ÖZGÜN ARAŞTIRMA ORIGINAL RESEARCH

Med J SDU / SDÜ Tıp Fak Derg ▶ 2021:28(4):585-590 doi: 10.17343/sdutfd.901212

DIAGNOSTIC IMPORTANCE OF THE CARHART NOTCH IN PATIENTS WITH CHRONIC OTITIS MEDIA

KRONİK OTİTİS MEDİA HASTALARINDA CARHART NOTCH'UNUN TANISAL ÖNEMİ

Ergin BİLGİN[1], Aykut Erdem DİNÇ[2], Duygu ERDEM[1], Sultan ŞEVİK ELİÇORA[1], Semih ALATAŞ[1]

[1] Department of Otorhinolaryngology, Faculty of Medicine, Zonguldak Bülent Ecevit University, Zonguldak, TURKEY

[2] Department of Otorhinolaryngology, Ekol Private Hospital, İzmir, TURKEY

Cite this article as: Bilgin E, Dinç AE, Erdem D, Şevik Eliçora S, Alataş S. Diagnostic Importance of the Carhart Notch in Patients with Chronic Otitis Media. Med J SDU 2021; 28(4): 585-590.

Öz

Amaç

Stapes fiksasyonuna bağlı otosklerozun neden olduğu yanlış sensörinöral kayıp, Carhart çentiği olarak bilinir. Bu çalışmanın amacı, kronik otitis media (KOM) hastalarında ameliyat öncesi ve sonrası odyometri sonuçlarını karşılaştırarak hava-kemik aralığı (HKA) ve kemik yolu (KY) işitme eşiklerinde meydana gelen değişiklikleri incelemek, hava yolu (HY) iletiminin KY iletimi üzerindeki etkilerini araştırmak, postoperatif HY'de iyileşmenin KY iyileşmesi üzerindeki etkilerini belirlemek, KOM' da Carhart çentiğinin varlığını tespit etmek ve cerrahinin Carhart çentiği üzerindeki etkilerini belirlemektir.

Gereç ve Yöntem

Bu retrospektif çalışmaya kliniğimizde Ocak 2012 – Mart 2017 tarihleri arasında tip 1 timpanoplasti uygulanan toplam 104 hasta dahil edildi. Preoperatif ve postoperatif 6. ay yapılan odyometrik değerlendirme sırasında ölçülen parametreler, 250-8.000 Hz frekanslarda HY işitme eşiklerini, 500-4.000 Hz'de KY işitme eşiklerini ve 500-4.000 Hz aralıklarla HKA değerlerini içermekteydi.

Bulgular

Cerrahi öncesi 104 hastanın 46'sında (% 44,2) Carhart çentik mevcuttu. Bu hastaların 25'inde (% 54,3) ameliyat sonrası Carhart çentiğinin düzeldiği görüldü (p = 0,029).

Sonuç

Timpanoplasti sonrası, sağlam ve hareketli bir kemikçik zinciri olan KOM olgularında 2.000 Hz'de HKA'daki belirgin iyileşme KY'de iyileşmeye yol açabilir. Carhart çentiği ayrıca KOM'da da mevcut olabilir.

Anahtar Kelimeler: Carhart notch, Saf ses odyometri, Kronik otitis media, Timpanoplasti

Abstract

Objective

The false sensorineural loss caused by otosclerosis due to stapes fixation is known as the Carhart notch. To examine the changes in air-bone gap (ABG) and bone-conduction (BC) hearing thresholds by comparing the preoperative and postoperative audiometry results in patients with chronic otitis media (COM), to investigate the effects of air conduction (AC) on BC, to determine the effects of postoperative improvement in AC on BC, to detect the presence of the Carhart notch in COM, and to determine the effects of surgery on the Carhart notch.

Material and Methods

A total of 104 patients who underwent type 1

Sorumlu yazar ve iletişim adresi /Responsible author and contact address: E.B. / erginbilgin67@hotmail.com
Müracaat tarihi/Application Date: 25.03.2021 • Kabul tarihi/Accepted Date: 17.08.2021
ORCID IDs of the authors: E.B: 0000-0001-7191-6209; A.E.D: 0000-0001-7006-7479; D.E: 0000-0002-7973-2719; S.Ş.E: 0000-0002-2915-3727; S.A: 0000-0002-5492-8918

tympnoplasty between January 2012 - March 2017 in our clinic were included in this retrospective study. Parameters measured during the preoperative and postoperative sixth month audiometric evaluation comprised AC hearing thresholds at the frequencies of 250-8,000 Hz, BC hearing thresholds at 500-4,000 Hz, and ABG values at 500-4,000 Hz intervals.

Results
Before surgery, the Carhart notch was present in 46 (44.2%) of the 104 patients. Postoperatively, the Carhart notch was observed to have been corrected in 25 (54.3%) of these patients (p=0.029).

Conclusion
After tympanoplasty, significant improvement in ABG may lead to improvement in BC at 2,000 Hz in COM cases with an intact and mobile ossicular chain. The Carhart notch may also be present in COM.

Keywords: Carhart notch, Pure tone audiometry, Chronic otitis media, Tympanoplasty

Introduction

Pathologies in the middle ear can prevent sound energy from reaching the inner ear. In this situation, there is deterioration of air-conduction (AC) thresholds (at least at certain frequencies) while bone-conduction (BC) thresholds are not affected [1]. Therefore, BC thresholds should be obtained as zero decibel (dB) or even better due to the occlusion effect. The resulting air-bone gap (ABG) can reach 60 dB. ABG can be observed in many middle ear pathologies. However, middle ear pathologies can also block BC and cause BC thresholds to worsen [2]. As a result, in addition to conductive hearing loss, the worsening of BC thresholds occurs [1,2]. For example, ossicular fixation caused by otosclerosis occurs at a lower ear resonance frequency of 2,000 Hz, which is lower than the normal BC threshold. Therefore, ABG expected in conductive hearing loss may decrease or disappear at around 2,000 Hz. The false sensorineural loss caused by otosclerosis due to stapes fixation is known as the Carhart notch (CN), which disappears when the middle ear resonance returns to normal after surgery [1]. 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) [2,3]. A study published in 2002 reported five different pathways contributing to BC hearing: a) sound transmitted into the external ear canal, b) middle ear ossicles stability, c) stability of the cochlear fluids, d) compression of the cochlear walls, and e) pressure transmission from the cerebrospinal fluid [4]. Considering these different pathways, it can be thought that many different external or middle ear pathologies causing conductive hearing loss (in situations a or b) can contribute to CN formation by deteriorating BC [5]. Therefore, CN is not specific to otosclerosis which is characterized by conductive hearing loss.

There are only a few studies that discuss the changes in ABG, AC and BC thresholds changes and presence of CN in individuals underwent tympanoplasty due to chronic otitis media. The aims of this study were to examine the changes in air-bone gap (ABG) and BC hearing thresholds at the frequencies of 500, 1,000, 2,000 and 4,000 Hz by comparing the preoperative and postoperative sixth-month pure tone audiometry test results of patients that underwent type 1 tympanoplasty with the diagnosis of chronic otitis media, to investigate the effects of AC on BC, to determine the effects of postoperative improvement in AC on BC, to detect the presence of the CN in chronic otitis media, and to determine the effects of surgical treatment on the CN.

Material and Methods

Prior to the study, ethical approval was obtained from the Bülent Ecevit University Clinical Research Ethics Committee (Date: 27.07.2016 – Number: 2016/09/07). The study was carried out with 104 patients who presented to the ear, nose and throat clinic of the hospital with the complaints of discharge from the ear and hearing loss between January 2012 and March 2017, received a diagnosis of chronic otitis media, and underwent type 1 tympanoplasty.

Chronic otitis media cases aged eight to 70 years that were intraoperatively confirmed to have an intact and mobile ossicular chain were included in the study. Patients with chronic otitis media progressing with a cholesteatoma or tympanic membrane retraction, those with intraoperative tympanosclerosis, and those with ossicular chain fixation or dislocation were not included in the study.

For the study, the audiology archive of the ear, nose and throat clinic of the university was retrospectively

screened. Parameters measured during the audiometric evaluation comprised AC hearing thresholds at the frequencies of 250, 500, 1,000, 2,000, 4,000 and 8,000 Hz, BC hearing thresholds at 500, 1,000, 2,000, and 4,000 Hz, and ABG values at 500-4,000 Hz intervals. The preoperative and early postoperative (six-month) pure tone audiometry test results of the 104 patients were compared in terms of ABG and BC decibels at the pure tone averages of 500, 1,000, 2,000, and 4,000 Hz.

Statistical Analysis

Statistical analysis was undertaken using SPSS v. 19.0. The categorical variables were obtained as frequency and percentages, and continuous variables as median, minimum and maximum values. In the comparison of categorical variables between the groups, Yates' chi-square test was used. The Wilcoxon test was conducted to examine the variation between the dependent continuous variables. In all statistical comparisons, p values < 0.05 were considered statistically significant.

Results

Considering the gender characteristics of the 104 patients included in the study, 59 (56.7%) were female and 45 (43.3%) were male. When the patients were examined in terms of age, the minimum age was eight while the maximum age was 70 years. The mean age was calculated as 38 years.

The postoperative decrease in ABG at four frequencies (500, 1,000, 2,000, and 4,000 Hz) was found to be statistically significant ($p < 0.001$) (Table 1). While the changes in BC values at 500, 1,000 and 4,000 Hz was not statistically significant ($p = 0.576$, $p = 0.599$, and $p = 0.382$, respectively), the decrease in BC at 2,000 Hz was statistically significant ($p < 0.001$) (Table 2). In other words, improvement in AC affected the BC hearing threshold at 2,000 Hz.

In this study, the CN was present in 46 (44.2%) of the 104 patients that underwent tympanoplasty. In 25 (54.3%) of these 46 patients, the CN was observed to have been corrected by surgery, which was statistically significant ($p = 0.029$). In the patient group with the CN, the postoperative decreases in ABG were significant at all frequencies ($p < 0.001$, $p < 0.001$, 0.004, and 0.003 for 500, 1,000, 2,000, and 4,000 Hz, respectively). There was a postoperative 5.76 dB improvement in the mean BC threshold value at 2,000 Hz, while the mean CN value was improved by 7.19 dB.

Table 1 Preoperative and postoperative ABG values at 500-4000 Hertz frequency

	500 Hertz	1000 Hertz	2000 Hertz	4000 Hertz
Preoperative	30 dB (55-0)	25 dB (50-5)	15 dB (35-0)	25 dB (55-0)
Postoperative	12.5 dB (40-0)	15 dB (40-0)	5 dB (45-0)	15 dB (55-0)
P value	p < 0.001	p < 0.001	p < 0.001	p < 0.001

ABG:Air Bone Gap; dB:Desibel; p < 0.05

Table 2 Preoperative and postoperative BC thresholds

	500 Hertz	1000 Hertz	2000 Hertz	4000 Hertz
Preoperative	10 dB (35-0)	5 dB (45-0)	20 dB (75-0)	10 dB (65-0)
Postoperative	10 dB (45-0)	5 dB (45-0)	15 dB (60-0)	10 dB (75-0)
P value	0.576	0.599	p < 0.001	0.328

BC:Bone-Conduction; dB:Desibel; p < 0.05

Discussion

In the present study, we found significant improvement in ABG at all frequencies in the range of 500-4000 Hz, but in contrast to the improvement in AC in the middle ear, the BC threshold significantly improved only at 2,000 Hz after type 1 tympanoplasty. An audiometric finding characteristic of otosclerosis is an increase in bone conduction threshold with a peak at 2,000 Hz known as CN [1]. Although the notch occurs at 2,000 Hz, a reduction in bone conduction sensitivity is seen from 500 to 4,000 Hz which is, on average, 5 dB at 500 Hz, 10 dB at 1000 Hz, 15 dB at 2000 Hz, and 5 dB at 4,000 Hz. Carhart attributed this phenomenon to "mechanical factors associated with stapedial fixation." The CN is not a true indication of "cochlear reserve" and this apparent bone conduction loss may be corrected by surgical intervention [6]. Tonndorf explained that the middle ear contribution to the total bone conduction response consists of an ossicular inertial component and a middle ear cavity effect [6]. He found the magnitude of the CN depended on the extent the middle ear contributed to the total bone conduction response in each of the species tested. Further, he explained the frequency of the notch varied depending on the resonant frequency of the ossicular chain for bone-conducted signals. Based on the work of Tonnndorf, it appears the CN peaks at 2,000 Hz due to the loss of the middle ear component close to the resonance point of the ossicular chain [6].

In an experimental study on human cadaveric specimens, Stenfelt et al. reported that at low frequencies, the ossicles vibrated with the surrounding bones, but at higher frequencies, they vibrated with larger movements compared to the surrounding bones [4]. This shows that the condition of the middle ear can be important in detecting the human BC threshold in the range of 1-3 kHz. In this study, we investigated the effect of improvement in ABG after surgery on the BC thresholds in patients diagnosed with chronic otitis media with an intact ossicular chain. The depression in BC at 2,000 Hz is known as the CN and is widely considered to indicate stapes fixation. However, only few studies have confirmed its usefulness in clinical practice. It has been reported that the middle ear does not contribute to BC at frequencies lower than 1,000 Hz [4]. In his study on human cadavers, Stenfelt noted a 5 to 10 dB decrease in BC at 1,200 to 2,700 Hz frequencies in the presence of incudostapedial joint disorders in the middle ear [5]. Kashio et al. attempted to formulate the presence/absence of the CN. They subtracted the mean BC level at 1,000 Hz and 4,000 Hz from the level at 2,000 Hz, and concluded that if the result was 10 dB or over, it indicated the presence of the CN [7]. We applied this formula to the patients that underwent type 1 tympanoplasty to investigate the presence of the CN and determined how it was affected by improvement in ABG after surgery.

In their study, Kashio et al. divided the patients into three groups as stapes fixation, incudostapedial joint separation, and malleus and incus fixation, and determined the CN rate of these groups as 31.4%, 26.3% and 30%, respectively [7]. Similarly, Kumar et al., evaluating 95 ears with serous otitis, detected the CN in 37 (38.9%) ears [8]. In a study by Shishegar et al. examining otitis media cases with effusion, the CN positivity rate was found to be 44.9% [9]. The authors also separately discussed the CN-positive serous otitis cases with the symptoms of dullness, redness and swelling in the eardrum as the group with the significant CN and reported their rate as 25.3%. In another study, Ahmad and Pahor calculated the rate of the CN as 26% in their sample of 50 patients with secretory otitis media [10]. In the current study, we found that the CN was positive in 46 (44.2%) of 104 patients that underwent tympanoplasty. When compared to the above-mentioned four studies, the CN rate was higher among our patients.

Kumar et al. detected glue fluid during myringotomy in 36 of 37 ears with serous otitis and the CN, and determined the ABG levels of the 37 patients as 10 dB and above [8]. Shishegar et al. found the mean ABG level as 25.3 dB in CN-positive patients with serous otitis [9]. In our study, we determined the preoperative ABG level as 15 at 2,000 Hz in patients with chronic otitis. Kumar et al. also noted that the CN was a very important indicator providing an understanding of the presence of glue fluid in myringotomy in patients with serous otitis and concluded that myringotomy should be performed in cases of CN positivity, type B curve in the tympanogram, and ABG of ≥30 dB [8]. Similarly, in the study of Shishegar et al., a strong correlation was found between the presence of glue fluid in the middle ear and CN positivity, type B tympanogram, ABG > 20 dB [9]. In a study discussing the factors that have influence on BC thresholds changes in individuals operated due to chronic otitis media, the authors noticed statistically significant BC improvement after myringoplasty and in patients with intact ossicular chain [11]. In the same study, no BC thresholds improvement was observed in patients with ossicular chain defects. Therefore, we may draw the conclusion that only those surgical procedures that enable the restoration of physiological relationships in the ossicular chain along with the restoration of its characteristic resonance frequency will exert a positive influence on the inner ear.

In our study, after tympanoplasty, the mean BC threshold value at 2,000 Hz improved by 5.76 dB, and the mean CN value improved by 7.19 dB. Kashio et al. reported that among their patient groups of stapes fixation, incudostapedial joint separation, and malleus and incus fixation, the lowest improvement in the postoperative CN value at 2,000 Hz was obtained from the stapes fixation group [7].

Kashio et al. only compared the improvement in BC at 2,000 Hz with the improvement in ABG and found no relationship [7]. Neither Shishegar et al. nor Kumar et al. compared the improvement between the postoperative ABG and the postoperative BC at different frequencies [8,9]. In contrast, we did perform this comparison at all frequencies. When we evaluated improvement in the preoperative and postoperative mean ABG values and the improvement in the preoperative and postoperative mean BC threshold values in all patients, we found a significant relationship between these two variables at the frequencies of 500, 1,000, 2,000, and 4,000 Hz. Considering only the group of patients with the CN, a significant relationship was only observed at the frequencies of 1,000 and 2,000 Hz ($p = 0.011$ and 0.026, respectively).

Lastly, although the CN is generally accepted as a useful finding in the diagnosis of otosclerosis, a study by Wegner et al. showed that there was not sufficient evidence to support this idea [12]. Wegner et al., who reviewed the study of Kashio et al. [7] on the diagnostic value of the CN at 2,000 Hertz in the diagnosis of otosclerosis, argued that this study had a high level of bias due to small sample sizes (315 patients), blinded observers, lack of data, and poorly standardized test procedures [12].

Conclusion

The CN, which is known to be specific to otosclerosis, can also be found positive in chronic otitis media affecting the middle ear. In this study, after the tympanoplasty, there was significant improvement in ABG at all frequencies in the range of 500-4000 Hz, but in contrast to the improvement in AC in the middle ear, the BC threshold significantly improved only at 2,000 Hz. This result shows that conductive hearing loss affects BC thresholds, and this effect is mostly seen at the level of middle ear resonance frequency. Tympanoplasty can lead to significant improvement in ABG and the BC level at 2,000 Hz in chronic otitis media cases with an intact and mobile ossicular chain.

Limitations

This study has certain limitations. Due to its retrospective design, the records of the patients obtained from medical charts may have been inaccurate or missing. The limited number of patients was another limiting factor. Patient- and disease-related factors that may affect functional outcomes should also not be overlooked. Finally, we investigated the functional outcomes only at the postoperative sixth month.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Ethical Approval

Ethical approval was obtained from the Bülent Ecevit University Clinical Research Ethics Committee (Date: 27.07.2016 – Number: 2016/09/07).

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Carhart R. The clinical application of bone conduction audiometry. Trans Am Acad Ophthalmol Otolaryngol. 1950;54:699-707. PMID: 15443033
2. Sakamoto T, Kakigi A, Kashio A, Kanaya K, Suzuki M, Yamasoba T. Evaluation of the Carhart effect in congenital middle ear malformation with both an intact external ear canal and a mobile stapes footplate. ORL J Otorhinolaryngol Relat Spec. 2011;73:61-67. https://doi.org/10.1159/000323010
3. Lee HS, Hong SD, Hong SH, Cho YS, Chung WH. Ossicular chain reconstruction improves bone conduction threshold in chronic otitis media. J Laryngol Otol. 2008;122:351-356. https://doi.org/10.1017/S0022215107009474
4. Stenfelt S, Hato N, Goode RL. Factors contributing to bone conduction: the middle ear. J Acoust Soc Am 2002;111:947-59 https://doi.org/10.1121/1.1432977
5. Stenfelt S. Middle ear ossicles motion at hearing thresholds with air conduction and bone conduction stimulation. J. Acoust Soc Am 2006;119:2848-58. https://doi.org/10.1121/1.2184225
6. Tonndorf, J. (1971). Animal experiments in bone conduction: Clinical conclusions. In I.M. Ventry, J.B. Chaiklin, & R.F. Dixon (Eds.), Hearing measurement: A book of readings (pp. 130-141). New York, NY: Appleton-Century-Crofts.
7. Kashio A, Ito K, Kakigi A. Carhart Notch 2-kHz

Bone Conduction Threshold Dip A Nondefinitive Predictor of Stapes Fixation in Conductive Hearing Loss With Normal Tympanic Membrane. Arch Otolaryngol Head Neck Surg 2011;137:236-40. https://doi.org/10.1001/archoto.2011.14

8. Kumar M, Maheshwar A, Mahendran S, Oluwasamni A., Clayton MI. Could the presence of a Carhart notch predict the presence of glue at myringotomy?. Clin Otolaryngol Allied Sci 2003;28:183-86. https://doi.org/10.1046/j.1365-2273.2003.00682.x
9. Shishegar M, Faramarzi A, Esmaili N, Heydari ST. Is Carhart notch an accurate predictor of otitis media with effusion?. M. Int J Ped Otorhinolaryngol 2009;73:1799-1802 https://doi.org/10.1016/j.ijporl.2009.09.040
10. Ahmad I, Pahor AL. Carhart's Notch: A Finding in Otitis Media With Effusion. Int J Pediatr Otorhinolaryngol 2002;17:165-70. https://doi.org/10.1016/s0165-5876(02)00080-0
11. Wiatr, M., Składzień, J., Wiatr, A., Tomik, J., Stręk, P., & Medoń, D. (2015). Postoperative bone conduction thresholds changes in patients operated on chronic otitis media-analysis. Otolaryngologia Polska, 69(4). https://doi.org/10.5604/00306657.1147030.
12. Wegner A, Bitermann AJN, Hentschel MA, Van der Heijden GJM, Grolman W. Pure-tone Audiometry in Otosclerosis: Insufficient Evidence for the Diagnostic Value of the Carhart Notch 2013;149:528-32. https://doi.org/10.1177/0194599813495661