients. All patients had unilateral perforation. Middle ear, ossicular chain and osseous labyrinth were reported as normal in preoperative high-resolution temporal bone computed tomography of all patient.

Twenty-seven (41.5%) perforations were in PI, 8 (12.3%) perforations PS, 25 (38.4%) perforations AI, and 5 (7.7%) perforations AS-localized. Nineteen (29.2%) perforations were in small perforations group and 46 (70.8%) perforations were in moderate perforation group. Thirty-three (50.7%) patients had conductive hearing loss and 25 (38.5%) patients had mixed hearing loss, whereas 7 (10.8%) patients had normal pure tone audiometry. AI group showed statistically significant mixed type hearing loss (p>0.05). There was no significant difference between sex or age and air-bone gap (p>0.05).

Average air-bone gap was 15.2 dB at the 0.5 kHz, 17.7 dB at 1 kHz, 15.1 dB at 2 kHz, 12.2 dB at 4 kHz in PI group; 15.0 dB at the 0.5 kHz, 16.2 dB at 1 kHz, 16.2 dB at 2 kHz, 16.2 dB at 4 kHz in PS group; 15.2 dB at the 0.5 kHz, 14.0 dB at 1 kHz, 13.0 dB at 2 kHz, 18.2 dB at 4 kHz in AI group; 11.0 dB at the 0.5 kHz, 11.0 dB at 1 kHz, 12.0 dB at 2 kHz, 12.0 dB at 4 kHz in AS group. There was not a statistically significant difference between all the groups at each frequency (0.5 kHz, 1 kHz, 2 kHz, and 4 kHz) for air-bone gap (Table 1).

Average bone conduction thresholds were 11.6 dB at the 0.5 kHz, 9.0 dB at 1 kHz, 11.6 dB at 2 kHz, 12.0 dB at 4 kHz in PI group; 14.3 dB at the 0.5 kHz, 15.0 dB at 1 kHz, 16.8 dB at 2 kHz, 18.1 dB at 4 kHz in PS group; 14.0 dB at the 0.5 kHz, 12.8 dB at 1 kHz, 20.0 dB at 2 kHz, 26.4 dB at 4 kHz in AI group; 7.0 dB at the 0.5 kHz, 8.0 dB at 1 kHz, 7.0 dB at 2 kHz, 11.0 dB at 4 kHz in AS group. Statistically significant decrease of bone conduction thresholds was observed in AI group when compared with other three groups at higher frequencies (2 and 4 kHz, p<0.05).

Average air-bone gap was 11.0 dB at the 0.5 kHz, 11.0 dB at 1 kHz, 10.2 dB at 2 kHz, 10.2 dB at 4 kHz in small perforation group and 16.5 dB at the 0.5 kHz, 17.5 dB at 1 kHz, 15.8 dB at 2 kHz, 16.9 dB at 4 kHz in moderate perforation group. Statistically significant difference was observed between small and moderate perforation groups in all frequencies (500, 1000, 2000 ve 4000 Hz, p value: p=0.025, p=0.025, p=0.037, p=0.034 respectively) (Table 2).

DISCUSSION

There are significant controversies about the effects of the eardrum perforation on the sound transmission. TM perforations cause a hearing loss (conductive type) that can be minimal and not annoying or in some patients it can reach at 60 dB approximately.

TABLE 1: Average air-bone gaps in all groups.

Frequency (KHZ)	ABG in Pi group (DB)	ABG in Ps group (DB)	ABG in ai group (DB)	ABG in As group (DB)	p value
0.5	15.2	15	15.2	11.0	>0.05
1	17.7	16.2	14.0	11.0	>0.05
2	15.1	16.2	13.0	12.0	>0.05
4	12.2	16.2	18.2	12.0	>0.05

ABG: air-bone gap; kHz: kilohertz; dB: decibel; PI: posteroinferior; PS: posterosuperior; AI: anteroinferior; AS: anterosuperior.

TABLE 2: Average air-bone gaps in small and moderate perforation groups.

Frequency (KHZ)	Average ABG in Small (1-2 mm) Perforation group (DB)	Average ABG in Moderate (3-5 mm) Perforation group (DB)	P value
0.5	11.0	16.5	0.025
1	11.0	17.5	0.025
2	10.2	15.8	0.037
4	10.2	16.9	0.034

ABG: air-bone gap; kHz: kilohertz; dB: decibel.

Sound can transmit into the cochlea with two different mechanisms named ossicular coupling that occurs by TM and ossicles and acoustic coupling.[12] Movement of the TM also causes a sound pressure in the tympanic cavity. Because of different spatial settling, the sound pressures within the tympanic cavity doesn't act at the both windows (oval and round) equally. The difference of the sound pressure between round and oval windows is called acoustic coupling. Both mechanisms result in action of the stapes. Additionally, annular ligament and cochlear impedances named as the stapes-cochlear input impedance restrict the stapes motion. Conductive hearing loss may be disclosed by 2 possible mechanisms in TM perforation; (1) reducing rate of surface area of TM to footplate (a reduction in ossicular coupling) and (2) decreasing of phase difference between round and oval windows (an increase in acoustic coupling).

Lots of groups have been sought to understand of the sound transmission mechanism of the normal, diseased and reconstructed middle ears in human temporal bones, simulated models or real patients.[12] There have been some studies, which reported good correspondence of the mechanical properties between the cadaver human middle ear and the in vivo condition.[12-14] On the other hand, some studies have not shown relationship between TM perforation size and hearing loss. In a recent clinical study, it has not shown significant relationship between the tympanic membrane perforation size and hearing loss in the four analyzed frequencies.[15] In the present study, we also found directly proportional relationship between size of perforation and hearing loss. However, we couldn't find statistically significant air-bone gap on lower frequencies. Some authors support that posteroinferior perforations cause worse hearing loss than others because of the direct exposure of the round window and lead to further phase difference reduction.[16] We also couldn't find statistically significant hearing worsening on PI group. However, in a clinical study by Mehta et al. correlation between localization and air-bone gap have not been determined.[6] In 2001, Voss et al. have also not found relationship between localization of TM perforation and sound transmission in cadaveric temporal bone middle ear.[9] Although, Ibekwe et al. have determined correlation between localization and hearing loss severity in chronic TM perforations, this correlation has not been detailed. Additionally, they have not determined correlation in acute TM perforation.[17] Except one, it has not been informed excluding the middle and inner ear pathologies that may result in conductive hearing loss such as ossicular chain pathologies, inflammatory and sclerotic changes of the middle ear, otosclerosis and superior semicircular canal dehiscence syndrome in all these studies.[6,16,17] Mehta et al. have compared anterior and posterior part of TM, and ruled out the inflammatory changes of middle ear during type I tympanoplasty, but not mentioned otosclerosis and superior semicircular canal dehiscence syndrome.[6] In the present study, we ruled out ossicular chain pathologies, inflammatory or sclerotic changes of the middle ear and otosclerosis during the surgery, and ruled out superior semicircular canal dehiscence by the preoperative high resolution temporal bone computed tomography. We compared the hearing loss in gradually small (less than 5 mm) perforation of TM quadrants and there were not found statistically significant difference between TM quadrants for air-bone gap. On the other hand, statistically significant decrease of bone conduction thresholds was observed in AI group at higher frequencies (2 and 4 kHz) when compared with other three groups. This condition may be due to comprise statistically significant mixed type hearing loss in AI group.

To the best of our knowledge, our study investigates, for the first time, a relation between air-bone gap or frequency dependence and TM perforation on four quadrants for less than 5 mm perforations with excluded the other possible middle and inner ear pathologies that may result air-bone gap. We also determined the relation between frequency and perforation of four TM quadrants.

CONCLUSION

The results showed that the air-bone gap increases with increasing size of perforation. However, no statistically significant air-bone gap differences between tympanic membrane quadrants were determined.

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