Original Article

Prognostic value of vestibular evoked myogenic potential and distortion product otoacoustic emission tests in patients with a diagnosis of sudden hearing loss: A preliminary report

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ABSTRACT

Objectives: This study aims to investigate whether vestibular evoked myogenic potentials (VEMPs) and distortion product otoacoustic emissions (DPOAEs) have prognostic values in the follow-up of patients diagnosed with idiopathic sudden sensorineural hearing loss (ISSNHL) with audiological tests.

Patients and Methods: Between June 2013 and January 2014, a total of 27 patients (11 males, 16 females; mean age: 44.9±13.8 years; range, 18 to 60 years) diagnosed with ISSNHL at their first admissions and underwent VEMP and DPOAE tests were included. As the treatment protocol, steroid treatment combined with hyperbaric oxygen therapy was initiated in all patients. At the second month of the treatment, all patients underwent VEMP and DPOAE tests once again. Hearing recovery was evaluated based on the hearing improvement, compared to the unaffected contralateral ear.

Results: The median recovery rate was statistically significantly higher in the patients with normal pre-treatment VEMP test results than those with abnormal VEMP test results (p=0.023). The median recovery rate was statistically significantly higher in the patients with normal post-treatment VEMP test results compared to those with abnormal post-treatment VEMP test results (p=0.031). The median recovery rate was also statistically significantly higher in the post-treatment DPOAE test positivity than the post-treatment DPOAE test negativity (p<0.001).

Conclusion: Our study results suggest that, in the follow-up of the prognosis of ISSNHL disease, VEMP test may have a prognostic value, while DPOAE test is an important parameter which can be used in the monitorization of the disease.

Keywords: Distortion product otoacoustic emission, prognostic factors, sudden hearing loss, vestibular evoked myogenic potential.

Idiopathic sudden sensorineural hearing loss (ISSNHL) is defined as hearing loss of ≥30 dB with an unknown etiology which develops suddenly within three days or sooner and affects consecutive three frequencies.[1] Its incidence is 5 to 20/100,000 in the general population.[1] Although it is more frequently encountered in young and middle-aged individuals, it can affect both sexes and all age groups.[1] Hearing loss is usually unilateral in 90% of cases and, in only 10% of the cases, a specific underlying cause is found. Since its etiology has not been fully elucidated yet, it still continues to be an important issue for otologists.

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Among its causes, vascular pathologies, viral infections, immune disorders, perilymphatic fistulas, and metabolic and toxic factors are considered.[2,3] Some theories have been proposed to explain these etiological factors. Among them, viral, vascular and autoimmune theories can be considered.[1,4-6] One of the most popular theories which aim to explain sudden hearing loss is the impairment of the blood supply of the inner ear.[7-10] Although many drug treatments including vasodilators, plasma expanders, and steroids have been found to be beneficial, a consensus has not been reached upon the treatment protocol, yet.[2,11-13] Therefore, varying therapeutic protocols and techniques can be implemented. Vestibular evoked myogenic potential (VEMP) testing is an objective, non-invasive, well-tolerated, and time-sparing test which evaluates saccular and inferior vestibular nerve functions.[14,15]

Otoacoustic emission (OAE) test is a non-invasive method of objective cochlear investigation which is particularly helpful in children.[14] Distortion product otoacoustic emissions (DPOAEs) have been by far the most intensely investigated type of OAE. They can be reliably measured from nearly all-human ears with normal cochlear and middle ear function. Their high test-retest reliability, coupled with their accuracy and objectivity in assessing cochlear function (outer hair cell function in particular), allows their use in monitoring dynamic changes in cochlear responsiveness, before apparent as a hearing loss.[16,17]

In the present study, we aimed to investigate whether VEMPs and DPOAEs had prognostic values in the follow-up of the patients diagnosed with ISSNHL based on the audiological tests.

PATIENTS AND METHODS

This prospectively study was conducted at ear, nose and throat clinic of Antalya Training and Research Hospital between June 2013 and January 2014. A total of 27 patients (11 males, 16 females; mean age: 44.9±13.8 years; range, 18 to 60 years) diagnosed with ISSNHL at their first admissions and underwent VEMP and DPOAE tests were included. Inclusion criteria were as follows: sudden onset of sensorineural hearing loss within the previous three days, an average pure tone audiometry (PTA) result of ≥30 dB, stable hearing loss without any variations, and lack of any previous treatment. A written informed consent was obtained from each patient. The study protocol was approved by the Antalya Training and Research Hospital Ethics Committee (Date: 07/04/2013; No: 22/3). The study was conducted in accordance with the principles of the Declaration of Helsinki.

To determine the probable etiological factors, parameters including complete blood count, routine biochemical panel, erythrocyte sedimentation rate, fasting blood glucose, free T3, free T4, thyroid-stimulating hormone, hepatitis B surface antigen, anti-hepatitis C virus, anti-human immunodeficiency virus, prothrombin time, activated partial thromboplastin time, and international normalized ratio were measured.

Audiological procedures

Before the treatment and at two months after the treatment, all patients underwent PTA, DPOES, and VEMP tests. The PTA, DPOE, and VEMP tests were performed by a single same audiologist using a single audiometer device for all patients.

The PTA was measured from 0.25 to 8 kHz (0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz). Threshold shifts in PTA were considered to be significant, if they showed an increment higher than 15 dB at one or more frequencies.

The DPOAEs were tested using the MADSEN Capella device (Natus Medical Denmark ApS, Taastrup, Denmark) at 2f2-f1 frequencies. Two simultaneous pure-tone signals (primaries) were presented to the ear at two different frequencies (f1 and f2, where f2>f1) and the 2f1-f2 cubic distortion-product component was recorded. In the DPgrams, recordings were obtained with a frequency ratio f2/f1 fixed at 1.22. Nine pairs of equal level primary frequencies (Ll = L2 = 65 dB SPL) were used at three points per octave, spanning f2 frequency range from 1,001 to 6,348 Hz. The 65 dB levels of the primary tones were used as these stimulus levels most reliably elicit DPOAEs from ears with hearing difficulties. The DPgram amplitude was determined for each patient. In the DPOAE test, DP1 levels were examined and levels over 65 dB were considered positivity.

The behavior of cervical VEMP reflexes were recorded using the Bio-logic Navigator PRO AEP (Natus Medical Inc., Mundelein, Illinois, USA) system latencies and amplitudes of P13 and N23 waves, and average threshold value of VEMP were found. VEMP was recorded in the supine position. The skin over the upper half of the sternocleidomastoid (SCM) muscle was cleaned with alcohol wipes, and surface electromyography electrode readings were recorded with a reference electrode on the upper edge of the sternum and a ground electrode on the forehead. Rarefaction clicks (105 dB nHL, 0.5 ms) were delivered to each ear through a headphone with a stimulation rate of 5 per sec. The patients were instructed to continuously raise their head to activate the SCM. The results were evaluated on the basis of comparative ratios between the first positive and first negative (P13-n=23) amplitude on the lesion side and that on the healthy side. We defined a ratio of <0.5 as an abnormal (also called negative, as in the study of Wang et al.) VEMP value.[18,19]

Treatment protocol

All patients diagnosed with sudden hearing loss underwent the same treatment protocol. Prednisolone was initiated at a dose of 1 mg/kg and the dose was tapered at a rate of 10 mg on every three days. Hyperbaric oxygen therapy was applied at 2.5 ATA for a total of 20 sessions.

Evaluation of the hearing recovery

Improvement rates of all patients were estimated at the end of the second month. Improvement rate was calculated by subtracting post-treatment level of the patient's hearing loss (HLpost) from his/her first measurement of hearing loss (HLpre) and by dividing the result by the difference between HLpre and hearing level of the intact contralateral ear (HLcontra). The result in percentage was used as the hearing improvement rate.[20]

Hearing improvement rate = (HLpre-HLpost)/(HLpre-HLcontra) × 100 (%)

Table 1. Clinical and demographical variables of patients

Variables	n	%	Mean±SD	Mean	Min-Max
Age (year)			44.9±13.8		18-60
Age groups					
≤45 years	12	44.4			
>45 years	15	55.6			
Sex					
Male	11	40.7			
Female	16	59.3			
Diabetes mellitus	11	40.7			
Hypertension	8	29.6			
Vertigo	8	29.6			
Tinnitus	6	22.2			
Side					
Right ear	19	70.4			
Left ear	8	29.6			
Healing percent				61.9	0.0-131.6
Healing percent ≥50	20	74.1			

SD: Standard deviation; Min: Minimum; Max: Maximum.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 11.5 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. Near normal distribution of continuous and discrete data was investigated using the Shapiro-Wilk test. Intergroup significance of the difference between medians was analyzed with the Student's t-test. To determine whether the medians of both sets of data were significantly different from one another, the Mann-Whitney U test was used. Categorical variables were evaluated with the likelihood ratio test or Fisher's exact test. A statistically significant change (if any) between pre- and post-treatment median PTA and DPOAE values was evaluated with the Wilcoxon signed-rank test, while the significance of distribution of data in audiograms was assessed with marginal homogeneity test. The significance of differences as for VEMP and DPOAE normality/positivity was investigated with the McNemar test. The most precise determinative factors in the prediction of the changes in the improvement rates were specified using the multivariate linear regression analysis. For each variable regression coefficient and 95% confidence intervals were calculated. A p value of <0.05 was considered statistically significant.

RESULTS

Demographic characteristics of the patients are shown in Table 1. The median improvement rate was 61.9% (range, 0 to 13.6%). In 74.1% (n=20) of the cases, improvement rates of ≥50% were detected.

Median pre- and post-treatment PTA levels were measured as 82.5 (range, 35.8 to 120) dB and 36.7 (range, 15 to 120) dB, respectively. Median post-treatment PTA level was statistically significantly higher than the pre-treatment PTA level (p<0.001) (Table 2).

Before the treatment, VEMP test normality was detected in 18 (66.7%) cases, while VEMP test normality was detected in 21 (77.8%) cases after the treatment. No statistically significant difference was observed between the frequencies of pre- and post-treatment VEMP test normality (p=0.250) (Table 3).

Median pre- and post-treatment DPOAE levels were -14.1 (range, -20.9 to 10.2) and -3.0 (range, -18.2 to 11), respectively. Compared to pre-treatment DPOAE level, post-treatment

Table 2. Pre- and post-treatment pure tone audiometry levels of study group

	Pre-treatment								
	<55 dB		55-89 dB		≥90 dB		Total		
	n	%	n	%	n	%	n	%	p
Post-treatment									<0.001
<55 dB	10	37.0	5	18.5	8	29.7	23	85.2	
55-89 dB	0	0.0	0	0.0	3	11.1	3	11.1	
≥90 dB	0	0.0	0	0.0	1	3.7	1	3.7	
Total	10	37.0	5	18.5	12	44.5	27	100.0	

	Pre-treatment								
	<35 dB		35-54 dB		≥55 dB		Total		
	n	%	n	%	n	%	n	%	p
Post-treatment									<0.001
<35 dB	0	0.0	7	26.0	4	14.8	11	40.8	
35-54 dB	0	0.0	3	11.1	9	33.3	12	44.4	
≥55 dB	0	0.0	0	0.0	4	14.8	4	14.8	
Total	0	0.0	10	37.1	17	62.9	27	100.0	

Table 3. Pre- and post-treatment VEMPs of study group

	Pre-treatment						
	Abnormal		Normal		Total		
	n	%	n	%	n	%	*p*
Post-treatment							0.250
Abnormal	6	22.2	0	0.0	6	22.2	
Normal	3	11.1	18	66.7	21	77.8	
Total	9	33.3	18	66.7	27	100.0	

VEMPs: Vestibular evoked myogenic potentials.

DPOAE level was statistically significantly higher (p<0.001). Pre-treatment DPOAE test positivity was detected in one (3.1%) case, while five (18.5%) cases demonstrated DPOAE test positivity after the treatment. No statistically significant difference was observed between the frequencies of pre- and post-treatment DPOAE test positivity (p=0.125) (Table 4).

Frequencies of VEMP normality did not demonstrate statistically significant differences regarding the hearing levels (p=0.256). The rates of VEMP normality did not demonstrate any statistically significant difference regarding hearing levels (p=0.406) (Table 5).

The VEMP test normality was detected in all (11/11) cases with post-treatment hearing levels above 35 dB, in 75% (9/12) of the cases with hearing levels of 35 to 54 dB and 25.0% (1/4) of the cases with hearing levels of ≤55 dB. The VEMP test normality rates demonstrated

Table 4. Pre- and post-treatment distortion product otoacoustic emissions of study group

	Pre-treatment						
	Abnormal		Normal		Total		
	n	%	n	%	n	%	*p*
Post-treatment							0.125
Negative	22	81.5	0	0.0	22	81.5	
Positive	4	14.8	1	3.7	5	18.5	
Total	26	96.3	1	3.7	27	100.0	

DPOAEs: Distortion product otoacoustic emissions.

Table 5. VEMPs and DPOAEs of the study group according to the pre-treatment pure tone audiometry levels

	35-54 dB		≥55 dB		
Variables	n	%	n	%	*p*
Pre-treatment VEMP					0.406
Abnormal	2	20.0	7	41.2	
Normal	8	80.0	10	58.8	
Pre-treatment DPOAEs					-
Negative	9	90.0	17	100.0	
Positive	1	10.0	0	0.0	

VEMPs: Vestibular evoked myogenic potentials; DPOAEs: Distortion product otoacoustic emissions.

Table 6. VEMPs and DPOAEs of the study group according to the post-treatment pure tone audiometry levels

	<35 dB		35-54 dB		≥55 dB		
	n	%	n	%	n	%	*p*
Post-treatment VEMP							0.005
Abnormal	0	0.0*	3	25.0	3	75.0*	
Normal	11	100.0*	9	75.0	1	25.0*	
Post-treatment DPOAE							0.005
Negative	6	54.5†	12	100.0†	4	100.0	
Positive	5	45.5†	0	0.0†	0	0.0	

VEMPs: Vestibular evoked myogenic potentials; DPOAEs: Distortion product otoacoustic emissions; * Significant difference was present between <35 dB group and ≥55 dB group (p=0.009); †: Significant difference was present between <35 dB group and 35-54 dB group (p=0.014)

statistically significantly differences for hearing levels (p=0.005) (Table 6).

The results of VEMP and DPOAE test results were compared based on post-treatment improvement rates (Tables 7, 8).

Compared to the group without vertigo, the rate of post-treatment VEMP test normality was statistically significantly lower in the vertigo group (p=0.044). No statistically significantly difference was observed between the groups with and without tinnitus in terms of the rates of VEMP test normality (p=0.284) (Table 9).

The median improvement rate in the group without a history of diabetes mellitus was statistically significantly higher, compared to the group with DM (p=0.044). The median improvement rate was statistically significantly higher in the group without vertigo, compared to the group with vertigo (p=0.025). The median improvement rate was statistically significantly higher in the group with tinnitus, compared to the group without tinnitus (p<0.001).

The median improvement rate in the group with pre-treatment VEMP normality was statistically significantly higher compared to the group with VEMP test abnormality (p=0.023). In comparison with the post-treatment VEMP test abnormality, the median improvement rate was statistically significantly higher in the group with VEMP test normality (p=0.031). In the group with post-treatment DPOAE test

Table 7. VEMPs and DPOAEs of the study group according to the pre-treatment recovery rates

Pre-treatment	Post-treatment							
	Total recovery		Partial improvement		No recovery		Total	
	n	%	n	%	n	%	n	%
VEMP								
Abnormal	0	0.0	8	29.6	1	3.7	9	33.3
Normal	9	33.3	9	33.3	0	0.0	18	66.7
Total	9	33.3	17	63.0	1	3.7	27	100.0
DPOAEs								
Negative	8	29.6	17	63.0	1	3.7	26	97.3
Positive	1	3.7	0	0.0	0	0.0	1	3.7
Total	9	33.3	17	63.0	1	3.7	27	100.0

VEMPs: Vestibular evoked myogenic potentials; DPOAEs: Distortion product otoacoustic emissions.

Table 8. VEMPs and DPOAEs of the study group according to the post-treatment recovery rates

Pre-treatment	Post-treatment							
	Total recovery		Partial improvement		No recovery		Total	
	n	%	n	%	n	%	n	%
VEMP								
Abnormal	0	0.0	5	18.5	1	3.7	6	22.2
Normal	9	33.3	12	44.5	0	0.0	21	77.8
Total	9	33.3	17	63.0	1	3.7	27	100.0
DPOAEs								
Negative	1	3.7	8	29.6	1	3.7	10	37.0
Positive	8	29.6	9	33.3	0	0.0	17	63.0
Total	9	33.3	17	63.0	1	3.7	27	100.0

VEMPs: Vestibular evoked myogenic potentials; DPOAEs: Distortion product otoacoustic emissions.

positivity, the median improvement rate was statistically significantly higher, compared to the group with DPOAE test negativity ($p<0.001$).

As a result of univariate analyses, the combined effect of all significant or presumably significant clinical factors effective on threshold value of the improvement rate were evaluated using multivariate linear regression analysis. When the effects of other probable factors were kept at a fixed level, the improvement was mostly influenced by post-treatment DPOAE test positivity, followed by the presence of tinnitus. When the effects of other probable factors were kept at a fixed level, post-treatment DPOAE test positivity led to an increase of 42.55 points

Table 9. Pre- and post-treatment VEMPs of the study group according to the vertigo and tinnitus anamnesis

Variables	VEMP abnormal		VEMP normal		*p*
	n	%	n	%	
Pre-treatment					
Vertigo					0.375
Absent	5	26.3	14	73.7	
Present	4	50.0	4	50.0	
Tinnitus					0.071
Absent	9	42.9	12	57.1	
Present	0	0.0	6	100.0	
Post-treatment					
Vertigo					0.044
Absent	2	10.5	17	89.5	
Present	4	50.0	4	50.0	
Tinnitus					0.284
Absent	6	28.6	15	71.4	
Present	0	0.0	6	100.0	

VEMPs: Vestibular evoked myogenic potentials.

Table 10. Multivariate linear regression analysis of the clinical factors effective on threshold value of the improvement rate

Variables	Regression coefficient	95% CI Min-Max	*p*
Age >45 years	14.710	-7.085 - 36.505	0.174
Diabetes mellitus	-7.130	-27.933 - 13.673	0.482
Hypertension	10.713	-15.394 - 36.819	0.401
Tinnitus	30.287	5.929 - 54.645	**0.017**
Vertigo	-8.380	-30.150 - 13.391	0.430
Post-treatment VEMP normal	15.804	-11.904 - 43.512	0.247
Post-treatment DPOAEs +	42.550	15.036 - 70.064	**0.004**

CI: Confidence interval; Min: Minimum; Max: Maximum; VEMPs: Vestibular evoked myogenic potentials; DPOAEs: Distortion product otoacoustic emissions.

(95% CI: 15.04-70.06) in the improvement rate (p=0.004). When the effects of other probable factors were kept at a fixed level, the presence of tinnitus induced an increase of 30.29 points (95% CI: 5.93-54.64) in the improvement rate (p=0.017) (Table 10).

DISCUSSION

In the treatment of sudden hearing loss, vasodilators, vitamins, steroids, anticoagulants, histamine, tranquilizers, diuretics, prostacyclins, hypervolemic hemodilution, carbogens, hyperbaric oxygen, and satellite ganglion blockage have been used.[21-23] Beneficial effects of high doses of steroids and hyperbaric oxygen have been shown in several studies.[21,24] In ISSHL, prognosis varies dependent on various factors. Some authors have reported age as an indicator of poor prognosis, while some others have not found such a correlation with age.[1,25] In our study, we found no statistically significant difference in the median improvement rates between the age groups. In the ISSNHL, sex has not been considered as a prognostic factor. Only in the study conducted by Samim et al.,[26] improved prognosis was associated with female sex. In our study, we detected similar median improvement rates between men and women. In addition, many researchers have indicated adverse effects of vestibular symptoms on prognosis.[1,25,27,28] Park et al.[29] investigated the effects of vestibular symptoms on improvement of hearing and reported worse prognosis in the presence of vestibular symptoms. In our study, the median improvement rate was statistically significantly higher in the group without any evidence of vertigo. In the literature, a consensus has not been reached about the prognostic value of tinnitus.[28,30] In our study, we detected statistically significantly higher median improvement rates in the group without tinnitus, compared to the group with tinnitus.

The association of sudden hearing loss with various systemic diseases has been investigated and vascular risk factors (overweight, hypercholesterolemia, hypertriglyceridemia, hyperuricemia and smoking) have been more frequently observed in patients with sudden hearing loss, compared to normal healthy population.[31,32] In the literature, glycemic level has been considered a prognostic factor.[1] In our study, in compliance with the literature, the median improvement rate was statistically significantly higher in the non-diabetic group, compared to the diabetic group.

According to a currently accepted general view, spontaneous recovery of sudden hearing loss ranges between 31% and 65% and, among treated patients, this rate varies between 35% and 85%.[1,33] Many etiological factors can explain these diverse outcomes. The most important issue is the definition of successful outcomes as for spontaneous recovery of sudden hearing loss. What is perceived from the definition of "successful outcomes" can change the

interpretation of the outcomes of the study. In the literature, various definitions have been used for significant post-treatment improvement. To the best of our knowledge, generally accepted criteria for successful outcome in patients with ISSHL have not been defined, yet. The improvement in any result of audiograms or the increase in discrimination scores, a hearing gain of 10 dB as detected on audiograms or as described by Wilson et al.,[33] and recovery of more than 50% in the baseline hearing loss have been suggested as criteria for successful outcomes.

Welgampola and Colebatch[34] applied VEMP method in normal population and used 250, 500, 1,000 and 2,000 Hz tone-burst stimulators. They obtained optimal responses at 500 and 1,000 Hz and they could not find a significant response among those elicited at 500 and 1,000 Hz. The authors also detected mean latencies for P13 and N23 at all frequencies applied as 12.3±1.36 and 21.4±1.69 ms, respectively. In another study, the authors reported the optimal response with application of 500 Hz tone burst.[33] In various investigations, stimulation at 95 dB nHL has been usually indicated to yield the optimal VEMP latencies.[36] Still, in our study, VEMP test was applied with tone-burst stimuli at a frequency of 500 Hz paired with a sound intensity of 95 dB nHL.

A limited number of studies in the literature have investigated the association between VEMP test and prognosis in ISSHL. Wang et al.[37] performed pre- and post-treatment ABR and VEMP tests in 88 patients with severe hearing loss and investigated the association between the results of these tests and degree of hearing gains. According to their study, patients with severe hearing loss with normal ABR and VEMP test results demonstrated a significantly better prognosis and also more favorable hearing improvement. Moreover, in their study, the authors concluded that the presence of vertigo was associated with a poor prognosis. Age, sex, diabetes mellitus, hypertension, and delayed treatment were not found to be significantly correlated with prognosis. Iwasaki et al.[38] performed auditory brainstem response (ABR) and VEMP tests in patients with severe hearing loss and demonstrated that the causative lesion could affect a large area in the inner ear, including the cochlea and saccule. Still, in their study, positive ABR and VEMP test results were associated with the improved prognosis.

Furthermore, Rajati et al.[39] compared VEMP test results and investigated the presence of vertigo in 43 patients with sudden hearing. They found that 14 patients had vertigo and 13 patients had abnormal VEMP test results. They also detected abnormal (n=6) and normal (n=8) VEMP test results in these patients with vertigo. The authors concluded that abnormal VEMP test results were associated with lower improvement rates. In another study, Hong et al.[40] investigated subclinical saccular lesions in 52 patients with sudden hearing loss without any evidence of vertigo and detected abnormal VEMP test results in 14 (24%) patients. The presence of abnormal VEMP test results without vestibular symptoms could indicate the impact of subclinical saccular lesion. In addition, Stamatiou et al.[41] performed VEMP tests and caloric tests in 86 patients with sudden hearing loss without any evidence of vertigo and detected abnormal VEMP and caloric test results in 30% and 52% of their patients, respectively. In our study, we investigated pre- and post-treatment VEMP test results and observed predominantly (75%) improved prognosis in patients with VEMP test normality and VEMP abnormality was not detected in patients with isolated vestibular symptoms. Still, in our study, lower improvement rates were observed in the patients with vestibular symptoms.

Mori et al.[20] performed a study in 78 patients with sudden hearing loss and used pre- and post-treatment DPOAE tests for the monitorization of the prognosis and demonstrated that changes in the DPOAE test results in patients with ≥50% hearing improvement were significantly more favorable. In their study, they interpreted DPOAE test positivity with a favorable prognosis and described age, treatment-onset time, baseline hearing level, and presence of vertigo as the prognostic factors. They also demonstrated the presence of vertigo as an apparently worse prognostic factor. In another study, Chao and Chen[42] conducted a study in 108 patients with sudden hearing loss and followed their patients with audiological examinations; i.e., VEMP, DPOAE, and ABR tests before treatment, on Day 7,

and at two months after treatment. The patients with a hearing loss of ≤65 dB were included and the authors concluded that normal ABR, VEMP, and DPOAE test results were significantly better prognostic factors.

In our study, compared to the pre-treatment DPOAE levels, a statistically significant increase was observed in the post-treatment DPOAE levels. Compared to the group with pre-treatment VEMP test abnormality, the median improvement rate was statistically significantly higher in the group with pre-treatment VEMP test normality. Compared to the group with post-treatment VEMP test abnormality, the median improvement rate was statistically significantly higher in the group with post-treatment VEMP test normality. Compared to the group with post-treatment DPOAE test negativity, the median improvement rate was statistically significantly higher in the group with DPOAE test positivity. As a result of univariate analysis, combined effect of all significant or presumably significant clinical factors effective on threshold value of the improvement rates were evaluated using multivariate linear regression analysis. When the effects of other probable factors were kept at a stable level, improvement was mostly influenced by post-treatment DPOAE test positivity, followed by the presence of tinnitus. When the effects of other probable factors were kept at a fixed level, post-treatment DPOAE test positivity led to an increase of 42.55 points (95% CI: 15.04-70.06) in the improvement rate. When the effects of other probable factors were kept at a fixed level, the presence of tinnitus induced an increase of 30.29 points (95% CI: 5.93-54.64) in the improvement rate.

If we refer to the limitations of our study, the low number of patients can be considered as our most important limitation.

In conclusion, we conclude that VEMP test is important in the follow-up of the patients with sensorineural sudden hearing loss. However, the DPOAE test can be used for the monitorization of the treatment, although it seems to be useless as a predictor of prognosis. In addition, presence of vertigo, diabetes mellitus, and VEMP test abnormality appear to be the predictors of poor prognosis, while tinnitus is a predictor of favorable prognosis.

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