Saccular Function in Children with Cochlear Implant

B Mujdeci[1], S Onder[2], S Allusoglu[2], A İriz[3], C Gocer[4], A Eryilmaz[2]

ABSTRACT

Objective: *The aim of this study was to evaluate vestibular evoked myogenic potential (VEMP) in patients with unilateral cochlear implant and normal hearing individuals.*
Methods: *The study group consisted of 20 children (9 girls, 11 boys; mean age 8.70 ± 2.34 years; range 6–14 years) who underwent unilateral cochlear implantation. As controls, 12 healthy volunteer children (6 girls, 6 boys; mean age 8.91 ± 2.77 years; range 6–14 years) also participated in the study. Testing of VEMP was performed in cochlear implant patients and in the control group.*
Results: *Vestibular evoked myogenic potential recorded in both ears of control individuals was normal, while VEMP was bilaterally obtained in 10 (50%) patients with cochlear implant. Two children (10%) showed no responses bilaterally. The mean P1 latencies and VEMP thresholds showed significant difference between implanted ears of patients with cochlear implant and the control group ($p < 0.05$). The mean VEMP thresholds showed significant difference between non-implanted ears of patients with cochlear implant and the control group ($p < 0.05$).*
Conclusions: *Some patients with cochlear implant show a saccular dysfunction. The addition of the VEMP test to the cochlear implantation test battery may provide useful information about the saccular function before and after surgery.*

Keywords: Cochlear implant, saccule, vestibular evoked myogenic potential, vestibular system

Función Sacular en Niños con Implante Coclear

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RESUMEN

Objetivo: *El objetivo de este estudio fue evaluar el potencial vestibular miogénico evocado (PVME) en pacientes con implante coclear unilateral e individuos con audición normal.*
Métodos: *El grupo de estudio consistió de 20 niños (9 niñas, 11 niños; edad promedio 8.70 ± 2.34; rango 6–14 años) que recibieron implantación coclear unilateral. También participaron en el estudio 12 niños voluntarios sanos (6 niñas, 6 niños; edad promedio 8.91 ± 2.77 años; rango 6–14 años). La prueba de PVME fue realizada en pacientes con implante coclear y en el grupo de control.*
Resultados: *El potencial vestibular miogénico evocado registrado en ambos oídos de los individuos de control fue normal, mientras que el PVME bilateral se obtuvo en 10 pacientes (50%) con implante coclear. Dos niños (10%) no mostraron respuestas bilateralmente. Las latencias P1 promedio y los umbrales de PVME mostraron diferencias significativas entre los oídos implantados de pacientes con implante coclear y el grupo control ($p < 0.05$). Los umbrales PVME promedios mostraron diferencias significativas entre los oídos no implantados de pacientes con implante coclear y el grupo control ($p < 0.05$).*
Conclusiones: *Algunos pacientes con implante coclear presentan una disfunción sacular. La adición de la prueba de PVME a la batería de prueba de la implantación coclear puede proporcionar información útil sobre la función sacular antes y después de la cirugía.*

Palabras claves: Implante coclear, sáculo, potencial vestibular miogénico evocado, sistema vestibular

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INTRODUCTION

Cochlear implants represent the most important advance in the treatment of individuals with severe to profound sensorineural hearing loss (1). Over the past two decades, cochlear implantation has become a widely accepted device to help deaf children to develop language skills (2, 3). Although cochlear implantation is considered to be safe, vestibular damage resulting from cochlear implant insertion has been reported both in adults and children (3, 4). It was estimated that risk of impairment varies videly from 6.3 to 93% for the horizontal canal and from 21 to 100% for the saccule (4, 5).

Vestibular evoked myogenic potential (VEMP) has been described as a useful clinical test of the vestibular system. Vestibular evoked myogenic potential orginates in the saccule and is conducted by the lower portion of the vestibular nerve all the way to the central nervous system, generating inhibitory electrical responses picked up by electrodes placed on the sternocleidomastoid muscle [SCM] (6–9). It is an objective, noninvasive and well tolerated test (10). It produces a biphasic (positive-negative) response and can be recorded from surface electrodes (6).

The aim of this study was to evaluate VEMP in patients with unilateral cochlear implant and normal hearing individuals.

SUBJECTS AND METHODS

The study group consisted of 20 children (9 girls, 11 boys; mean age 8.70 ± 2.34 years; range 6–14 years) with congenital or early-acquired profound sensorineural hearing loss who underwent unilateral cochlear implantation. These patients had normal middle ear function. As control, 12 healthy volunteer children (6 girls, 6 boys; mean age 8.91 ± 2.77 years; range 6 –14 years) also participated in the study. They had normal hearing and normal middle ear function. Type A tympanogram in the impedance audiometry was defined as normal (11).

The study was approved by the institutional review board of the institution. A written informed consent was obtained from the children's parents. Also, all children were counselled and informed regarding study participation.

Before vestibular testing, tympanometry was conducted to ensure that the middle ear space was functioning within normal limits for all subjects.

Testing of cervical VEMP was performed in cochlear implant patients and in the control group. Vestibular evoked myogenic potential testing was performed in the implanted children at least six months after implant activaton and was recorded with the cochlear implant device switched on. The VEMP was used to evaluate saccular function. Recordings were made in a Biologic Navigator Pro (version 7) SE system. Non-inverting electrode was placed on the midpoint of the ipsilateral SCM muscle, and the inverting electrode was placed on the muscle tendon just above the sternoclavicular junction. A ground electrode was placed on the midpoint of the contralateral SCM muscle. The VEMP test was performed in a supine position. Monaural stimulation with ipsilateral recording was conducted. During the recording, the children were instructed to turn their heads toward the contralateral side of the ear being tested.

Sound stimuli were presented to both ears *via* inserted earphones at a 500 Hz tone burst, stimulus rate 5.0/s, and rarefaction polarity. The acquisition parameters were as follows: amplification 5000 filter, setting 10–1500 Hz, time window 70 ms and number of sweeps 100–200. The VEMP latencies (P1 and N1) were measured at stimulus level of 95 dB HL. The VEMP response thresholds were determined using a down 10, up 5 dB step procedure.

The VEMP results of the subjects and the control group were analysed, and the values for latency and thresholds were calculated as mean ± standard deviation.

Statistical analysis was performed using the SPSS software version 18. For statistical analysis, the values of the cochlear implant patients and the control groups were compared by Mann Whitney U test. To analyse differences between values in cochlear implant patients, a Mann Whitney U test was used. Statistical significance was set at $p < 0.05$.

RESULTS

Table 1 represents a summary of the age, gender, ear with implant, age at implantation, cause of hearing loss and type of cochlear implant. Thirteen (65%) patients received a cochlear implant on the right and seven (35%) patients received a cochlear implant on the left. All patients underwent standard procedure for cochlear implantation involving a cortical mastoidectomy posterior tympanotomy and electrode insertion through a cochleostomy. Six implants were Nucleus, nine implants were MED-EL, and five implants were Advanced Bionics.

The mean age at receiving a cochlear implants was 4.52 ± 1.64 years. On average, children had their cochlear implant for a period of 4.12 ± 2.55 years at the time of VEMP assessment.

Vestibular evoked myogenic potential recorded in both ears of control subjects was normal, while VEMP was bilaterally obtained in 10 (50%) patients with cochlear implant. Two children showed no responses bilaterally. Examples of VEMP are shown in Figs 1 and 2.

Table 2 displays VEMP results as thresholds and wave latencies (P1 and N1) of the implanted and non-implanted ear. The mean VEMP threshold of the implanted ear was 87.5 ± 5.4 dB and the mean VEMP threshold of the non-implanted ear was 86.66 ± 7.47 dB. As regards P1 and N1 latencies, the mean P1 latency of implanted ear was 15.08 ± 1.38 ms and the mean N1 latency of implanted ear was 19.43 ± 2.21 ms. Similarly, the mean P1 latency of the non-implanted ear was 14.65 ± 1.78 ms and the mean N1 latency of the non-implanted ear was 19.41 ± 1.38 ms.

In the control group, the mean P1 wave latency was 13.73 ± 0.84 ms, the mean N1 wave latency was 19.22 ± 1.04 ms and the mean VEMP threshold was 78.33 ± 5.64 dB.

Table 1: Characteristics of 20 children with cochlear implant

Patient no	Age (years)	Gender	Ear with implant	Age at implantation (years)	Cause of hearing loss	Type of CI
1	6	F	Right	4	Prelingual, congenital	Advanced Bionics
2	7	M	Right	5	Prelingual, congenital	Advanced Bionics
3	8	F	Right	5.5	Other	Advanced Bionics
4	8	M	Left	3.5	Prelingual, congenital	MED-EL
5	9	F	Right	7	Other	MED-EL
6	8	M	Right	6	Congenital	MED-EL
7	8	M	Right	4	Congenital	Advanced Bionics
8	14	M	Left	5.5	Congenital	Nucleus
9	9	M	Left	6.5	Prelingual, congenital	Nucleus
10	7	M	Left	1	Hereditary	Nucleus
11	8	F	Right	2.5	Prelingual, congenital	MED-EL
12	13	F	Left	2	Prelingual, congenital	MED-EL
13	11	M	Right	6	Prelingual, congenital	MED-EL
14	9	M	Left	5	Other	MED-EL
15	8	M	Right	5	Other	MED-EL
16	6	M	Left	2. 5	Prelingual, congenital	Nucleus
17	9	F	Right	7	Prelingual, congenital	Nucleus
18	7	F	Right	4.5	Prelingual, congenital	Nucleus
19	13	F	Right	5	Hereditary	MED-EL
20	6	F	Right	4	Other	Advanced Bionics

Cl: cochlear implants

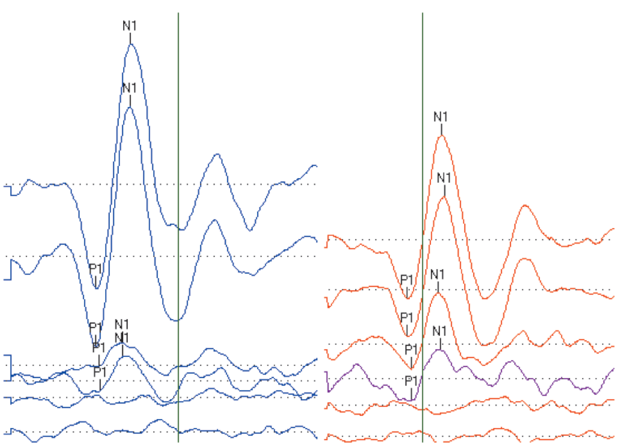

Fig. 1: Vestibular evoked myogenic potential of a control subject.

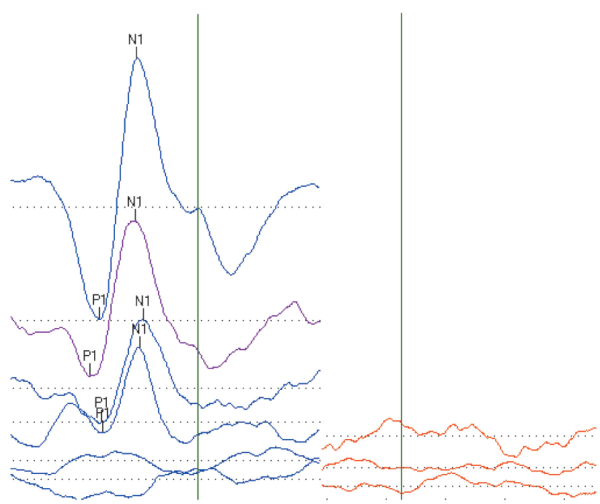

Fig. 2: Vestibular evoked myogenic potential result of a patients with cochlear implants.

Table 2: Results of vestibular evoked myogenic potential in patients with cochlear implant

Patient	İmplanted ear P1 latency	Non-implanted ear P1 latency	İmplanted ear N1 latency	Non-implanted ear N1 latency	İmplanted ear VEMP threshold	Non-implanted ear VEMP threshold
1	14.29	13.46	17.52	16.89	90.00	95.00
2	Absent	Absent	Absent	Absent	Absent	Absent
3	15.04	13.14	17.83	19.18	85.00	80.00
4	13.77	16.16	18.87	19.53	80.00	85.00
5	16.06	13.66	21.37	19.12	95.00	95.00
6	14.39	14.50	19.29	19.18	90.00	85.00
7	15.66	13.25	17.52	20.17	90.00	75.00
8	17.31	16.79	24.80	21.43	95.00	95.00
9	Absent	13.04	Absent	18.35	Absent	85.00
10	Absent	19.49	Absent	21.47	Absent	95.00
11	Absent	13.04	Absent	17.52	Absent	85.00
12	14.18	14.70	19.70	20.12	80.00	80.00
13	Absent	14.18	Absent	20.64	Absent	80.00
14	13.14	14.50	19.08	20.22	85.00	80.00
15	16.98	13.14	18.35	21.06	85.00	75.00
16	Absent	17.10	Absent	20.51	Absent	85.00
17	Absent	14.39	Absent	17.83	Absent	95.00
18	Absent	13.25	Absent	18.14	Absent	95.00
19	Absent	15.95	Absent	18.16	Absent	95.00
20	Absent	Absent	Absent	Absent	Absent	Absent

The mean P1 latencies and the mean VEMP thresholds showed significant difference between implanted ears of patients with cochlear implant and the control group ($p < 0.05$). The mean VEMP thresholds showed significant difference between non-implanted ears of patients with cochlear implant and the control group ($p < 0.05$). No statistically significant difference was found between implanted and non-implanted ears of patients with cochlear implant regarding the mean P1, N1 latencies and VEMP thresholds ($p > 0.05$).

DISCUSSION

The purpose of this study was to investigate VEMP results in patient with unilateral cochlear implant compared to normal hearing individuals. Testing of VEMP was performed in each patients with cochlear implant and all volunteers in the control group. The mean wave latencies of P1, N1 and the mean thresholds of VEMP in the patient and the control groups were evaluated.

The VEMP responses in both ears of control subjects were normal in this study. Comparisons of each VEMP measurement showed differences in mean VEMP P1 latencies and the mean VEMP thresholds between implanted ears of patients with cochlear implant and the control group ($p < 0.05$). The mean VEMP thresholds in implanted ears of patients with cochlear implant (87.5 ± 5.4 dB) was significantly higher than the control groups (78.33 ± 5.64 dB). The mean VEMP thresholds were significantly different ($p < 0.05$) between non-implanted ears of patients with cochlear implant (86.66 ± 7.47 dB) and the control group (78.33 ± 5.64 dB). No statistically significant difference was found between implanted and non-implanted ears of patients with cochlear implant regarding the mean P1, N1 latencies and VEMP thresholds in our study ($p > 0.05$). But 50% of patients with cochlear implant (n = 10) demonstrated absent VEMP responses on the side of implantation. Of these, only two patients (10%) demonstrated absent VEMP responses on both sides.

This result was consistent with previously reported cases of the effect of cochlear implantation on the VEMP response (5, 11). Saccular function was considered significantly reduced if the VEMP was absent (12). Researchers have indicated that change in saccule response ranges from 30 to 40% following implantation (5, 11).

The cochlear implants may affect the vestibular system (4). There are two problems for vestibular end organs after cochlear implant. One is direct trauma from insertion caused by the electrodes of the cochlear implant (13). Histopathological analysis revealed significant damage to the vestibular end organ in approximately half of the temporal bones after cochlear implant implantation. Cochlear implantation may lead to anatomical changes to additional inner ear structures, particularly the saccule (14). The other problem is that electrical stimulation may affect cochlear nerve, facial nerve and vestibular nerve in patients with a multichannel cochlear implant because of current spread (13, 14). It has been suggested that especially young children may be more at risk for vestibular dysfunction (5). Krause *et al* (15), reported that the cochlear implant represents a significant risk factor for sacculus impairment.

Melvin *et al* (5), explained that five of the 16 post-implanted ears (31%) had either a disappearance of a prior measured VEMP or a > 10 dB increase (worsening) of VEMP threshold. Psillas *et al* (16), found that in the postoperative six-month period, the disappearance of VEMP suggested that the saccule of the children could be extensively damaged following cochlear implantation. Unlike other studies (3, 5, 16), there was no pre-operative VEMP test in our study, thus, pre-implantation VEMP responses of patients cannot be definitively known. Pre-implantation VEMP assessment can help to evaluate the preoperative vestibular condition.

The limitations of our study are the limited number of subjects that participated in the study, only postoperative VEMP was evaluated and not being able to assess the preoperative VEMP responses.

CONCLUSION

The VEMP results showed significant difference between patients with cochlear implant and the control group. Similar results were obtained between the implanted and non-implanted ears of cochlear implant patients. The VEMP test is well tolerated by children. The addition of the VEMP test to the cochlear implantation test battery may provide useful information about the saccular function before and after surgery.

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