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Original Article

Do Vestibular-Evoked Myogenic Potential Abnormalities in Patients with Cochlear Implant Only Reflect Saccular Dysfunction?

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OBJECTIVE: The objective of this study was to explore the usefulness of 1000-Hz tone burst (TB) stimuli for detecting cervical vestibular-evoked myogenic potential (cVEMP) abnormalities in patients with a cochlear implant (CI).

MATERIALS and METHODS: Thirty asymptomatic patients who received unilateral CI because of severe bilateral sensorineural hearing loss were assessed for cVEMP produced by TB stimuli at two frequencies (500 and 1000 Hz) in the airway. VEMPs were recorded when the devices were switched to the on (CI-on) and off (CI-off) positions.

RESULTS: At the CI-on position, the surgical side (SS) 500-Hz response rates (15/30) were significantly higher than the SS 1000-Hz response rates (9/30) (p=0.031), while the non-operated control side (CS) 500-Hz response rates (20/30) were higher than the CS 1000-Hz response rates (18/30), but the difference was not significant (p=0.50). At the CI-on position, the SS 500-Hz response rates (15/30) were lower than the CS 500-Hz response rates (20/30), but the difference was not significant (p=0.063). However, the SS 1000-Hz response rates (9/30) were significantly lower than the CS 1000-Hz response rates (18/30) (p=0.004). When there was no significant difference between the 500-Hz amplitudes on either side, the SS 1000-Hz amplitudes were found to be significantly lower (p=0.04).

CONCLUSION: CIs have the potential to cause mechanical damage and electrical stimulation to the vestibular system. Possible implant-mediated mechanical damage and electrical stimulation in the high-frequency region affecting the cVEMP response could be found by a 1000-Hz stimulus.

KEYWORDS: Cochlear implant, vestibular evoked myogenic potentials, saccule

INTRODUCTION

Cervical vestibular-evoked myogenic potentials (cVEMPs) are short-latency electromyographical responses that are obtained as a result of auditory stimulation of the vestibular receptors in the saccule. They reflect the saccule and inferior vestibular nerve functions and occur in the sternocleidomastoid (SCM) muscles [1, 2]. A cochlear implant (CI) system converts acoustic energy to electrical energy and triggers the cochlear nerve through electrical stimulation of the spiral ganglion. CI may affect cVEMP responses by mechanical trauma or electrical stimulation [3, 4]. Because of their anatomical proximity, it is argued that CI affects the vestibular system, particularly the saccule [5, 6]. However, it is not clear whether the reported cVEMP abnormalities are caused by saccular dysfunction or by electrical stimulation arising from the implant. Therefore, in this study, patients with asymptomatic CIs were assessed for cVEMPs produced by tone burst (TB) stimuli at two frequencies (500 and 1000 Hz) in the airway. The objective of this study was to explore the usefulness of 1000-Hz TB stimuli for detecting cVEMP abnormalities in patients with CI.

MATERIALS and METHODS

Following the approval of the local ethics committee of our institution, this cross-sectional study was conducted.

Written consents were obtained from 30 patients who had received a unilateral CI because of severe bilateral sensorineural hearing loss. Patients with no inner ear abnormalities, with no history of other ear disorders, and without vestibular symptoms at postoperative follow-up were included in the study. Intact eardrums and normal middle ear pressures were confirmed by otoscopy and tympanogram.

The cVEMP testing was performed in a quiet room using surface electrodes with the patient in a sitting position with a rotational biofeedback method. An Eclipse EP 25 VEMP system (Interacoustics AS; Assens, Denmark) was used for recording the responses. Two active electrodes were placed in the middle one-third area of each SCM muscle, a reference electrode was placed on the upper

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end point of the sternum, and the ground electrode was placed on the forehead. cVEMPs were recorded using a 100 dBnHL (128 dB SPL), stimulus at 500-Hz and 1000 Hz-TB by air conduction. Filtering was not performed for the electromyography (EMG) signal. Each patient received 200 stimuli on average.

For the surgical side (SS) and non-operated control side (CS), the VEMPs were recorded when the CI device was switched both to the on (CI-on) and off (CI-off) positions. The presence of the response, the latencies of the first positive (P13) and the subsequent negative wave (N23), N23–P13 latencies and amplitudes, and the amplitude asymmetry were calculated. For asymmetry, those with [LA/SA)/(R+L)]≥0.34 were considered abnormal.

SPSS 15.0 (SPSS Inc.; Chicago, IL, USA) for the Windows program was used for the statistical analysis. Comparisons of two independent groups were made by using the Mann–Whitney U test, whereas comparisons of more than two independent groups were made by using the Kruskal–Wallis test. While the rates of the categorical variables between the independent groups were analyzed by using chi-square analysis, those between the dependent groups were analyzed by using the McNemar test. The correlations between the numeric variables were examined with Spearman's correlation analysis. The statistical alpha significance level was accepted as p<0.05.

RESULTS

Thirty asymptomatic CI patients (14 males and 16 females) aged 8–40 (average: 14.9±9.0) years were included in the study.

The responses in the two sides were evaluated at two frequencies and in the CI-on/off positions (Figure 1). Under all circumstances, lower response rates were obtained from the SS. From the patients in whom SS responses were received, the responses from the CS were obtained, as well.

At the CI-on position, the surgical side (SS) 500-Hz response rates (15/30) were significantly higher than the SS 1000-Hz response rates (9/30) (p=0.031), while the CS 500-Hz response rates (20/30) were higher than the CS 1000-Hz response rates (18/30), but not to a statistical significance (p=0.50).

At the CI-on position, the SS 500-Hz response rates (15/30) were lower than the CS 500-Hz response rates (20/30), but the difference was not significant (p=0.063). However, the SS 1000-Hz response rates (9/30) were significantly lower than the CS 1000-Hz response rates (18/30) (p=0.004).

At the CI-off position, no significant differences were found between the response rates of the two ears depending on the stimulus frequency.

As in the healthy adult controls, the 1000-Hz P13 and N23 latencies were determined to be significantly shorter for both sides (Table 1). At the CI-on position, shorter latency values were obtained for both sides, but they were not statistically significant. At both stimulus frequencies, the latency values on the SS were found to be shorter.

For both stimuli, the amplitudes of the SS were found to be lower (Figure 2). At the CI-off position, the amplitude on the SS was higher, wile at the CI-on position, the amplitude on the non-operated side was higher.

For the 500-Hz stimulus, responses with higher amplitudes were obtained on both sides but they were not statistically significant.

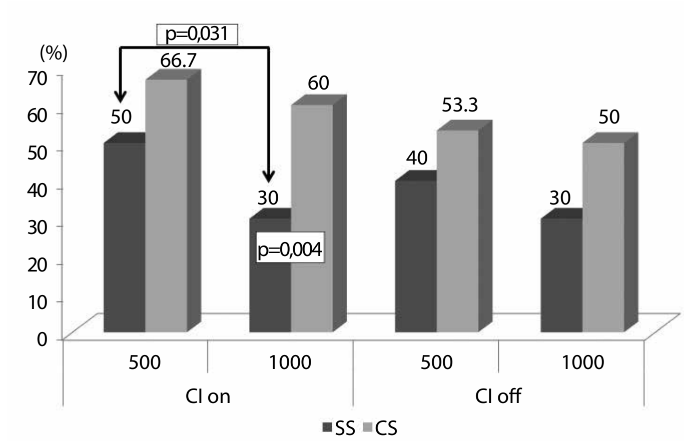

Figure 1. CI-on/off response rates at both sides (%)
SS: surgical side; CS: non-operated control side

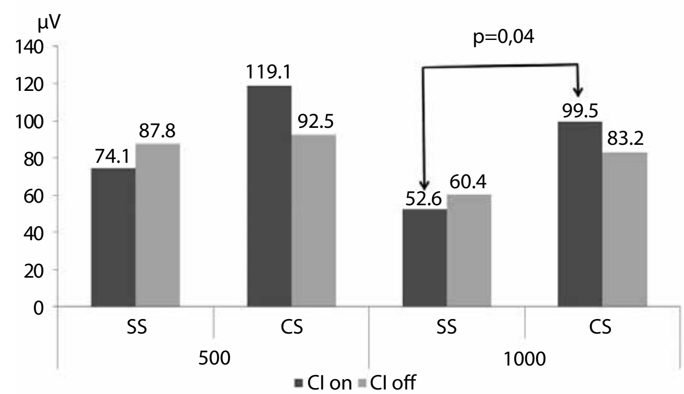

Figure 2. Amplitude values obtained at two stimulus frequencies
SS: surgical side; CS: non-operated control side

Table 1. CI-on/off latency values of the two frequencies (ms)

		500 Hz			1000 Hz		
		SS	CS	p	SS	CS	p
P13	CI-on	15.0±1.1	15.3±1.1	0.507	12.7±0.7	13.7±1.4	0.058
	CI-off	15.1±1.2	15.5±1.3	0.137	13.0±0.9	14.0±1.5	0.091
	p	0.286	0.801		0.150	0.937	
N23	CI-on	22.8±1.4	23.2±1.5	0.975	19.3±1.2	20.7±1.9	0.553
	CI-off	23.0±1.3	23.8±1.9	0.332	19.9±1	21.1±2	0.144
	p	0.479	0.409		0.833	0.790	

SS: surgical side; CS: non-operated control side

Table 2. Amplitude asymmetry ratio

(LA–SA)/(R+L)	CI-on	CI-off	p
500 Hz	0.28±0.19	0.19±0.16	0.508
1000 Hz	0.32±0.18	0.12±0.14	0.028

SS: surgical side; CS: non-operated control side

When there was no significant difference between the 500-Hz amplitudes on either side, the SS 1000-Hz amplitudes were found to be significantly lower (p=0.04). This is why the CI-on/off asymmetry ratio was found to be significant for the 1000-Hz stimulus (p=0.028) (Table 2).

DISCUSSION

Auditory stimuli excite the vestibular receptors through otoconial action at low frequencies and through the mechanical effect of liquid pressure at high frequencies [7]. The bilateral cVEMP response rates of healthy adults to 500- and 1000-Hz TB stimuli are reported to be 94% and 89%, respectively, depending on the stimulus frequency [8].

In the evaluation of saccular function after CI, only 500-Hz TB stimuli are used, and a wide range of cVEMP abnormalities have been reported [9-12]. It has been reported that cVEMP responses were not obtained, at a rate of 19%–62%, among patients with severe sensorineural hearing loss because of the anatomic and phylogenetic relationship of the cochlea with the vestibular organs, particularly the saccule; therefore, the extent of cVEMP responses and how CIs affect them remain unclear [13-16].

If preoperative evaluation is performed, it would be easy to detect postoperative changes by a single-frequency stimulus. However, when we are unaware of the preoperative status of a patient, considering the wide range of abnormalities reported in the literature, postoperative assessment is difficult using only single-frequency stimuli.

To the best of our knowledge, this is the first study to compare cVEMP responses in asymptomatic CI patients on the basis of both 5000-Hz and 1000-Hz stimuli. In the present study, the response rates were lower for SS with both stimuli. There was no significant difference between the response rates of either side in the evaluations conducted at the 500-Hz TB stimulus. However, in the evaluations conducted at the 1000-Hz stimulus, responses were obtained at the rates of 30% and 60% on the SS and the CS, respectively, and the difference between them was found to be significant. The response rates on the SS were 50% and 30% at the 500-Hz and 1000-Hz stimuli, respectively, and the difference between them was found to be significant. In all the patients for whom responses were obtained at 1000 Hz on the SS, the responses were obtained from the CS as well. Therefore, it is possible that mechanical trauma might be higher in patients for whom responses were not obtained at 1000 Hz on the SS.

Another possible effect of CI is changing the responses due to electrical stimulation. Black et al. [17] reported that responses were obtained from two patients with vestibular stimulation at the first activation of the CI. Jin et al. [18, 19] also reported that when the CI was activated, responses were received from patients who had previously lost the response post-operatively. On the other hand, Katsiari et al. [11] stated exactly the opposite, reporting that the preoperative response observed in the CS was lost after activating the device in the postoperative period. Since, only the 500-Hz stimulus was used in these previous evaluations, it was assumed that the implant-mediated stimulation was in the apical turn [20-22]. In this study, at the 1000-Hz stimulus, we obtained responses from the SS of one patient and from the CS in two patients only with the CI-on position. Two theories are suggested for this. The first is that CIs designed with tonotopic organization may generate electrical stimulation in a manner other than the apical turn, affecting the different channels with frequency susceptibility. The second theory is that the responses assumed to be obtained as a result of electrical stimulation may not absolutely reflect the function of the saccule. As we determined in two of our cases, the effect on the CS could be possible only through the direct inferior vestibular nerve or the central effect out of the saccule [12, 18, 23]. From that aspect, the implant-mediated effect can be likened to VEMP variants with galvanic stimulation [24].

In CI patients, reference values were not determined in terms of cVEMP latency and amplitude values. However, Jin et al. [19] reported that P13 and N23 latencies became longer after CI surgery. On the other hand, in the present study, shorter latency values were found at both frequencies on the SS when the device was at the on position, but this was not statistically significant.

Xu et al. [25] reported that the amplitude of the non-operated ear at the CI-on position increased. Similarly, in our study, the amplitude of the CS at the CI-on position also increased. However, the amplitude difference between ears and the amplitude asymmetry ratio were found to be significant only at the CI-on position by a 1000-Hz TB stimulus.

In some medical centers, the examination of cVEMPs has become routine before CI surgery [12].owever, in our study, the states of the patients' cVEMP responses before surgery were unknown. The long period of time between the surgery and testing can be considered another limitation of this study. Previous studies have reported that there was no significant difference between the tenth day and the sixth month and between the ninth month and the sixth year in terms of the obtained response rates [12, 18, 26]. In the present study, testing was performed 37.6±21.4 months post-surgery. No significant correlation was determined between the post- operative period and the responses.

Cochlear implants have the potential to create mechanical damage and electrical stimulation to the vestibular system. In this study, CI patients were evaluated based on cVEMPs at 500-Hz and 1000-Hz TB stimuli. It was observed that implant-mediated electrical stimulation could occur in a manner other than the apical turn and could affect the responses in the CS. Possible implant-mediated mechanical damage and electrical stimulation in the high-frequency region affecting the cVEMP response could be found by 1000-Hz stimulus.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of İstanbul Training and Research Hospital (506/25-07-2014).

Informed Consent: Written informed consent was obtained from the parents of the patients and patients who participated in this study.

Peer-review: Externally peer-reviewed.

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