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Original Article

Evaluation of utricular and saccular function in BPPV patients: The role of VEMP in diagnosis

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Abstract

Aim: The pathological cause of Benign Paroxysmal Positional Vertigo (BPPV) is the degeneration of the otolith organs (utricle and sacculus). Vestibular Evoked Myogenic Potentials (VEMP) assess the functions of the otolith organs. The objective of this research was to evaluate the otolith organ functions of patients with unilateral idiopathic BPPV (canalolithiasis of the posterior and lateral semicircular canals) by cVEMP and oVEMP tests.

Material and Methods: The study prospectively included 35 patients with BPPV (canalolithiasis of the posterior and lateral semicircular canals) and 30 healthy individuals. Bilateral cVEMP and oVEMP tests were administered to all participants. Participants were divided into three groups: control, BPPV-affected ear, and unaffected ear.

Results: In our study, cVEMP and oVEMP abnormalities were statistically significantly different both between the affected and unaffected ear groups and between the affected ear and control groups. There were statistically significant differences in the cVEMP and oVEMP amplitude values both between the affected and unaffected ear groups and between the affected ear and control groups. Also, the asymmetry ratios of the cVEMP and oVEMP tests were statistically significantly different between the case group and the control group. The cVEMP and oVEMP wave latencies (p1, n1, p1-n1) were not statistically significantly different among the BPPV-affected ear, unaffected ear, and control groups. The results of measurements were not statistically significantly different between the posterior and lateral canal involvement subgroups of BPPV patients.

Conclusion: Abnormal cVEMP and oVEMP test results, which are observed more frequently in patients with BPPV compared to the control group, indicate utricular and saccular degeneration. Higher oVEMP abnormality ratios compared to those of cVEMP in BPPV patients suggest that utricular dysfunction may be more common than saccular dysfunction.

Keywords: Benign paroxysmal positional vertigo; cervical/ocular vestibuler evoked myogenic; vertigo

INTRODUCTION

Benign Paroxysmal Positional Vertigo (BPPV) is a peripheral vestibular disorder characterized by nystagmus that accompanies sudden onset, short-term dizziness triggered by angular head movements (1). BPPV is one of the most common causes of vertigo. Although BPPV is more common in middle and advanced age groups, it can be seen in almost all age groups (2). The one-year prevalence of BPPV increases with age. The incidence of BPPV in the age group of over 60 years is 7 times higher than the incidence found in the age group of 18-39-years (3). Most BPPV cases are idiopathic; however, BPPV can be secondary to head trauma, Meniere's disease, vestibular neuritis, sensorineural hearing loss, migraine, diabetes, osteoporosis, preferred sleep position, or prolonged bed rest (4). BPPV is suggested to occur when otoconia originating from otolith organs enter the semicircular canals (SCC) (5). The entry of otoconia into SCC resulting in unfavourable effects on the endolymph is a condition that manifests itself by positional vertigo (6). Of the three SCC; BPPV is most commonly seen in the posterior SCC, followed by the horizontal and anterior SCC (7). The diagnosis of BPPV is made by performing the positional diagnostic manoeuvres that allow for the observation of the canal-specific nystagmus (8). While the Dix-Hallpike maneuver or the side-lying test is used for the diagnosis of posterior and anterior canal BPPV, the head roll test is used for the diagnosis of horizontal canal BPPV (9). The diagnosis of BPPV is very important for correct planning of the treatment.

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Vestibular evoked myogenic potentials (VEMP) refer to electromyographic responses resulting from the stimulation of the vestibular labyrinth via acoustic, vibratory, or electrical stimuli, and the VEMP test is used for assessing the functions of the otolith organs (10). The VEMP test, which evaluates the integrity of the vestibular system, is divided into two: cervical VEMP (cVEMP) and ocular VEMP (oVEMP). While cVEMP measured from the sternocleidomastoid muscle assesses the saccular function, oVEMP measured from the extraocular muscles assesses the utricular function (11). Considering the diagnostic benefit of VEMP, the inclusion of these tests in the neuro-otological test battery can contribute to improvements in the better evaluation of otolith organ functions (12). VEMP is used as a diagnostic test for many diseases such as vestibular neuronitis, Meniere's Disease, acoustic neuroma, and superior semicircular canal dehiscence (SSCD) (13). VEMP can serve as a test battery supporting the BPPV diagnosis because otoconia falling into SCC from the utricular macula are involved in the aetiological mechanism, and some studies suggest that the saccular macula and saccular nerve ganglion cells are degenerated in BPPV (14).

A literature review revealed that the cVEMP thresholds and latencies were not different between the BPPV and the control groups (15). The rate of abnormal waves were 30% for cVEMP and 56.7% for oVEMP in BPPV patients (16). Another study obtained higher asymmetry ratios in BPPV patients compared to the control group and found no significant latency differences between the BPPV and control groups (17). In another study on BPPV patients, VEMP latencies were observed to be significantly different between the BPPV-affected ear group and the control group but the VEMP latencies were not significantly different between the unaffected ear group of BPPV patients and the control group (18). The aim of this study was to evaluate the otolith organ functions of patients diagnosed with unilateral idiopathic BPPV (canalolithiasis of the posterior and lateral semicircular canals) by using the cVEMP and oVEMP tests.

MATERIAL and METHODS

This study was conducted as a prospective study. The study was conducted in the audiology unit of the otorhinolaryngology department of Inonu University Turgut Ozal Medical Center betweenMarch 2020 and July 2020. The study included a total of 65 individuals, 35 individuals who underwent ear-nose-throat (ENT) examinations, were admitted to the clinic for balance testing, and were diagnosed with BPPV based on anamnesis and results of the positional tests, and 30 healthy individuals with no pathological finding on any examination. Individuals diagnosed with BPPV constituted the case group, while the healthy individuals constituted the control group of the study. The approval for the study was obtained from the Non-Interventional Clinical Research Ethics Committee of Inonu University Institute of Health Sciences . Each study participant gave consent. Patients with Meniere's disease, migraine-related dizziness, trauma-related BPPV, vertebrobasilar insufficiency, postural hypotension, neurological disorders, systemic diseases, head and neck problems, eye and vision problems, and communication disabilities were not included in the study. Every study participant underwent the positional tests included in the videonystagmography device. In addition, every study participant underwent cVEMP and oVEMP tests and the results of all study-related assessments were recorded. Of the 35 individuals constituting the case group, 19 were diagnosed with posterior canal BPPV and 16 with lateral canal BPPV based on the results of the Dix-Hallpike and the head roll diagnostic maneuvers performed on every study participant. After undergoing the Dix-Hallpike and Head Roll diagnostic maneuvers, every participant filled in a demographic data form.

C-VEMP

All individuals included in the case and control groups underwent the cVEMP test. The cVEMP test was administered to the study participants when they were in the sitting position. In order to record electromyography (EMG) signals from the sternocleidomastoid (SCM) muscle, individuals were asked to turn their heads to the opposite direction of the stimulated side. Thus, the contraction of the SCM muscle was achieved. The EMG activity was recorded by surface electrodes. The active electrodes were placed on the 1/3 portion of the SCM muscle, the reference electrode was placed on portion of the SCM muscle tendons near the sternum, and the ground electrode was placed on the mid-forehead. The stimulus was delivered at 500 Hz - 100 dB nHL via ER-3A insert earphones. In order to confirm the reliability and observe the repeatability of the obtained responses, cVEMP waves were recorded as two separate traces. Waves with positive and negative peaks, namely P1 (P13) and N1 (N23) respectively, were recorded. The absence of P1 and N1 waveforms or the observation of abnormal waves was defined as "no response".

O-VEMP

The oVEMP test was performed on all individuals in the case and control groups. The oVEMP test was performed when the study participants were in the sitting position. During the test, a fixed target was designated to make the participants look at a single point. The participants were instructed to fix their gaze at the specified target only by means of their eye movements and without raising their heads throughout the test. The participants' gazing at the fixed target resulted in ipsilateral and contralateral extraocular muscle activations and the responses were recorded by surface electrodes placed around the eyes of individuals. The active electrodes were placed on the lower eyelid of both eyes, the reference electrodes were placed 1 cm below the active electrodes, and the ground electrode was placed on the mid-forehead. During the test, each individual kept looking at the target steadily without raising his/her head. The stimulus was delivered at 500

Hz - 100 dB nHL via ER-3A insert earphones. In order to confirm the reliability and repeatability of the responses obtained, oVEMP waves were taken as 2 traces. Waves with a negative peak (N1) and a positive peak (P1) were recorded. The absence of P1 and N1 waveforms or the observation of abnormal waveforms was defined as "no response".

Sample

The sample of this study was determined by power analysis. Based on the calculations performed by using the G*Power 3.1 software, the sample size was determined as 60 with an effect size of 0.80, an error margin of 0.05, at a confidence level of 0.95, and with 0.85 representation power for the target population (19). Using volunteer sampling as one of the non-probabilistic sampling methods; the study participants were selected from the population of patients, who were diagnosed with BPPV.

Statistical Analysis

The data analysis was performed with the SPSS (Statistical Package for the Social Sciences) 25 software. The level of significance was set at (p) 0.05 for comparison tests.

The conformity of the data to a normal distribution was checked with the Kolmogorov–Smirnov test (20) to determine whether parametric or nonparametric methods would be used. Because the data distribution in all variable groups conformed to a normal distribution ($p>0.05$), the statistical analysis was carried out by using the parametric test methods. For the normally distributed data, the intergroup comparisons of the independent binary groups were performed by using the two-sample t-test for testing the difference between two population means. The Levene's test was used for checking the homogeneity of variance ($p>0.05$) in order to decide which test result would be examined for the comparisons.

RESULTS

The participants were divided into two main groups as the case group and the control group. The case group of the study included the BPPV-affected ears and the unaffected ears of the BPPV patients. The results were presented separately for each group in the following tables as mean, standard deviation, numbers, and percentages (%).

The study inluded 35 participants in the case group and 30 participants in the control group. While 54.3% (19) of the participants in the case group were female, 45.7% (16) were male. In the control group, 56.7% (17) were female and 43.3% were male. The mean age in the case group was 43.14±10.35 years; the oldest and the youngest patients were 65 and 18 years old, respectively. The mean age in the control group was 43.7 ± 8.35 years ranging from 57 to 22 years (Table 1).

Table 1. Demographic Characteristics of BPPV and Control Groups

Variable		Number	Percentage (%)	Number	Percentage (%)
Gender	Female	19	54.3	17	56.7
	Male	16	45.7	13	43.3
Total		35	100.0	30	100.0
Age		Mean ± SD	Min / Max	Mean ± SD	Min / Max
		43.14 ± 10.35	18 / 65	43.7 ± 8.35	22 / 57

SD: Standard Deviation

Table 2. cVEMP and oVEMP Abnormalities in the BPPV and Control Groups

Measurements		cVEMP				oVEMP			
		Affected Ear		Unaffected Ear		Affected Ear		Unaffected Ear	
		Number	Percentage (%)	Number	Percentage (%)	Number	Percentage (%)	Number	Percentage (%)
Case	Observed	25	71.4	33	94.3	21	60.0	33	94.3
	Unobserved	10	28.6	2	5.7	14	40.0	2	5.7
Total		35	100	35	100	35	100	35	100
		Number		Percentage (%)		Number		Percentage (%)	
Control	Observed	30		100.0		29		96.7	
	Unobserved	0		0.0		1		3.3	
Total		30		100.0		30		100.0	

In the case group patients who underwent cVEMP measurements in the affected ear, the number of patients under observation was 25 (71.4%) and the number of patients not taken under observation was 10 (28.6%). In the participants who underwent cVEMP measurements in the unaffected ear group, the number of patients under observation was 33 (94.3%) and the number of patients not taken under observation was 2 (5.7%). In the participants who underwent oVEMP measurements in the affected ear group, the number of patients under observation was 21 (60.0%) and the number of patients not taken under observation was 14 (40.0%). In the participants who underwent oVEMP measurements in the unaffected ear group, the number of patients under observation was 33 (94.3%) and the number of patients not taken under observation was 2 (5.7%). The measured values of cVEMP were calculated for all participants in the control group. In the control group participants who underwent oVEMP measurements, the number of patients taken under observation was 29 (96.7%) and the number of patients not taken under observation was 1 (3.3%). The numbers of participants in the case and control groups were 35 and 30, respectively (Table 2).

The cVEMP p1-n1 amplitude and the oVEMP p1-n1 amplitude values were statistically significantly different between the affected and unaffected ear groups ($p<0.05$; Table 3). The measured values of the other variables were not statistically significantly different between the affected and unaffected ear groups ($p>0.05$; Table 3).

The cVEMP p1-n1 amplitude and the cVEMP asymmetry values were statistically significantly different between the case group and the control group ($p<0.05$; Table 4). There were no statistically significant differences in the measured values of the other variables between the case group and the control group ($p>0.05$; Table 4).

Table 3. Comparison of the Measured Values of the cVEMP and oVEMP Parameters In the BPPV Group

Groups		cVEMP			oVEMP		
		Mean ± SD	t-Value	p-Value	Mean ± SD	t-Value	p-Value
p1	Affected	13.68 ± 2.24	0.559	0.578	15.72 ± 1.38	-0.531	0.598
	Unaffected	13.39 ± 1.68			15.93 ± 1.41		
n1	Affected	21.02 ± 1.43	-0.258	0.798	11.33 ± 1.72	1.39	0.17
	Unaffected	21.14 ± 1.98			10.81 ± 1.05		
p1-n1 latency	Affected	7.74 ± 1.44	-0.247	0.806	4.95 ± 0.81	-0.696	0.49
	Unaffected	7.83 ± 1.25			5.13 ± 0.99		
p1-n1amp	Affected	46.14 ± 19.6	-2.392	0.020*	2.01 ± 0.87	-5.487	0.001*
	Unaffected	60.92 ± 25.74			4.34 ± 2.15		

SD, Standard Deviation; *p<0.05, the significance test of the difference between the two means (t-test)
**Levene's test p-values: p> 0.05 means that variances are homogeneous, p<0.05 means that variances are not homogeneous

Table 4. Comparison of the Measured Values of the Parameters of the cVEMP and oVEMP Between the BPPV-Affected Ear and Control Groups

Groups		cVEMP			oVEMP		
		Mean ± SD	t-Value	p-Value	Mean ± SD	t-Value	p-Value
p1	Affected	13.68 ± 2.24	0.982	0.329	15.72 ± 1.38	-0.494	0.623
	Control	13.24 ± 1.71			15.87 ± 1.1		
n1	Affected	21.02 ± 1.43	-1.696	0.094	11.33 ± 1.72	0.985	0.328
	Control	21.69 ± 1.71			11.02 ± 1.01		
p1-n1 latency	Affected	7.74 ± 1.44	-1.929	0.062	4.95 ± 0.81	-0.817	0.416
	Control	8.35 ± 0.98			5.15 ± 1.05		
p1-n1amp	Affected	46.14 ± 19.6	-2.442	0.017*	2.01 ± 0.87	-6.97	0.001*
	Control	58.36 ± 21.58			4.14 ± 1.83		
Asymmetry	Case	6.45 ± 4.4	4.006	0.001*	37.61 ± 19.17	4.006	0.001*
	Control	22.66 ± 17.99			8.57 ± 6.56		

SD, Standard Deviation; *p<0.05, the significance test of the difference between the two means (t-test)
**Levene's test p-values: p> 0.05 means that variances are homogeneous, p<0.05 means that variances are not homogeneous

There were statistically significant differences in the oVEMP p1-n1 amp and oVEMP asymmetry values between the case group and the control group (p<0.05; Table 4). There were no statistically significant differences in the measured values of the other variables between the case group and the control group (p>0.05; Table 4).

There were no statistically significant differences in the measured values of the n1 latency, p1 latency, p1-n1 latency, p1-n1 amp of cVEMP and the n1 latency, p1 latency, p1-n1 latency, p1-n1 amp of oVEMP between the unaffected ears of the BPPV patients and the left ears of the control group participants (p>0.05; Table 5).

There were no statistically significant differences in the measured values of n1 latency, p1 latency, p1-n1 latency, p1-n1 latency of cVEMP and n1 latency, p1 latency, p1-n1 latency, p1-n1 amp of oVEMP between the posterior and lateral canals (p>0,05; Table 6).

Table 5. Comparison of the Measured Values of the cVEMP and oVEMP Parameters Between the Unaffected Ear Subgroup of the BPPV group and the Control Group

Groups		cVEMP				oVEMP			
		Mean ± SD	Levene's Test	t-Value	p-Value	Mean ± SD	Levene's Test	t-Value	p-Value
p1	Unaffected	13.39 ± 1.68	0.742**	0.598	0.552	15.93 ± 1.41	0.112**	0.17	0.866
	Control	13.11 ± 1.96				15.87 ± 1.11			
100n1	Unaffected	21.14 ± 1.98	0.627**	-0.896	0.374	10.81 ± 1.05	0.729**	-0.602	0.549
	Control	21.57 ± 1.82				10.97 ± 1.01			
p1-n1 latency	Unaffected	7.83 ± 1.25	0.044**	-1.515	0.135	5.13 ± 0.99	0.751**	-0.343	0.733
	Control	8.25 ± 0.94				5.22 ± 1.04			
p1-n1amp	Unaffected	60.92 ± 25.74	0.341**	0.322	0.748	4.34 ± 2.15	0.192**	0.671	0.505
	Control	58.98 ± 21.66				4.01 ± 1.62			

SD, Standard Deviation; *p<0.05, the significance test of the difference between the two means (t-test)
**Levene's test p-values: p> 0.05 means that variances are homogeneous, p<0.05 means that variances are not homogeneous

Table 6. Comparison of the cVEMP and oVEMP Values for Posterior and Lateral BPPV Groups

Groups			cVEMP			oVEMP		
			Mean ± SD	t-Value	p-Value	Mean ± SD	t-Value	p-Value
Affected Ear	p1	Posterior	13.69 ± 2.7	0.042	0.967	15.58 ± 0.77	-0.336	0.739
		Lateral	13.65 ± 1.6			15.72 ± 1.36		
	100n1	Posterior	20.87 ± 1.47	0.817	0.423	11.31 ± 1.93	-0.110	0.914
		Lateral	21.22 ± 1.43			11.4 ± 1.16		
	p1-n1 latency	Posterior	7.95 ± 1.59	0.042	0.967	4.95 ± 0.83	-0.008	0.993
		Lateral	7.47 ± 1.25			4.95 ± 0.81		
	p1-n1amp	Posterior	43.32 ± 18.39	0.817	0.423	2.11 ± 1.01	0.805	0.431
		Lateral	49.73 ± 21.38			1.77 ± 0.28		

SD, Standard Deviation; *p<0.05, the significance test of the difference between the two means (t-test)
**Levene's test p-values: p> 0.05 means that variances are homogeneous, p<0.05 means that variances are not homogeneous

DISCUSSION

In our study, both the utricular and the saccular functions were evaluated by the cVEMP and oVEMP tests. Because the reflex arc of cVEMP passes through the saccule and the inferior vestibular nerve and the reflex arc of oVEMP passes through the utricle and the superior vestibular nerve, VEMP becomes a specific test for lesion determination (21). When cVEMP and oVEMP test results are evaluated in combination, they provide complementary information about the vestibular system. The examination of the pathophysiology of BPPV reveals the widely accepted role of the utricular macula because of the anatomical proximity of the utricle with SCC. Furthermore, it is argued that not only the utricular macula but also the saccular macula is affected in patients with BPPV. It is suggested

that the otolith organs can affect the VEMP test results because the otolith organs are involved in the reflex arcs of cVEMP and oVEMP (13).

In our study, the abnormality ratios of cVEMP and oVEMP obtained from the affected ears of the BPPV patients were higher compared to those obtained from the unaffected ear and control groups. In the cVEMP test, abnormal responses were obtained from the affected and unaffected ear subgroups of the BPPV patients at ratios of 28.6% and 5.7 % respectively. However, normal waves were obtained from all of the control group participants in the cVEMP test. In the oVEMP test, abnormal waves were obtained from the affected and unaffected ear subgroups of the BPPV patients, as well as from the control group, at ratios of 40.0% 5.7%, and 3.3%, respectively. The ratios of VEMP abnormalities obtained in our study are consistent with the ratios reported by studies in the literature (15-17,22-26). The abnormality ratios in VEMP in our study are similar to those obtained by the studies of Hong SM (24.5%), Yetiser et al. (23.5%), and Kim et al. (20%) (26-28). Moreover, Pascual et al. reported that the abnormality ratios of cVEMP obtained from affected ears were 16.67% in BPPV patients and 49.25% in the control group, while the abnormality ratios of oVEMP were 61.19% and 6.67% in the affected ear group and the control group respectively (29). Contrary to our study, Korres et al. obtained equal ratios of abnormal VEMP responses from the affected ears and unaffected ears in the group with BPPV (17).In our study, the abnormality ratios of oVEMP were higher than those of cVEMP in the BPPV-affected ear group. The review of the literature reveals that our study results are consistent with the reports in the literature (15-17,24,27,30,31). These results show that the involvement of the utricular macula occurs more in comparison to the involvement of the saccular macula. However, some studies have reported that the abnormality ratios of cVEMP obtained from the BPPV-affected ears are not statistically different from those ratios obtained from the unaffected ears and control group ears (15-17).

In our study, the wave amplitudes obtained from the BPPV-affected ears in the cVEMP and oVEMP tests were statistically lower than those obtained from the unaffected ears of the patients and the control group ears. Previous studies also reported that the waves obtained from the affected ears of patients with BPPV were of lower amplitudes (28, 30, 32).

In our study, the p1, n1, p1-n1 latencies of the cVEMP and oVEMP waves obtained from the affected ears of the BPPV patients did not differ statistically from those obtained from the unaffected ears and the control group. Karatas et al., (33) Korres et al., (17) and Aguirre et al. (24) reported that the P1 and N1 latencies obtained from the affected ears of BPPV patients were not statistically significantly different from those obtained from unaffected ears and control group ears (18). Studies that support our study results are available in the literature regarding the absence of differences in the p1, n1, and p1-n1 latencies across the groups. (23,26-28,30,33,34) Contrary to our study; Hong et al., (27) Akkuzu et al., (30) and Yang et al. (23) reported that affected ears of patients with BPPV had prolonged p1 latencies. In addition, some studies in the literature have reported prolonged latencies of different parameters (17, 18, 24, 27, 30). Failures in obtaining responses or prolonged latencies in the VEMP test in BPPV patients indicate degenerations in the saccular macula, utricular macula, and the vestibular ganglion cells, and the involvement of the lower brain stem and the vestibulospinal system (23).

The amplitude asymmetry ratios of the VEMP waves we obtained from patients with BPPV were found to be statistically higher than the asymmetry ratios of the waves we obtained from the control group. Hong et al., too, reported that the amplitude asymmetry ratios of BPPV patients were higher than those of the control group (27). On the contrary, Karatas et al. did not find any significant difference between the asymmetry ratios of the BPPV group and the asymmetry ratios of the control group (33).

Our study found no statistically significant differences in the cVEMP and oVEMP parameters (p1 latencies, n1 latencies, p1-n1 latencies, p1-n1 amplitudes, and asymmetry ratios) between the patients with lateral SCC BPPV and patients with posterior SCC BPPV. Hong et al. and Yang et al., too, reported no statistically significant differences between the posterior and lateral SCC involvement (23,27). In light of these results, it is understood that using the oVEMP and cVEMP tests separately or together does not provide information about the localization of the canal with pathology.

CONCLUSION

It is observed that abnormality ratios of cVEMP and oVEMP increase in patients with BPPV compared to healthy individuals due to otolith organ degeneration. Higher oVEMP abnormality ratios compared to those of cVEMP in BPPV patients suggest that utricular dysfunction may be more common than saccular dysfunction. The lower cVEMP and oVEMP wave amplitudes obtained from the BPPV-affected ears compared to the unaffected ears and the control group ears, and the higher wave asymmetry ratios than those of the control group (in favour of the affected ear) indicate the need to use these tests together. We are of the opinion that using the cVEMP and oVEMP tests together can provide information about the involved ear. However, the absence of differences in the cVEMP and oVEMP test parameters between the lateral and posterior SCC involvement groups suggests that these tests cannot be used to determine the affected canal.

Competing interests: The authors declare that they have no competing interest.

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