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Low Amplitude of Ocular Vestibular-Evoked Myogenic Potentials Can Denote Poor Prognosis in Patients with Idiopathic Sudden Sensorineural Hearing Loss

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ABSTRACT

Objective: To assess vestibular evoked myogenic potentials (VEMP), both cervical (c-VEMP) and ocular (o-VEMP), in patients diagnosed with unilateral sudden hearing loss and presenting with vestibular symptoms and to determine whether these responses can serve as predictive parameters for recovery.

Materials and Methods: Patients diagnosed with unilateral sudden sensorineural hearing loss (SSHL) and vertigo and healthy volunteers without ear pathology were included. All participants underwent ear tests, including pure tone audiometry and c-VEMP and o-VEMP tests.

Results: When comparing the VEMP values of the patients who showed improved hearing with those who did not, it was observed that the o-VEMP amplitude of non-improved patients was statistically lower ($p=0.013$). Moreover, in the non-improved group, the c-VEMP P1 latencies were lower, and the amplitude asymmetry ratio (AAR) of c-VEMP was significantly higher than that in the control group, significantly ($p=0.006$ and $p<0.001$, respectively; Mann Whitney U test with Bonferroni Correction $p<0.017$).

Conclusion: In patients with SSHL and vertigo, VEMP testing is beneficial for detecting the vestibular component of the disease. There was no asymmetry in VEMP responses between the affected and unaffected ear sides. Patients with SSHL who have vertigo have poor hearing loss recovery rates in the case of low-amplitude o-VEMP responses.

Keywords: Hearing loss sudden, vestibular evoked myogenic potentials, prognosis

INTRODUCTION

Sensorineural hearing loss is a significant issue affecting many individuals, with an estimated 300 million adults and 32 million paediatric cases worldwide. Idiopathic sudden sensorineural hearing loss (SSHL) refers to the rapid onset of hearing loss within a span of three days, typically affecting one ear but occasionally bilateral, with a minimum threshold shift of 30 dB across three consecutive frequencies on pure-tone audiometry (1, 2). The management of sudden hearing loss without a discernible cause remains challenging in otolaryngology, as its underlying histopathological basis is not well understood and is still being explored through various studies.

Histological examination of patients with SSHL revealed the most common degeneration in the saccule (3). Numerous studies have demonstrated that patients with SSHL exhibit vestibular manifestations even in the absence of overt symptoms (3, 4). Approximately 30%–40% of patients with SSHL simultaneously experience vertigo, and these patients have a worse prognosis for hearing recovery than those without vertigo (5, 6).

Vestibular evoked myogenic potential (VEMP) testing is a method used to measure the electrophysiological reflex arc in muscles through stimulation of peripheral vestibular organs and muscles (7, 8). Generally, two reflex arcs, vestibulo-

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collic and vestibulo-occular reflex arcs, are used in testing. The biphasic surface potential recorded from the ipsilateral sternocleidomastoid muscle is called cervical VEMP (c-VEMP), and it tests the function of the saccule, inferior vestibular nerve, and inferior vestibular nucleus. VEMP recorded from extraocular muscles is called ocular VEMP (o-VEMP), and it tests the function of the utricle and superior vestibular nerve (8-11).

In the existing literature, VEMPs have been used to investigate the potential impact of idiopathic SSHL on the vestibular system, whether or not it is accompanied by vertigo. Researchers have observed that the saccule is affected more than the semicircular canals in patients with vertigo and SSHL (3). Despite extensive investigations into labyrinthine functions using various neurophysiological tests, no consensus has been reached.

This study aims 1) to assess both c-VEMP and o-VEMP responses in patients diagnosed with unilateral sudden hearing loss and presenting with vestibular symptoms and 2) to determine whether these responses can serve as predictive parameters for recovery. By evaluating these parameters, researchers can gain insights into the involvement of the vestibular system in SSHL and its potential implications for prognosis and treatment.

MATERIALS and METHODS

This retrospective clinical study was conducted at a tertiary referral centre. Patients diagnosed with both SSHL and vertigo and healthy volunteers without ear pathology were included. The participants were between 18 and 75 years old and had type A tympanogram. Patients who presented with external or middle ear pathologies, central nervous system pathologies, head trauma, other vestibular diseases, recurrent or bilateral sudden deafness, or uncontrolled comorbid diseases (hypertension or diabetes mellitus); those who did not receive treatment for 2 weeks after sudden deafness; or individuals lost to follow-up were excluded.

Sudden deafness was defined as a rapid drop in sensorineural hearing loss of more than 30 dB for at least three consecutive frequencies that occurred in less than three days and had no discernible explanation. All patients were regularly monitored at the clinic and underwent audiometry. Before treatment, all patients underwent an otoscopic examination and a battery of inner-ear tests, including tympanometry, pure tone audiometry, c-VEMP, and o-VEMP tests. Upon admission, all patients received systemic steroid treatment and hyperbaric oxygen therapy for 20 sessions.

This study was approved by the Okmeydanı Research and Education Hospital and was designed according to the Declaration of Helsinki. The study group patients gave their informed consent for participation in the study (Date: 16.04.2019, No: 1258).

Audiometry

Pure-tone audiometry was conducted at 500, 1000, 2000, and 4000 Hz. According to the modified Siegel's criteria proposed by Cheng et al. the audiograms were categorised as grade 1 (<25 dB), grade 2 (26–45 dB), grade 3 (46–75 dB), grade 4 (76–90 dB), and grade 5 (>90 dB) using the ICS_CHARTR EP 200 system (Baastrup, Denmark) (12). The audiometric evaluations were conducted in a soundproof AC 40 audiometry cabin calibrated to ISO 9001 standards. Air and bone conduction were tested at octave intervals from 250 to 8000 Hz and 500 to 4000 Hz.

According to Cheng et al.'s modified Siegel criteria, post-treatment hearing recovery was categorised as complete recovery (final hearing level<25 dB), partial recovery (hearing gain>15 dB and final hearing level 26–45 dB), slight improvement (hearing gain>15 dB and final hearing level 46–75 dB), no improvement (hearing gain<15 dB and final hearing level 76–90 dB), and non-serviceable ear (final hearing level>90 dB) (12).

VEMPs

Both c-VEMP and o-VEMP tests were performed on all participants to evaluate their vestibular symptoms using the ICS-CHARTER EP 200 evoked potential system (CN Otometrics North America, Schaumburg, IL, USA. VEMP waves were analysed to compare the patients with the control group based on the latencies, amplitudes, and the amplitude asymmetry ratio (AAR) of c-VEMP (P1, N1) and o-VEMP (N1, P1). The AAR was calculated as AAR = 100 x (Ar - Al) / (Ar + Al), where Al and Ar represent the left and right amplitudes, respectively. According to the normal values of VEMP levels obtained from healthy control subjects for 95 dB at our laboratory, a peak limit of 34.2% for c-VEMP and 35% for o-VEMP was defined for the AAR, and values exceeding these limits were considered abnormal.

Acoustic stimulation for both o-VEMP and c-VEMP was performed using an ICS Medical Insert Earphones (ER 3A/5A Insert Earphone 300 ohms). The impedance difference between the electrodes remained below 3 kOhm. An amplitude value of 0 was assigned to ears with no response.

c-VEMP

The reference electrode was placed over the sternum, and the ground electrode was placed on the nasion close to the hairline in the midline. The active electrodes were placed over the sternocleidomastoid muscle and nasion. Rest periods were provided to alleviate fatigue, if necessary. The parameters recorded included 500-Hz tone bursts with a repetition rate of 5.1 tone bursts per second, a minimum of 50 sweeps per waveform, an intensity level of 95 dB HL (decibel hearing level), rise-plateau fall times of 2.0–1.0–2.0 ms, and at least two waveforms per condition. After the stimulus, the initial negative-positive biphasic waveform included the peaks P1 (positive) and N1 (negative).

o-VEMP

All participants were instructed not to contract their facial muscles and to maintain a gaze at a predetermined point approximately two metres away while keeping their heads in a fixed position and looking upward at an angle of 30° 40°. The reference electrode was positioned in the infraorbital position at a distance of 3 cm, and the ground electrode was placed on the forehead. The active electrodes were placed over the infraorbital position on the face at distances of 1 and 3 cm. The parameters recorded included 500-Hz tone bursts with rise-plateau-fall times of 1.5–0–1.5 ms, a repetition rate of 5.1 tone bursts per second, a minimum of 50 sweeps per waveform, and an intensity level of 95 dB HL. After the stimulus, the first biphasic waveform peaks were negative (N1) and positive (P1).

Statistical analysis

Descriptive statistical methods (mean, median, standard deviation [SD], frequency, percentage, minimum, and maximum) were used to evaluate the data. Pearson's chi-square test was used to compare the qualitative variables. The Shapiro–Wilk test was used to analyse the quantitative variables' normal distributions. The Student's t-test was used to compare two independent groups whose quantitative variables were normally distributed, while the Mann–Whitney U-test was used to compare groups whose distributions were not normally distributed. The Wilcoxon test was used when distributions varied from normal; a paired t-test was performed for dependent groups. Accepted criteria for statistical significance were $p<0.05$.

RESULTS

Clinical manifestations comprised hearing loss and vertigo/dizziness in all 40 patients. Our study was conducted with 64 cases, of which 37.5% (n=24) were healthy controls and 62.5% (n=40) were patients. Among the cases, 54.7% (n=35) were female and 45.3% (n=29) were male. The ages ranged from 18 to 74 years, with a mean age of 45.37±12.47 years. There were no statistically significant differences in age and gender distribution between the groups ($p>0.05$). In the patient group, 47.5% (n=19) had problems in their right ear, while 52.5% (n=21) had problems in their left ear (Table 1). Additionally, no differences were observed between the subgroups according to the hearing level of the patients by age (Table 2).

According to pure tone audiometry, the mean hearing levels were 69.7+27.9 dB in the patient group and 12.5+5.7 dB in the control group. The patient group's mean hearing level was significantly high ($p<0.001$).

Before treatment, hearing loss in the patient group was as follows: 17.5% (n=7) had grade 2, 27.5% (n=11) had grade 3, 30% (n=12) had grade 4, and 25% (n=10) had grade 5 hearing loss (Table 2).

Table 1: Demographic data

		SSHL Patients			Control (n=24)	p value
		Right side (n=18)	Left side (n=12)	Total (n=40)		
Gender (n)	Male	7	12	19	10	0.553*
	Female	11	10	21	14	
Age (mean±SD)		47.5±11.6	44.3±16.3	45.75±14.3	44.8±8.9	0.697**

*Pearson Chi-Square test, **Student t Test, SSHL: Sudden sensorineural hearing loss, SD: Standard deviation

Table 2: Hearing status of patients with SSHL

Characteristics of the SSHL group (n=40)		Age (mean±SD)	p value
Pre-treatment hearing loss	Mild (n=7)	43.0±5.8	0.798*
	Moderate (n=11)	52.2±9.8	
	Severe (n=12)	42.6±14.2	
	Complete (n=10)	44.4±21.0	
Post-treatment Modified Siegel Classification	Class1 (n=7)	41.3±10.8	0.397*
	Class2 (n=3)	44.3±26.5	
	Class3 (n=13)	45.8±12.7	
	Class4 (n=17)	47.8±15.3	
Recovery status	Recovered (n=23)	44.2±13.7	0.438**
	Not-recovered (n=17)	47.8±15.3	

*One-Way ANOVA, **Student t Test, SSHL: Sudden sensorineural hearing loss, SD: Standard deviation

Table 3: Comparison of VEMP parameters between the SSHL and control groups

		SSHL patients (n=40)		Control (n=48)	p* value
		Recovered (n=23)	Non-recovered (n=17)		
c-VEMP (mean±SD)	P1 latency	12.12±7.49	11.99±6.72	16.14±1.32	0.009
	N1 latency	19.66±11.42	19.24±11.47	25.66±2.18	0.039
	Amplitude	140.15±143.93	126.69±130.97	156.22±123.83	0.382
	AAR	47.26±36.66	60.19±33.90	24.99±20.04	0.721
o-VEMP (mean±SD)	P1 latency	12.99±6.19	9.70±8.37	15.47±1.15	0.782
	N1 latency	8.64±4.21	6.80±5.94	10.50±1.12	0.002
	Amplitude	7.96±6.90	3.07±3.95	7.74±5.62	0.004
	AAR	39.80±33.80	57.59±41.83	24.49±17.73	0.063

*Kruskal–Wallis test, VEMP: Vestibular evoked myogenic potential, SSHL: Sudden sensorineural hearing loss, AAR: Amplitude asymmetry ratio, SD: Standard deviation

After treatment, the outcomes of the patients were as follows: complete recovery with 7.7% (n=7), partial recovery with 7.5% (n=3), slight improvement with 32.5% (n=13), and no improvement with 42.5% (n=17) of the cases. In total, 57.5% of the cases showed improvement, whereas 42.5% showed no improvement (Table 2).

In both the control and patient groups, there was no statistically significant difference between the ear sides for either the c-VEMP or o-VEMP parameter (p>0.05; Wilcoxon test). In comparing VEMP responses between the SSHL and control groups, the P1 and N1 latencies of c-VEMP were lower in the SSHL group (p=0.009, p=0.039, respectively). Moreover, the amplitude of o-VEMP was lower in the SSHL group (p=0.002), and both the AAR of c-VEMP and o-VEMP were higher in the SSHL group (Table 3).

When comparing the VEMP values of the patients who improved hearing with those who did not, it was found that the o-VEMP amplitude of non-improved patients was statistically lower (p=0.013). Moreover, in the non-improved group, the c-VEMP P1 latencies were lower, and the AAR of c-VEMP was significantly higher than that in the control group (p=0.006, and p<0.001, respectively; Mann–Whitney U test with Bonferroni correction p<0.017).

DISCUSSION

The results of VEMP testing on SSHL with vertigo. We observed that both the c-VEMP and o-VEMP responses were abnormal in patients with idiopathic SSHL, and a low amplitude of o-VEMP may predict poor prognosis.

The present study evaluated hearing before and after treatment according to Cheng et al.s modified Siegel criteria (12). Cheng et al. reported that 51% of 110 patients with SSHL experienced hearing improvement. In our study, 57.5% of 40 patients with SSHL experienced hearing improvement after treatment.

VEMP results may vary according to age (13, 14). Khan et al. compared the c-VEMP results among different age groups and observed that the c-VEMP response rate was extremely high in adolescents (13). Additionally, Jha et al. studied the differences in VEMP results according to age. They concluded that c-VEMP decreased only at 500 and 750 Hz, whereas o-VEMP changed at all frequencies according to age (14). Age and sex did not differ in our study between the two groups or across the patient group subgroups, therefore that these factors had no bearing on outcomes.

Accompanying the cochlear system, the vestibular system has been shown to be affected in SSHL based on c-VEMP, o-VEMP, or both c-VEMP and o-VEMP testing (15-18). However, some studies also used caloric tests in addition to VEMP tests. Iwasaki et al. studied SSHL with vertigo using VEMPs and caloric tests. They observed that caloric tests provide information about the function of the semicircular canals, whereas VEMPs provide information about the saccule. Moreover, in SSHL, the saccule is affected more than the semicircular canals; thus, VEMP testing is more sensitive than caloric tests for detecting vestibular function in SSHL (3). Liang et al. used both VEMP and caloric tests to detect the recovery of patients with SSHL and claimed that caloric tests were not predictive of the prognosis of SSHL (19). Thus, our study focused on VEMP tests (both c-VEMP and o-VEMP) to analyse SSHL patients.

Many studies on SSHL with or without vertigo using VEMP tests have shown that VEMP tests are abnormal in SSHL, and the saccule and utricle, as well as the cochlea, are included in the pathophysiology of SSHL. Jiang et al. compared patients with SSHL with and without vertigo using the VEMP test but did not include a healthy control group. SSHL patients with vertigo had severe hearing loss and higher abnormal VEMP results (20). Lim et al. demonstrated that abnormal o-VEMP was significantly more related to hearing loss in patients with SSHL and vertigo. They concluded that this was because the arterial supply of the saccule included more collateral arteries than the utricle, thereby causing resistance to ischaemia (21). Yigider et al. also studied VEMP responses in patients with SSHL. Their study group had no vestibular symptoms, and the healthy control group was not included. They compared patients' bilateral ears and determined that c-VEMP responses differed between the ears bilaterally, whereas o-VEMP responses were similar (22).

In this study, we used both c-VEMP and o-VEMP levels to compare patients with SSHL with vertigo and a healthy control group. We observed that both the VEMP and control test results in patients with SSHL were abnormal. However, the VEMP responses were similar bilaterally between the ear sides. Kizkapan et al. also found no bilateral ear differences using VEMP testing (23).

VEMP testing has been used in the literature to evaluate not only the diagnosis but also the prognosis of SSHL (19, 23). Kizkapan et al. studied the prognosis of SSHL using caloric and VEMP tests and compared the caloric test results with the degree of hearing loss before and after treatment. However, they compared the VEMP results between the control and case groups, not considering the degree of hearing loss. They concluded that the VEMP responses were abnormal before treatment but improved after SSHL treatment (23). Similarly, Liang et al. evaluated the prognosis of SSHL using the VEMP test. They compared patients according to hearing improvement. They concluded that abnormal VEMP levels may predict poor prognosis in patients with SSHL (19). The study aim was to investigate VEMP results before treatment and the predictive value of hearing recovery after treatment. We observed that only low-amplitude o-VEMP was correlated with a poor prognosis of SSHL. Patients with low-amplitude o-VEMP showed less hearing recovery. Therefore, hearing loss may be permanent and unresponsive to treatment if the utricle and superior vestibular nerve are affected in patients with SSHL.

The small sample size in our study is a major limitation. Although caloric testing was less vulnerable to detect vestibular function in SSHL than VEMP testing, it might be included in the differential diagnosis of vertigo. Moreover, to evaluate the changes in vestibular function after SSHL treatment, VEMP responses might be analysed in the patients' follow-up periods.

CONCLUSION

VEMP testing is beneficial for detecting the vestibular component of SSHL with vertigo. There was no asymmetry in VEMP responses between the affected and unaffected ear sides. Patients with SSHL and vertigo have poor recovery rates of hearing loss in cases of low-amplitude o-VEMP responses.

Ethics Committee Approval: This study was approved by the Ethics Committee of the University of Health Sciences, Okmeydanı Training and Research Hospital (Date: 16.04.2019, No: 1258).

Informed Consent: The study group patients gave their informed consent for participation in the study.

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