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Evaluation of Carhart's Notch in Patients with Serous Otitis Media

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ABSTRACT

Objective: To investigate the changes in bone-conduction and air-bone gap in patients with serous otitis media and to evaluate the presence of Carhart's notch.

Material and Methods: Patients with unilateral serous otitis media were included in the study. Audiometric evaluation comprised air-conduction and bone-conduction hearing thresholds, and air-bone gap values. The preoperative and postoperative pure tone audiometry results of 45 patients were compared in terms of the air-bone gap and bone-conduction thresholds.

Results: Carhart's notch was present in 17 (37.8%) patients preoperatively. For pure tone audiometry, there was a statistically significant decrease in air-bone gap at all frequencies postoperatively. The postoperative decrease in the bone-conduction thresholds was statistically significant only at 2 kHz. In the postoperative period, a 4.7 dB improvement was observed in the bone-conduction threshold at 2 kHz for patients with Carhart's notch.

Conclusion: Carhart's notch may be present in patients with serous otitis media. It is not specific to otosclerosis.

Keywords: Otitis Media with Effusion; Audiometry; Hearing Loss, Conductive; Bone Conduction; Carhart's Notch

INTRODUCTION

Carhart's notch (CN) is an audiogram finding first described by Raymond Carhart in 1950 in otosclerosis patients, which involves the greatest depression in bone conduction (BC) thresholds without any change in air conduction (AC) thresholds at 2 kHz (1). Therefore, BC is very important in the formation of CN. A study published in 2005 reported five different pathways contributing to BC hearing: a) sound transmitted into the external ear canal, b) middle ear ossicle stability, c) stability of the cochlear fluids, d) compression of the cochlear walls, and e) pressure transmission from cerebrospinal fluid (2). Considering these different pathways, it is thought that many different external or middle ear pathologies causing conductive hearing loss (in situations a or b) may contribute to CN formation by deteriorating BC.

Serous otitis media (SOM) is a middle ear pathology characterized by the existence of fluid in the middle ear cavity without signs or symptoms of acute ear infection (3). The existence of fluid in the middle ear cavity affects transmission of sound from the external ear to the inner ear, causing an increase in the stiffness and mass of the middle ear system and conductive hearing loss occurs (4). There are studies in the literature that revealed the relationship between CN and middle ear pathologies (e.g., congenital or acquired ossicular chain anomalies and otitis media with effusion) (5-7). Therefore, CN is not specific to otosclerosis, which is characterized by conductive hearing loss.

The aim of this study was to investigate the changes in BC and air-bone gap (ABG) in SOM patients and to evaluate the presence of CN.

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MATERIAL AND METHODS

The patients operated on between October 2017 and October 2019 with a diagnosis of SOM were included in the study. The ethical committee of the institution approved the study protocol (Zonguldak Bülent Ecevit University, Human Research Ethics Committee, Date: 16/10/2019, Approval Number: 2019-169-16/10), and the study adhered to the Declaration of Helsinki. The study was designed retrospectively, and therefore informed consent was not obtained.

Patients with unilateral SOM were included in the study in accordance with the following inclusion criteria: 1) 6 to 65 years of age; 2) presence of clinical signs of SOM (otoscopy revealing matte appearance, bubbles, amberish or honey-like color, fluid accumulation behind the tympanic membrane, retraction of the tympanic membrane, etc.), normal examination of other ENT areas (especially on nasopharyngeal endoscopy) and absence of systemic signs of infection; 3) conductive hearing loss on pure-tone audiometry (PTA) and type B tympanogram curve of the affected ear; 4) no recovery after three months of medical treatment (antibiotics and/or decongestants and/or nasal steroids); 5) placement of a tympanostomy tube (TT) for SOM treatment (Shepard, Invotec, Jacksonville, USA); 6) diagnosis of SOM confirmed by aspirating serous fluid from myringotomy; 7) undergoing a PTA test before TT placement (preoperative); and 8) undergoing a PTA test after removal of TT from the external ear canal (postoperative, at least six months after surgery).

The exclusion criteria were as follows: 1) bilateral presence of SOM; 2) history of any otologic disease (otosclerosis, cholesteatoma, chronic otitis media, Meniere's disease, barotrauma, etc.); 3) history of any otological surgery (TT placement, tympanoplasty, mastoidectomy, etc.); 4) not attending follow-up after TT placement; 5) developing complications due to TT placement (permanent perforation of the tympanic membrane, inflammation and discharge in the middle ear, etc.); and 6) removal of TT from the tympanic membrane or external ear canal earlier than six months postoperatively.

All patients underwent PTA using the same audiometer (GSI-61 clinical audiometer device [Grason-Stadler, Eden Prairie, Minnesota, USA]), performed by the same audiologist in a soundproof room. Parameters measured during the audiometric evaluation comprised AC hearing thresholds at the frequencies of 0.25, 0.5, 1, 2, 4, and 8 kHz, BC hearing thresholds at 0.5, 1, 2, and 4 kHz, and ABG values at 0.5-4 kHz intervals. The criterion for CN was taken as a minimum depression of 10 dB in BC in comparison with the rest of the thresholds at 2 kHz. The preoperative and postoperative 0.5, 1, 2, and 4 kHz PTA test results for 45 patients were compared in terms of the ABG and BC thresholds.

Data analysis was performed using SPSS v. 24.0. In descriptive analyses, categorical variables are presented as percentages and continuous variables as mean±standard deviation (median, min-max) values. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov-Shapiro-Wilk's test) to determine whether they were normally distributed. Since the PTA measurements were not normally distributed, non-parametric tests were conducted to compare these parameters. The Wilcoxon test was used to compare the changes in the PTA measurements from the preoperative period to the postoperative period. Statistical significance was considered at $p<0.05$.

RESULTS

Forty-five patients with SOM were included in the study. Twenty-eight (62.2%) patients were male and 17 (37.8%) were female. The mean age of the patients was 30.3 ± 22.2 (median:21, min:6-max:65) years.

In the PTA performed in the preoperative and postoperative periods, the mean ABG (at 0.5, 1, 2, and 4 kHz frequencies) for patients with SOM were 21.9±8.7 dB (median:18.8, min:2.5-max:41.3) and 7.1±2.9 dB (median:6.3, min:1.3-max:15), respectively. For patients with SOM and CN positive, the mean ABG in the preoperative and postoperative periods were 23.8±7.7 dB (median:22.5, min:12.5-max:36.3) and 8.1±3.2 dB (median:7.5, min:2.5-max:15), respectively. The postoperative decrease in ABG at all four frequencies (0.5, 1, 2, and 4 kHz) was found to be statistically significant ($p<0.001$) (Table 1). While the differences between the preoperative and postoperative period in terms of the BC thresholds values obtained at 0.5, 1, and 4 kHz were not statistically significant ($p=0.660$, $p=0.219$, and $p=0.417$, respectively), the decrease in the BC thresholds at 2 kHz was statistically significant ($p<0.001$) (Table 2). In other words, improvement in AC affected the BC hearing threshold at 2 kHz.

Table 1. Preoperative and postoperative ABG values at different frequencies.

Frequency (kHz)	Preoperative Median (min-max)	Postoperative Median (min-max)	p^a
0.5	25.0 dB (0-55)	10.0 dB (0-20)	*<0.001*
1	25.0 dB (0-50)	10.0 dB (0-15)	*<0.001*
2	5.0 dB (0-25)	0.0 dB (0-10)	*<0.001*
4	25.0 dB (0-45)	10.0 dB (0-35)	*<0.001*

ABG: air-bone gap, dB: decibel, p<0.05 was accepted as significant,
[a]: p-value for Wilcoxon test

Table 2. Preoperative and postoperative BC values at different frequencies.

Frequency (kHz)	Preoperative Median (min-max)	Postoperative Median (min-max)	p^a
0.5	10.0 dB (0-65)	5.0 dB (0-65)	0.660
1	5.0 dB (0-65)	5.0 dB (0-65)	0.219
2	25.0 dB (5-75)	20.0 dB (0-75)	*<0.001*
4	15.0 dB (0-85)	10.0 dB (0-85)	0.417

BC: bone conduction, dB: decibel, p<0.05 was accepted as significant,
[a]: p-value for Wilcoxon test

Preoperatively, CN was present in 17 (37.8%) of the 45 patients. In the CN group, the ABG decreases at all frequencies (0.5, 1, 2, and 4 kHz) were statistically significant according to postoperative PTA ($p<0.001$, $p<0.001$, $p=0.005$, and $p=0.001$, respectively) (Table 3). In the postoperative period, PTA revealed a 3.2 dB improvement in the BC threshold at 2 kHz, while the patients with CN showed an improvement of 4.7 dB.

Table 3. ABG change in SOM patients with CN.

Frequency (kHz)	Preoperative Median (min-max)	Postoperative Median (min-max)	p[a]
0.5	30.0 dB (20-45)	10.0 dB (5-15)	*<0.001*
1	35.0 dB (10-50)	10.0 dB (0-15)	*<0.001*
2	5.0 dB (0-25)	0.0 dB (0-10)	*0.005*
4	25.0 dB (0-45)	15.0 dB (0-30)	*0.001*

ABG: air-bone gap, dB: decibel, $p<0.05$ was accepted as significant,
[a]: p-value for Wilcoxon test

DISCUSSION

The depression in BC at 2 kHz is known as CN and is widely considered to indicate stapes fixation. Conijn et al. showed a good relationship between conductive loss in PTA and conductive loss findings estimated in brain-evoked response audiometry for frequencies other than 2 kHz (8). Although the decrease in BC at 2 kHz is based on stapes fixation in otosclerosis, this condition was also reported in other middle ear pathologies such as primary malleus fixation and SOM (5-10). Kumar et al. reported that the accumulation of glue fluid in the middle ear of SOM patients and edema in the middle ear mucosa may cause impedance in the sound transmission resulting in CN (7).

In a study by Shishegar et al. examining patients with SOM, the CN positivity rate was found to be 44.9%. The authors also separately discussed the CN-positive SOM cases based on the presence of dullness, redness, and swelling in the tympanic membrane and reported their rate as 25.3% (11). Kumar et al., evaluating 95 ears with SOM, detected CN in 37 (38.9%) ears (7). In another study, Ahmad and Pahor calculated the rate of CN as 26% in their sample of 50 patients with SOM (9). In a study by Telmesani et al., the ability of CN to predict the presence of effusion was evaluated in patients with SOM and CN positivity was reported in 97 of 148 ears (65.5%). The authors found the sensitivity and specificity of CN in predicting effusion in SOM were 85.2% and 87.5%, respectively (12). In the current study, we found that CN was positive in 17 (37.8%) of the 45 patients with SOM. The CN positivity rate might have been higher in our study considering that we used only 2 kHz frequency for CN positivity. Previous studies used different frequencies like 0.5, 1, 2 or 4 kHz to evaluate CN positivity (9, 11). It may be suggested that the CN definition should be redefined in order to ensure integrity in the literature and for more accurate comparison of studies.

Kashio et al. divided their patients into three groups as stapes fixation, incudostapedial joint dislocation, and malleus-incus fixation, and determined the CN rates of these groups as 31.4%, 26.3%, and 30%, respectively. In addition, in the presence of CN at a frequency of 2 kHz, they found an improvement in BC hearing thresholds in the postoperative period that was recorded as 4.3 dB, 15 dB, and 19.2 dB, respectively (13). In our study, after TT placement in SOM patients with CN, the hearing threshold in BC improved by an average of 4.7 dB. When BC hearing improvements were compared with Kashio's study, the closest group to the SOM group in our study was the stapes fixation group. The common feature of SOM (via fluid in the middle ear occluding the round window) and stapes fixation (via oval window involvement) is that the windows in the middle ear related with cochlear fluids are affected. In other words, we think that the elimination of the occlusion effect in the oval or round window in the presence of CN is a factor that improves BC hearing together with ABG. As a result, occlusion of the oval or round window for any reason may cause a false depression in BC at 2 kHz on the audiogram.

Kumar et al. detected glue fluid during myringotomy in 36 of 37 ears with SOM and CN, and found the ABG levels of the 47 patients were 10 dB and above (7). Shishegar et al. reported the mean ABG level was 25.9 dB in CN-positive patients with SOM (11). In our study, we determined the preoperative ABG level was 23.8 dB in patients with SOM and CN positive. Kumar et al. also stated that CN was a very important indicator providing an understanding of the presence of glue fluid in myringotomy in patients with SOM and concluded that myringotomy should be performed in cases with CN positivity, type B curve in the tympanogram, and an ABG of ≥30 dB (7). Similarly, in a study by Shishegar et al., a strong correlation was found between the presence of glue fluid in the middle ear and CN positivity, type B tympanogram, and ABG >20 dB (11).

We also recommend myringotomy for SOM patients if the ABG is >20 dB, without CN positivity. In addition, according to the results of our study, in cases with CN positivity, myringotomy should be performed considering the improvement of BC at 2 kHz.

Kashio et al. compared the improvement in BC at 2 kHz with the improvement in ABG and found no relationship in different middle ear pathologies (13). Cook et al., on the other hand, found a weak but significant link between the improvement in AC at 2 kHz and the improvement in BC after stapes surgery (14). However, neither Shishegar et al. nor Kumar et al. compared the improvement between postoperative ABG and postoperative BC at different frequencies (7, 11). When we evaluated the improvement in the mean postoperative ABG and BC threshold values compared to the preoperative period, we found a significant decrease in ABG at the frequencies of 0.5 kHz, 1 kHz, 2 kHz, and 4 kHz ($p<0.001$). However, only the decrease in the BC threshold at 2 kHz was statistically significant ($p<0.001$). BC is very important to identify CN in the audiogram. In fact, one point to consider is that CN can be more detectable in middle ear pathologies. In routine PTA, only the main frequencies such as 0.5, 1, 2, and 4 kHz are used. On the other hand, CN may also occur at non-routinely used intermediate frequencies like 3 kHz. Therefore, we recommend further studies to detect the presence of CN at frequencies that are not routinely tested in middle ear pathologies.

Lastly, Yasan H. reported that while CN at 2 kHz indicates stapes footplate fixation, CN at 1 kHz indicates mobile stapes footplate (15). In our study, 2 kHz was used to determine the CN. After myringotomy was performed in SOM patients with CN, all patients had a remarkable improvement in ABG and an improvement in 2 kHz BC was observed. Therefore, contrary to Yasan H.'s study, CN did not indicate stapes footplate fixation in our study. Most otorhinolaryngologists consider the association of CN - otosclerosis as an inseparable binary and they immediately look for the presence of CN in the audiograms of patients suspected of having otosclerosis. Considering all these studies contributing to the literature, including our study, the tenet of "CN is specific to only otosclerosis" should be abandoned.

The patients' hearing status assessment needs a sustained effort to simultaneously take into consideration many parameters, including patient's cooperation. In the present study, we did not make a standardization on this subject. On the other hand, the retrospective design of the study and the small number of patients included in the study are two other limitations of our study. Prospective studies with larger number of patients are needed on this subject.

CONCLUSION

In the present study we found that CN, which is known to be specific to otosclerosis, could also be positive in SOM. The placement of TT can lead to a significant improvement in ABG and BC level at 2 kHz in patients with SOM.

Ethics Committee Approval: The ethical committee of the institution approved the study protocol (Zonguldak Bülent Ecevit University, Human Research Ethics Committee, Date: 16/10/2019, Approval Number: 2019-169-16/10), and the study adhered to the Declaration of Helsinki.

Informed Consent: The study was designed retrospectively, and therefore informed consent was not obtained.

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