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ORIGINAL ARTICLE
ORİJİNAL ARAŞTIRMA

Evaluation of Cervical Vestibular Evoked Myogenic Potentials in Conductive or Mixed Hearing Losses

İletim Tipi veya Mikst Tip İşitme Kayıplarında Servikal Vestibüler Uyarılmış Miyojenik Potansiyellerin Değerlendirilmesi

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ABSTRACT

Aim: To evaluate the role of Cervical Vestibular Evoked Myogenic Potentials (cVEMP) in the differential diagnosis of middle and inner ear pathologies by analyzing the test results in conductive or mixed hearing loss in patients with intact tympanic membrane.

Material and Method: The study included 50 patients (67 ears) with intact tympanic membranes and had air-bone gap in pure tone audiometry test, who applied to otorhinolaryngology department between January 2019 and September 2022. The cVEMP test results of these patients were evaluated and analyzed.

Results: The age range of the patients was 18-75, the mean age was 47.55±13.59, half of them were male and half were female. The most common middle ear pathology was otosclerosis (62%), while the most common inner ear pathology was superior semicircular canal dehiscence (10%). In the other patients (28%), pathologies such as tympanosclerosis, chronic mastoiditis, serous otitis media, ossicular chain pathology, otic capsule dehiscence, and middle ear mass were found. While no cVEMP response was obtained in 41 (82%) of the patients, cVEMP response was obtained in 9 (18%) patients.

Conclusion: Preoperative cVEMP response, threshold and amplitude values may help in the differential diagnosis of conductive or mixed hearing loss in patients with intact tympanic membrane. Thus, it can be used to determine the patients to be operated on and the surgical approach.

Keywords: Cervical vestibular evoked myogenic potentials, conductive hearing loss, mixed hearing loss, air-bone gap, otosclerosis, semicircular canal dehiscence

ÖZ

Amaç: Timpanik membranın intakt olduğu iletim tipi veya mikst tip işitme kayıplarında Servikal Vestibüler Uyarılmış Miyojenik Potansiyeller (cVEMP) testi sonuçları analiz edilerek orta ve iç kulak patolojilerinde cVEMP testinin ayırıcı tanıdaki rolünün değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntem: Çalışmaya Ocak 2019-Eylül 2022 tarihleri arasında Kulak Burun Boğaz Hastalıkları polikliniğine başvuran ve timpanik membranları intakt olup saf ses odyometri testinde hava-kemik aralığı mevcut olan 50 hasta (67 kulak) dahil edilmiştir. Bu hastaların cVEMP testi sonuçları değerlendirilerek analiz edilmiştir.

Bulgular: Hastaların yaş aralığının 18-75, yaş ortalamasının 47,55±13,59, yarısının erkek ve yarısının kadın olduğu saptanmıştır. Hastalarda en sık orta kulak patolojisi otoskleroz olup (%62), en sık iç kulak patolojisi ise süperior semisirküler kanal dehissansı (%10) olarak saptanmıştır. Diğer patolojiler (%28) ise timpanoskleroz, kronik mastoidit, seröz otitis media, kemikçik zincir patolojisi, otik kapsül dehissansı, orta kulakta kitledir. Hastaların 41'inde (%82) cVEMP yanıtı alınamamışken 9'unda (%18) cVEMP yanıtı alınmıştır.

Sonuç: Ameliyat öncesi cVEMP yanıtı, eşik ve amplitüd değerleri, sağlam kulak zarı olan hastalarda iletim tipi veya mikst işitme kaybının ayırıcı tanısında yardımcı olabilir. Böylelikle ameliyat edilecek hastaların ve kullanılacak cerrahi yaklaşımın belirlenmesinde kullanılabilir.

Anahtar Kelimeler: Servikal vestibüler uyarılmış miyojenik potansiyeller, iletim tipi işitme kaybı, mikst tip işitme kaybı, hava kemik aralığı, otoskleroz, semisirküler kanal dehisansı

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INTRODUCTION

In the presence of air-bone gap in pure tone audiometry test, if the bone conduction thresholds are <20 dB at 250-4000 Hz, it is considered as conductive hearing loss (CHL), and if it is >20 dB at one or more frequencies, it is considered as mixed hearing loss (MHL) (1). Conductive hearing loss is mostly caused by the outer and/or middle ear, but it can also be caused by the inner ear (third window syndrome). Sensorineural hearing loss is usually seen in inner ear pathologies. In the third window syndrome, the hearing threshold increases due to the loss of sound energy transmitted to the inner ear by the air conduction. As a result of the decrease in the impedance of the inner ear fluids, the hearing threshold decreases due to the increase in the sound energy transmitted to the inner ear by the bone conduction and air-bone gap occurs (2).

Vestibular evoked myogenic potentials (VEMP) is a neurophysiological evaluation technique used to evaluate the vestibular functions of the patients (3). VEMPs can be classified as ocular VEMP (oVEMP) and cervical VEMP (cVEMP) according to where the electrodes are recorded. Cervical VEMP is a short-latency inhibitory response that can evaluate the function of the sacculocolic pathway measured over the ipsilateral sternocleidomastoid muscle (4). In recent years, the use of cVEMP test in audio-vestibular clinical applications has become increasingly common.

Halmagyi et al. (5) showed that cVEMP responses were not obtained when the air-bone gap was greater than 20 dB in pure tone audiometry, Bath et al. (6) reported that 97% of patients with CHL did not have a cVEMP response. Even if the vestibulospinal reflex arc is intact in CHLs due to outer and middle ear pathologies, cVEMP response may not be obtained due to decreased air conduction (7). For these reasons, it is not suitable to be used in the differential diagnosis of outer and middle ear pathologies. In inner ear pathologies such as superior semicircular canal dehiscence (SSCD), the dehiscence plays the role of the third window, making the inner ear membranes more sensitive to sound and pressure (8). For this reason, cVEMP responses can be obtained even at low sound intensities in CHLs due to inner ear pathologies. This enables the cVEMP test to be used in the differential diagnosis of inner ear and middle ear pathologies.

There are limited studies in the literature evaluating the role of cVEMP test in differential diagnosis. However, the fact that the tympanic membrane is intact in most CHLs originating from the inner ear and the tympanic membrane is perforated or adhesive due to chronic otitis media in middle ear pathologies makes the use of cVEMP unnecessary in the differential diagnosis. In addition, cVEMP may have a role in differentiating middle ear pathologies with intact tympanic membrane, such as otosclerosis, from inner ear pathologies. Therefore, it would be more accurate to compare cVEMP findings in patients with intact tympanic membrane. Furthermore, immitancemetry, another test used in differential diagnosis, can also be used in patients with intact tympanic membranes, and when evaluated together with cVEMP, it can make the diagnosis easier. However, there is no such study in the literature. Current studies either included patients with perforated/adhesive tympanic membranes, or acoustic immitancemetry was not evaluated.

In our study, it was aimed to evaluate the findings of cVEMP test in conductive or mixed hearing loss with intact tympanic membrane and to determine the importance of this test in the differential diagnosis of inner and middle ear pathologies.

MATERIAL AND METHOD

Study design and ethical approval

The study is in the nature of a retrospective patient cards review and ethical approval of the study was obtained from the Non-Invasive Clinical Research Ethics Committee (Date - No: 21.10.2021-0426). Informed consent form did not obtained from the participants due to the nature of the study.

Study group

Fifty patients (67 ears) who applied to the otorhinolaryngology department between January 2019-September 2022 and were evaluated in the audiology unit were included. The tympanic membranes of all patients were intact and those with air-bone gap in the pure tone audiometry test were analyzed by evaluating together the acoustic immitancemetry, cVEMP test and computed tomography results, if any.

Inclusion criteria

1. Absence of external ear canal (EEC) pathology
2. Intact tympanic membrane
3. Presence of pure tone audiometry, acoustic immitancemetry, and cVEMP tests
4. Air-bone gap in pure tone audiometry greater than 10 dB at more than 3 frequencies between 250 and 4,000 Hz or more than 15 dB at 2 or more frequencies

Exclusion criteria

1. EEC pathology
2. Perforated/adhesive or severe retracted tympanic membrane
3. Absence of at least one of the pure tone audiometry, acoustic immitancemetry, and cVEMP tests
4. Pure sensorineural hearing losses

Obtaining and evaluating data

Pure tone audiometry: Tests were performed using the Interacoustics model AC40 S3.6, 1996 (Interacoustics AS, Assens, Denmark). 500 Hz, 1 kHz, 2 kHz and 4 kHz air and bone conduction hearing thresholds were averaged. Those with air-bone gap were included in the study.

Acoustic immitancemetry: It was carried out with Neurosoft Audio-Smart Immitancemeter (Ivonovo, Russia) using 226 Hz probe tone. Along with tympanometry, ipsilateral and contralateral acoustic reflex measurements were made at frequencies of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

Cervical vestibular evoked myogenic potentials: Tests were performed using the Interacoustics Eclipse Ep 15 ABR system (Middelfart, Denmark). The active electrodes were placed on the middle 1/3 of the sternocleideomastoid (SCM) muscle, the ground electrode was placed on the mid-forehead, and the reference electrode was placed on the sternoclavicular joint where the SCM muscle was attached to the sternum. Attention was paid to ensure that the impedances of the surface electrodes were below 5 kΩ. In the sitting position, the participants rotated their heads to the opposite side of the tested ear. In this way, tonic activation of the ipsilateral SCM muscle is provided. Records were taken by setting the "EMG controlled recording" option, which can collect data only when the desired muscle tone can be achieved in the test system. A 500 Hz tone burst stimulus was delivered using insert headphones (E-A-R Tone 3A ABR, 3M, St. Paul, MN, USA). Stimulus Polarity: Rarefaction, Rate: set to 5.1. In filtering; High Pass Filter: 10 Hz and Low Pass Filter: 3000 Hz. The average number is taken as 200. First, the electromyographic activity of the SCM muscle was measured by sending a stimulus at the level of 100 dB nHL to the right ears. Afterwards, cVEMP threshold values were determined by decreasing the stimulus level in 5 dB steps. After testing the right ear, the left ear was tested with the same test pattern. The latency of the first positive component (p13) and first negative component (n23) of each cVEMP response was measured in milliseconds (ms). The amplitude of p13n23 was measured in microvolts (μV) from the positive peak (p13) to the next trough (n23).

Computed tomography (CT): It was preferred for imaging middle ear and inner ear pathologies. Patients with suspected SSCD were evaluated with high resolution CT (HRCT).

Statistical Analysis

Study data were analyzed with software SPSS 24.0 (SPSS Inc., Chicago, IL, USA). A descriptive statistical evaluation was made in terms of the groupings of the data and their relations with each other. In the descriptive findings, categorical variables were presented as percentage distributions and continuous variables as mean ± standard deviation.

RESULTS

Descriptive data

The gender distribution and mean age of the patients are presented in **Figure 1**.

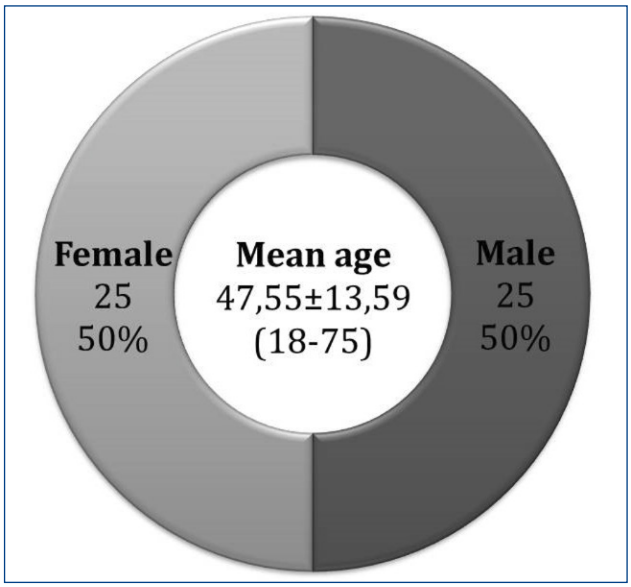

Figure 1. Gender distribution and mean age of the patients

Preliminary diagnoses of patients

The definitive diagnosis of the patients behind an intact tympanic membrane is very unlikely without explorative tympanotomy. Therefore, the diagnosis of patients should be considered as a preliminary diagnosis. Otosclerosis (n=31) was found to be the most common middle ear pathology in the patients, and SSCD was found to be the most common inner ear pathology in 5 of them. In the other 14 patients, tympanosclerosis (n=4), chronic mastoiditis (n=4), serous otitis media (n=3), ossicular chain pathology (n=1), otic capsule dehiscence (n=1), middle ear mass (n=1) pathologies were found. The most common diagnoses and distributions of the patients are given in **Figure 2**.

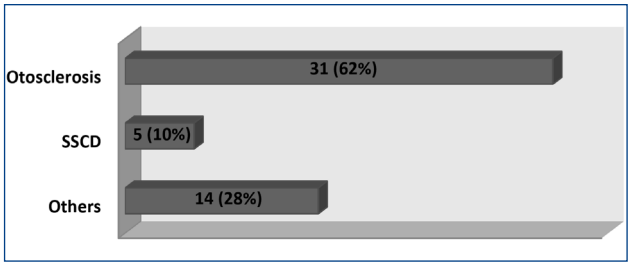

Figure 2. The most common diagnoses and distribution of patients (SSCD: Superior Semicircular Canal Dehiscence)

Cervical VEMP findings

While no cVEMP response was obtained in 41 (82%) of the patients, cVEMP response was obtained in 9 (18%) patients. An example for each patient with or without a response to the cVEMP test is given in **Figure 3**. Of the patients without cVEMP response, 28 were otosclerosis and 13 had other middle ear pathologies. Of the patients with cVEMP response, 5 had SSCD, 1 had otic capsule dehiscence, and 3 had otosclerosis. Retrofenestral type was found in temporal CT in two of those with otosclerosis, and antefenestral type in one. Air-bone gap mean, acoustic immitancemetry and cVEMP findings of middle ear and inner ear pathologies are summarized in **Table 1** comparatively.

DISCUSSION

In our study, cVEMP results of 50 patients (67 ears) with intact tympanic membrane and hearing loss with air-bone gap were evaluated together with pure tone audiometry, acoustic immitancemetry and temporal CT (if necessary). In this context, it is the first study in the literature to the best of our knowledge. There are studies evaluating the results of cVEMP in hearing loss with air-bone gap in the literature, but these are studies that either include tympanic membrane pathologies or other tests evaluated in this study in the differential diagnosis were not evaluated (9,10). In addition, while cVEMP cannot be obtained in conductive hearing losses originating from the middle ear, cVEMP thresholds can be obtained at lower levels in conductive hearing losses originating from the inner ear. In order to examine this difference, cVEMP thresholds were also examined in our study.

cVEMP response was obtained in 9 of the patients with conductive and mixed hearing loss in our study, and 6 of them were inner ear pathology, while 3 of them were otosclerosis. Konukseven et al.(10) reported that 4 of 176 patients with CHL had cVEMP response, and 3 of them had SSCD and one had enlarged vestibular aqueduct syndrome. Zhou et al.(9) evaluated 120 patients and found that no cVEMP response was obtained in patients with middle ear pathology (n=50), and cVEMP response was obtained in all 59 patients with inner ear pathology. In addition, they reported that cVEMP response was also obtained in 11 patients with Meniere's disease and high jugular bulb. Yang et al. (11) found that cVEMP response

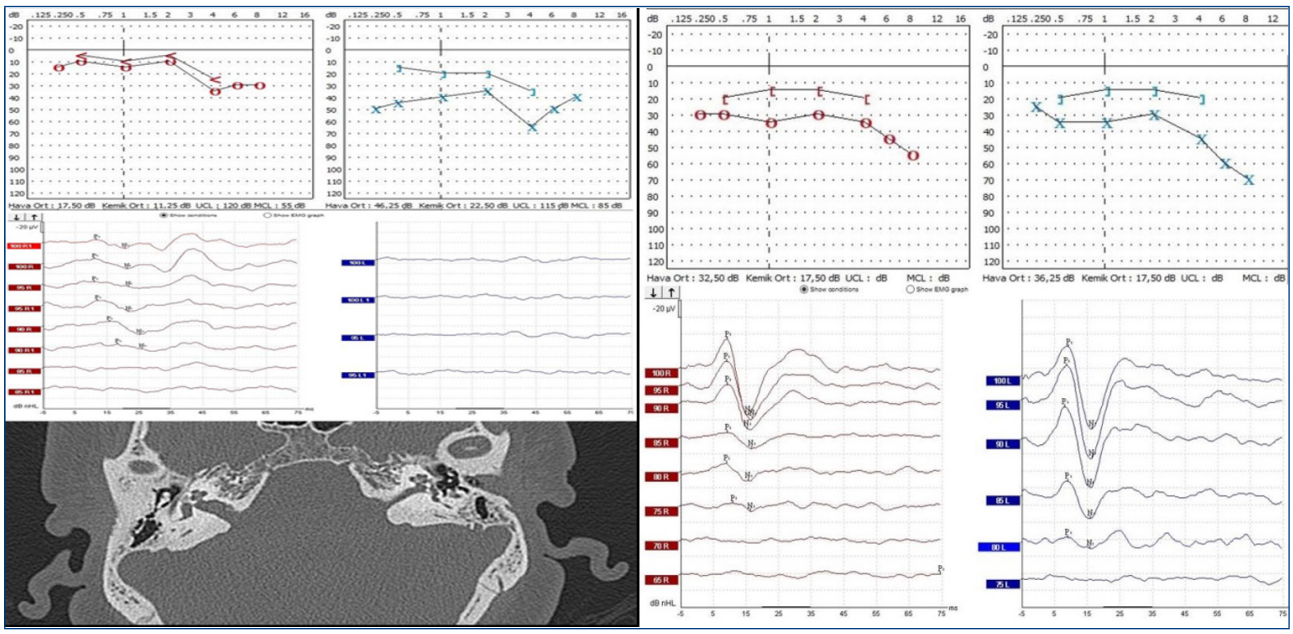

Figure 3. Pure tone audiometry, cVEMP and CT image of the patient with prediagnosis of otosclerosis on the left and pure tone audiometry, cVEMP results of the patient with bilateral SSCD on the right. The patient on the left had CHL in the left ear, and cVEMP response could not be obtained in the same ear. On temporal CT, antefenestral type otosclerosis was reported on the left. The patient on the right had bilateral CHL and cVEMP response was obtained in both ears. In the temporal CT report, it was stated that he had bilateral SSCD.

Table 1. Findings of middle ear and inner ear pathologies

	Air-bone gap mean	Tympanometry		Acustic reflex		cVEMP	
		Type A	Other types	(+)	(-)	response (+)	response (-)
Middle ear pathologies	Right:24,0 dB (n=23 ears) Left: 24,97 dB (n=37 ears)	13	47	17	43	3	57
Inner ear pathologies	Right: 14,33 dB (n=3 ears) Left: 22, 25 dB (n=4 ears)	7	-	7	-	7	-
Total	67 ears	20	47	24	43	10	57

cVEMP: Cervical vestibular evoked myogenic potentials

was obtained in the early period in patients with otosclerosis, but cVEMP response could not be obtained with the progression of the disease. In our study, when temporal bone CT of 3 patients with cVEMP response was examined, retrofenesteral type otosclerosis was reported in 2 and antefenesteral type otosclerosis was reported in 1 patient. The reason for the response positivity in these patients was thought to be related to the localization of the disease in the retrofenesteral type, and the possibility of being in the early stage of the disease in the antefenesteral type. Because antefenestral type otosclerosis was detected in the other 28 otosclerosis patients without cVEMP response, and this finding was confirmed in 8 patients who were operated on.

Pathologies that cause conductive hearing loss originating from the inner ear; semicircular canal and otic capsule dehiscences, large vestibular aqueduct syndrome, Paget's disease and congenital inner ear malformations are some of them (10). While it is possible to distinguish most of these pathologies with temporal bone CT, dehiscences cannot be differentiated despite thin section high resolution computed tomography (HRCT). It has been reported that this condition can mostly be confused with otosclerosis, but if there is a cVEMP response, SSCD should be considered in the differential diagnosis (12-14). In our study, SSCD was detected in 5 patients and otic capsule dehiscence was found in 1 of the patients with suspected otosclerosis, and cVEMP responses were obtained in all of these 6 patients. It was observed that these patients had low cVEMP thresholds such as 65 dB nHL, 75 dB nHL. This result shows that cVEMP thresholds can also be used as a diagnostic tool in clarifying the diagnosis of conductive hearing loss originating from the inner ear. Although our findings support the literature, they also contribute by evaluating cVEMP thresholds. Therefore, despite the air-bone gap determined in the audiogram, SSCD should be considered first in cases with normal acoustic reflexes and who cVEMP thresholds are obtained, especially at low sound intensity. We believe that it may be more appropriate to evaluate cVEMP response and thresholds before HRCT in these patients. However, there are studies in the literature showing that conductive hearing loss originating from the middle ear and inner ear can coexist, although it is rare. Since there are no other clinical, audiological, or electro-physiological criteria to rule out the presence of SSCD associated with otosclerosis, HRCT is recommended before each stapes surgery in case of coexistence of ipsilateral otosclerosis and SSCD (14).

In addition to obtaining cVEMP response at low thresholds in patients with SSCD, larger cVEMP wave amplitudes can be obtained. Roditi et al. (15) reported that cVEMP wave amplitudes were larger (173.8 microvolts) in patients with SSCD and lower thresholds were found in these patients. For this reason, further studies that can examine cVEMP wave amplitudes as well as cVEMP thresholds in conductive hearing loss originating from the inner ear may be beneficial. In addition, Zuniga et al. (16) investigated which of the cVEMP thresholds and oVEMP wave amplitudes is more specific and sensitive in the diagnosis of SSCD. They determined that oVEMP amplitudes were more effective than cVEMP thresholds in the diagnosis of SSCD. Hunter et al. (17), on the other hand, reported that both cVEMP thresholds and oVEMP amplitudes depend on a number of factors, and both are good diagnostic test tools for defining SSCD. In the light of this information, studies that will investigate the effectiveness of the oVEMP test in the diagnosis of conductive hearing loss originating from the inner ear will contribute to the literature.

Limitations of the study

Since our study is of a retrospective nature, its implications may be limited. In order to accurately define the true sensitivity and specificity of the cVEMP test in the differential diagnosis of air-bone gap in pure tone audiometry in middle and inner ear pathologies, prospective studies that evaluate more patients are needed.

CONCLUSION

When the data of our study and the literature data are combined, evaluating the response and threshold values in the cVEMP test may help in the differential diagnosis of hearing loss with an air-bone gap for which no obvious cause can be detected by otoscopy or otomicroscopy, and can be used as a screening test, especially in patients who are considered for surgery. It can reduce radiation exposure and cost by reducing the need for temporal high-resolution computed tomography, especially in patients who are not considering surgery.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Izmir Katip Celebi University Atatürk Training and Research Hospital Non-Invasive Clinical Research Ethics Committee (Date: 21.10.2021 Decision No: 0426).

Informed Consent: Informed consent form did not obtained from the participants due to the nature of the study.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Martini A, Mazzoli M, Stephens D, Read AP. Definitions, protocols and guidelines in genetic hearing impairment. John Wiley & Sons Incorporated; 2001.
2. Scarpa A, Ralli M, Cassandro C, et al. Inner-Ear Disorders Presenting with Air-Bone Gaps: A Review. J Int Adv Otol 2020;16(1):111-6.
3. Colebatch JG, Halmagyi GM. Vestibular evoked potentials in human neck muscles before and after unilateral vestibular deafferentation. Neurology 1992;42:1635-6.
4. Colebatch JG, Halmagyi GM, Skuse NF. Myogenic potentials generated by a click-evoked vestibulocollic reflex. J Neurol Neurosurg Psychiatry 1994;57,190-7.
5. Halmagyi GM, Colebatch JG, Curthoys IS. New tests of vestibular function. Bailliere's Clin. Neurol 1994;3:485-500.
6. Bath AP, Harris N, McEwan J, Yardley MP. Effect of conductive hearing loss on the vestibulo-collic reflex. Clin Otolaryngol Allied Sci 1999;24:181-3.
7. Rosengren SM, Welgampola MS, Colebatch JG. Vestibular evoked myogenic potentials: past, present and future. Clin Neurophysiol 2010;121:636-51.
8. Göçer C, Dinç AS. Superior Semisirküler Kanal Dehissansı. KBB ve BBC Derg 2019; 27(2):70-5.
9. Zhou G, Poe D, Gopen Q. Clinical use of vestibular evoked myogenic potentials in the evaluation of patients with air-bone gaps. Otol Neurotol 2012;33(8):1368-74.
10. Konukseven Ö, Müderris T, Müjdeci B, Gökdoğan Ç, Aksoy S. İletim tipi patolojilerde hava yolu vestibüler uyarılmış myojenik potansiyellerin ayırıcı tanıdaki rolü. JAREM. 2013;3(1):24-27.
11. Yang TL, Young YH. Vestibular-evoked myogenic potentials in patients with otosclerosis using air and bone conducted tone burst stimulation. Otol Neurotol 2007;28:1-6.
12. Minor LB, Cremer PD, Carey JP, Della Santina CC, Streubel SO, Weg N. Symptoms and signs in superior canal dehiscence syndrome. Ann N Y Acad Sci 2001;942:259-73.
13. Mikulec AA, McKenna MJ, Ramsey MJ, et al. Superior semicircular canal dehiscence presenting as conductive hearing loss without vertigo. Otol Neurotol 2004;25:121-9.
14. Minor LB. Clinical manifestations of superior semicircular canal dehiscence. Laryngoscope 2005;115(10):1717-27.
15. Roditi RE, Eppsteiner RW, Sauter TB, Lee DJ. Cervical vestibular evoked myogenic potentials (cVEMPs) in patients with superior canal dehiscence syndrome (SCDS). Otolaryngol Head Neck Surg 2009;141(1):24-8.
16. Zuniga MG, Janky KL, Nguyen KD, Welgampola MS, Carey JP. Ocular versus cervical VEMPs in the diagnosis of superior semicircular canal dehiscence syndrome. Otol Neurotol 2013;34(1):121-6.
17. Hunter JB, Patel NS, O'Connell BP, et al. Cervical and Ocular VEMP Testing in Diagnosing Superior Semicircular Canal Dehiscence. Otolaryngol Head Neck Surg 2017;156(5):917-23.