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Vestibular evoked myogenic potentials in chronic otitis media before and after surgery

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Abstract

Conclusion. The pathology of chronic otitis media (COM) could delay and reduce the energy transfer of sound to the inner ear. The significant improvement of postoperative vestibular evoked myogenic potential (VEMP) response rate and p13 latencies in the group of patients with no or negative postoperative ABG gain provided evidence that the sound energy inducing a VEMP might be different from the energy producing the auditory perception. *Objective*. To evaluate the VEMP in patients with COM before and after surgery. *Subjects and methods*. Twenty-four subjects with unilateral COM were enrolled. A pure tone audiogram and VEMP using 500 Hz unilateral short tone-burst stimulations were recorded before and 3 months after surgery. The postoperative VEMP responses were compared with the responses before surgery and the healthy controls. *Results*. After surgery, the 500 Hz air–bone gap (ABG) decreased significantly and the VEMP response rate increased significantly from 41.7% to 66.7% ($p < 0.05$, bi-test). However, both the preoperative and postoperative p13 latencies were significantly longer than those of the healthy controls ($p < 0.05$, Wilcoxon rank-sum test). In the 18 patients whose 500 Hz ABG did not improve with surgery, the p13 latencies were significantly shorter postoperatively ($p < 0.05$, sign test), and the response rate also improved significantly from 44.4% (8/18) to 77.8% (14/18) ($p < 0.05$, bi-test).

Keywords: *VEMP, chronic otitis media, air–bone gap, tympanoplasty, ossiculoplasty*

Introduction

Vestibular evoked myogenic potential (VEMP) is a reflex myogenic potential of neck muscles elicited by stimulating the vestibular system with click or tone-burst sound stimuli. The reflex is believed to be sacculocolic conducted through the inferior vestibular nerve [1,2], and the VEMP has also been used clinically to test the vestibular functions in labyrinthine and central vestibular pathologies [3–5].

An acoustically evoked VEMP response is dependent upon a good energy transfer of sound from middle ear to inner ear. The VEMP is presumably absent in the presence of a conductive hearing loss > 20 dB air–bone gap (ABG) [6], although a VEMP response was also elicited in subjects with chronic otitis media (COM) [7]. The degree of ABG did not significantly correlate with the appearance of VEMP response [7]. With regard to the appearance of VEMP, it also remains unclear if the ABG is closed or diminished after surgery for COM. In a previous study, the VEMP responses were significantly affected by middle ear effusion (MEE) [8]. The VEMP response rate was significantly increased and the p13 latencies returned to the normal range after the conductive hearing loss (CHL) was reduced by tympanic aspiration. COM is another middle ear pathology characterized by an eardrum perforation causing various degrees of CHL. However, the middle ear pathology in COM can be removed and reconstructed surgically with tympanoplasty. In this

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study, the VEMP was collected in the COM subjects preoperatively and was compared with the postoperative response. Both the preoperative and postoperative responses were compared with the healthy controls to examine the effects of middle ear pathology on VEMP response.

Subjects and methods

Subjects

Twenty-four subjects (14 male, 10 female) with unilateral COM and/or chronic mastoiditis or cholesteatoma were included in this study. The ages of the subjects ranged from 28 years to 78 years, and the median was 50 years. The right ear was affected in 10 subjects and the left ear in 14 subjects. The age, sex, diagnoses and surgical procedures of the study subjects are shown in Table I.

Methods

A pure tone audiogram (PTA) and VEMP were performed before surgery. Tympanoplasty and/or mastoidectomy were performed for each patient according to the pathological conditions of the middle ear, such as chronic mastoidis and cholesteatoma. An ossiculoplasty modified type III or modified type IV was used to reconstruct the ossicular chain if there was any discontinuity of the ossicles. Three months after surgery, another PTA and VEMP were collected for further analysis. The test battery for each subject included otoscopy, a preoperative PTA, a preoperative VEMP, a postoperative PTA and a postoperative VEMP. The 500 Hz ABG was defined as the difference between air-conduction and bone-conduction hearing threshold levels at 500 Hz.

Acquisition of VEMPs

The subjects were instructed to lie in a supine position during VEMP recording. The electrodes were fixed at the upper half of each sternocleidomastoid muscle, and the reference electrodes were fixed at the lateral ends of the sternum notch. The ground electrode was placed on the subject's forehead. The subjects were instructed to raise their head unsupported during recording. The sound stimuli (500 Hz rarefaction short tone burst, 2 ms rise/fall, 2 ms plateau) were conducted to the ear monoaurally at the rate of 5 Hz with an insertion-type earphone. The electromyographic signals were amplified (gain = 5000) and collected with a band-pass filter (30–2000 Hz) by a digital system (model Navigator Pro Loader Ver. 3.00, Bio-Logic System Corp., Mundelein, IL, USA). The analysis time was 53.3 ms. The responses to 64 stimuli were averaged for 1 trial, and 2 trials were acquired for 1 complete test. The latencies of p13 and n23 of the two trials were averaged to represent the latencies of each test,

Table I. Age, sex, diagnosis and surgical procedures of the study subjects.

Age (years)	Sex	Side	Diagnosis	Surgical procedure
76	M	R	COM with chronic mastoiditis	Tympanoplasty modified type III
64	F	L	COM with chronic mastoiditis	Tympanoplasty modified type III
49	M	R	COM with chronic mastoiditis	Tympanoplasty modified type III
33	M	L	Cholesteatoma	Tympanoplasty modified type III + mastoidectomy
49	F	L	COM with chronic mastoiditis	Tympanoplasty modified type III
38	F	L	Cholesteatoma	Tympanoplasty modified type III + mastoidectomy
70	F	L	COM with chronic mastoiditis	Tympanoplasty modified type III
77	M	L	COM with chronic mastoiditis	Tympanoplasty modified type III
65	F	L	COM	Tympanoplasty type I
78	M	L	COM with chronic mastoiditis	Tympanoplasty modified type IV
47	M	R	Cholesteatoma	Tympanoplasty modified type III + mastoidectomy
53	M	R	Cholesteatoma	Tympanoplasty modified type III + mastoidectomy
68	M	R	COM	Tympanoplasty type I
28	F	L	COM	Tympanoplasty type I
41	F	L	COM	Tympanoplasty type I
52	M	R	COM	Tympanoplasty type I
44	M	L	COM	Tympanoplasty type I
55	M	R	COM	Tympanoplasty modified type III
56	M	L	COM	Tympanoplasty type I
62	M	R	COM	Tympanoplasty type I
50	F	L	Cholesteatoma	Tympanoplasty modified type III + mastoidectomy
48	M	R	Cholesteatoma	Tympanoplasty modified type III + mastoidectomy
36	F	R	COM	Tympanoplasty type I
50	F	R	Cholesteatoma	Tympanoplasty modified type III + mastoidectomy

M, male; F, female; R, right; L, left; COM, chronic otitis media.

and the maximum of the p13–n23 amplitudes of the two trials was assigned as the amplitude of the test.

The VEMP asymmetry ratio (VAR) was calculated as $100 \times [(Au - Aa)/(Aa + Au)]$, where Au is the amplitude of p13–n23 on the unaffected side and Aa is the p13–n23 amplitude on the affected side. The VAR was expressed as a percentage.

The latency of p13 for the 23 healthy control subjects (11 male and 12 female, aged 18–50 years) at our laboratory was 12.98 ± 1.13 ms (mean ± 2 SD), and the latency of n23 was 19.46 ± 4.80 ms. The p13–n23 amplitude of the healthy controls was 142.7 ± 74.9 μV, and the VAR of the healthy controls was $15\% \pm 10\%$. The hearing thresholds of the healthy control were <25 dB HL at the frequencies of 250, 500, 1000, 2000, 4000 and 8000 Hz. There was no medical history of hearing loss, vertigo attack, hypertension, diabetes or neurological diseases for the healthy volunteers.

Statistical analysis

The preoperative and postoperative p13 latencies of COM were compared with the healthy controls using the Wilcoxon rank-sum test. The preoperative p13 latencies and ABG were compared with the postoperative latencies and ABG using sign tests, respectively. The preoperative and postoperative VEMP response rates were compared with the bi-test. The VEMP response rates between various degrees of conductive hearing loss were tested with Fisher's exact test. Statistical significance was assumed for $p < 0.05$. The software used for statistical analysis was STATA for Windows Release 8.0, StataCorp., College Station, TX, USA. Values are expressed in mean $\pm$ SE or mean $\pm$ SD.

Results

After tympanoplasty, the hearing thresholds improved significantly ($p < 0.05$, sign test), and the 500 Hz ABGs also improved significantly from 38.1 to 31.7 dB ($p < 0.05$, sign test). The preoperative VEMP response rate was 41.7% (10/24) and was significantly lower than the postoperative response rate of 67.7% (16/24) ($p < 0.05$, bi-test). Comparing with the control subjects, the preoperative p13 latency (14.70 ± 3.66 ms, mean $\pm$ SD) and postoperative p13 latency (14.96 ± 4.15 ms, mean $\pm$ SD) were significantly longer in the subjects with COM ($p < 0.05$, Wilcoxon rank-sum test).

To explore the relationship between ABG and VEMP response, the subjects were divided into two groups using 500 Hz ABG of 30, 35 and 40 dB HL for comparisons. Preoperatively and postoperatively, the VEMP response rate was not significantly different between the group of patients with ABG <30 dB HL and the group with ABG ≥ 30 dB HL ($p > 0.05$, Fisher's exact test). Neither was there a significant difference between the VEMP response rate of ABG <35 dB HL and ABG ≥ 35 dB HL ($p > 0.05$, Fisher's exact test), and the VEMP response rate of ABG <40 dB HL and ABG ≥ 40 dB HL ($p > 0.05$, Fisher's exact test), both preoperatively and postoperatively. The results are summarized in Table II.

Because of the chronic infections of middle ear in COM with chronic mastoiditis and/or cholesteatoma, the ABG is not easily closed and may even become greater after surgical procedures such as tympanoplasty, mastoidectomy and/or ossiculoplasty. The postoperative hearing gain was usually a little more than 10 dB HL [9,10]. The preoperative and postoperative audiograms and VEMPs of a study subject with left-sided COM and chronic mastoiditis showing no significant hearing gain by surgery are illustrated in Figure 1. The hearing threshold levels were not significantly changed postoperatively, and a typical VEMP response was observed in the unaffected ear (right ear) before tympanoplasty (Figure 1B) and after tympanoplasty (Figure 1D). However, before surgery, the VEMP response was absent for the affected ear (left ear) (Figure 1A), and a VEMP response appeared (Figure 1C) after surgery, although the p13 latencies were still longer than those of the healthy individuals.

Table II. Correlations between the case number of VEMP appearance and 500 Hz air–bone gap (ABG).

	Preoperative			Postoperative		
ABG (dB HL)	VEMP+	VEMP−	*p* value	VEMP+	VEMP−	*p* value
≥30	6	12		7	5	
<30	4	2	0.17	9	3	0.33
≥35	3	8		5	5	
<35	7	6	0.19	11	3	0.15
≥40	3	8		4	3	
<40	7	6	0.19	12	5	0.43

VEMP+, appearance of VEMP response; VEMP−, absent VEMP response. Fisher's exact test was used.

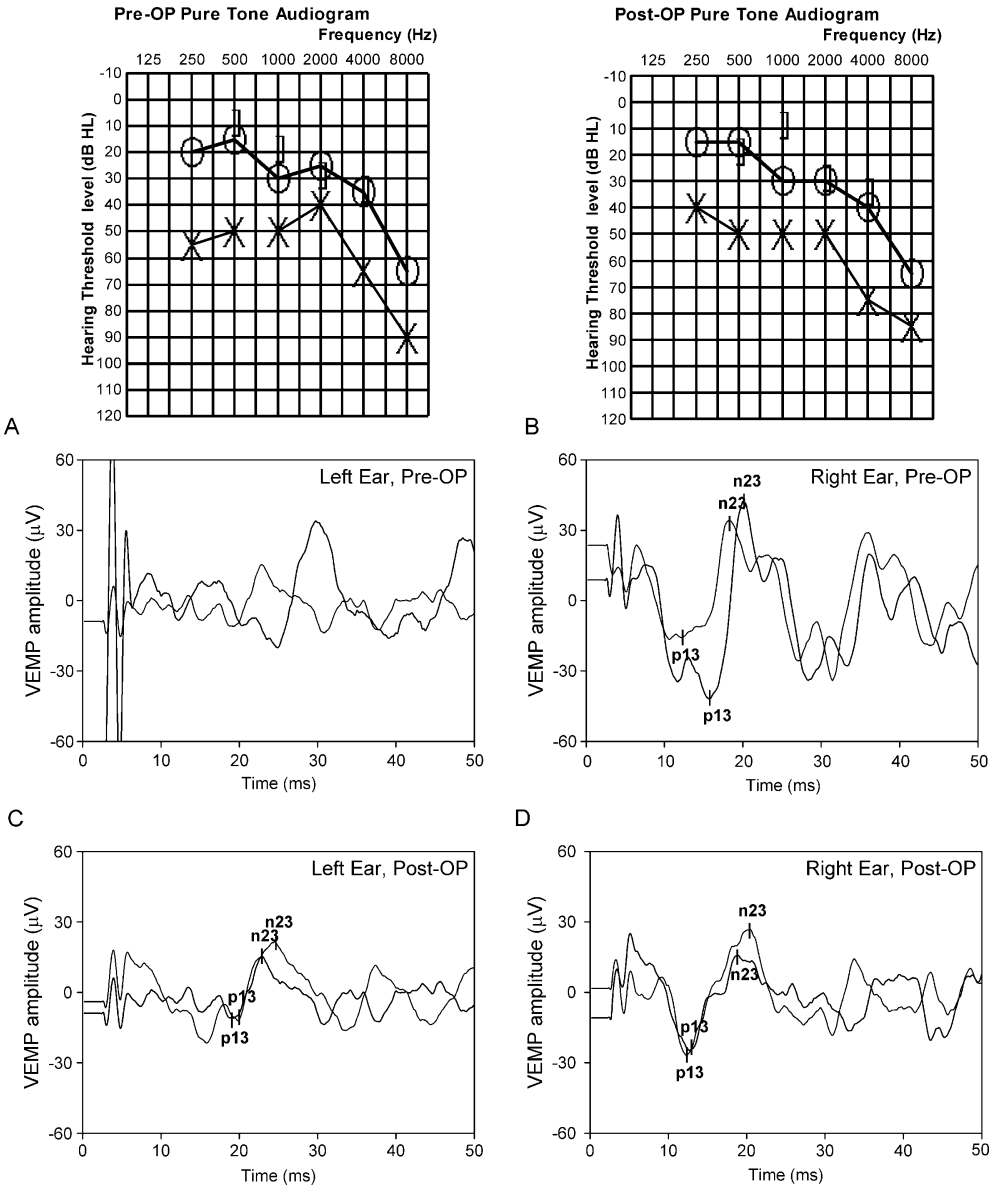

Figure 1. The preoperative and postoperative pure tone audiograms and vestibular evoked myogenic potentials (VEMPs) of a study subject with left-sided chronic otitis media (COM) before (A, B) and after tympanoplasty (C, D). O, X, right and left air conduction level;], left bone conduction level.

Among all subjects, 18 patients had a 500 Hz ABG difference (preoperative ABG – postoperative ABG) of $\leq$10 dB HL (Figure 2). For these 18 patients, the preoperative 500 Hz ABG was not significantly different from the postoperative 500 Hz ABG ($p = 0.21$, sign test). However, the preoperative p13 latencies were still longer than those of the healthy controls ($p < 0.05$, Wilcoxon rank-sum test), and the p13 latencies significantly shortened postoperatively ($p < 0.05$, sign test). In addition, the VEMP response rate improved significantly from 44.4% (8/18) to 77.8% (14/18) after surgery ($p < 0.05$, bi-test), although there was no significant improvement in 500 Hz ABG.

Discussion

In this communication, the preoperative and postoperative VEMPs of the subjects with COM were collected to investigate the effects of surgery on VEMP. The mean hearing threshold level and 500 Hz ABG improved significantly with surgery. Accordingly, the VEMP response rate increased significantly from 41.7% to 66.7% with surgery. However, the p13 latency was significantly longer than in the healthy individuals both preoperatively and postoperatively, although the latency delay was usually reported in the patients with brainstem lesions [11]. In addition, the amount of ABG did not correlate significantly with the appearance of

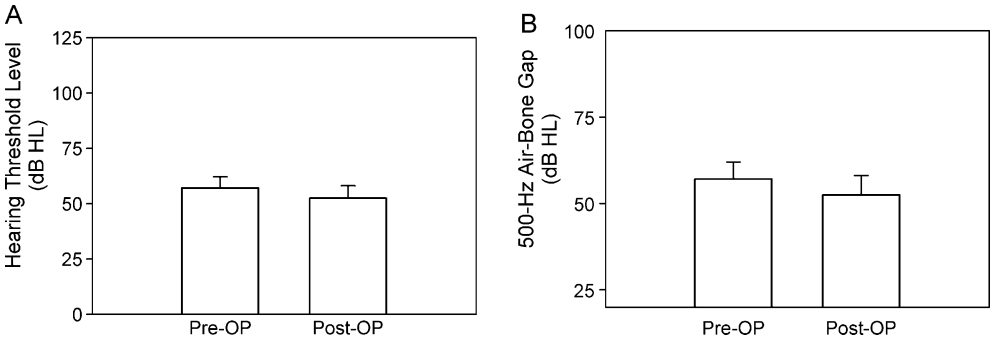

Figure 2. The hearing threshold level and 500 Hz air–bone gap (ABG) of the subjects with no or negative postoperative ABG gain before and after tympanoplasty for chronic otitis media (COM). There was no significant difference between preoperative and postoperative hearing threshold level and 500 Hz ABG ($p > 0.05$, sign test).

VEMP. Besides, the VEMP response rate of the subjects showing no postoperative improvement of 500 Hz ABG also increased significantly with surgery. The energy transfer of sound to elicit a VEMP may be different from the energy transfer to elicit auditory perceptions.

Typically, a successful sound-induced VEMP depends on a good energy transfer from the middle ear to the inner ear. The VEMP is believed to be absent in the presence of a conductive hearing loss with ABG of >20 dB [6]. Yang and Young observed positive VEMP responses in 59% of the subjects with COM using ipsilateral tone-burst stimulations. They concluded that neither tympanic membrane perforation nor 500 Hz ABG would predict the presence of VEMP response [7]. In addition, the p13 and n23 latencies of the affected ears were not significantly different from the latencies of the contralateral healthy ear. However, the VEMP response of the non-responsive subjects remains unclear if the middle ear pathology is removed and reconstructed with surgery.

In this study, the preoperative VEMP responses of the subjects with COM were either non-responsive or significantly delayed. More importantly, although the VEMP response rate and 500 Hz ABG were significantly improved with surgery, the postoperative p13 latencies of the VEMP responsive subjects remained longer than in the healthy controls, even though there was a trend of latency shortening after the ear surgery. In a previous study discussing the VEMP responses in subjects with middle ear effusion (MEE) [8], the VEMP responses were either non-responsive or significantly delayed in the existence of MEE. However, after the middle ear fluid was cleared by tympanic aspiration, the latencies and VAR returned to the range of the healthy controls. The recovery of VEMP response was prompt and immediate after the middle ear fluid was removed.

The latency delay in postoperative COM is persistent, although the ABG was significantly decreased. This may imply a persistent pathology that delays energy transfer of acoustic stimulus to the saccule resulting from chronic inflammation of otitis media. Besides, the appearance of VEMP response was not significantly correlated with the amount of ABG preoperatively and postoperatively. It is deduced that the pathology of COM that delays the VEMP response is not the same as the pathology that reduces hearing acuity and presents as an ABG.

In the 18 subjects with no or negative gain of 500 Hz ABG, the p13 latencies decreased significantly and the VEMP response rate increased significantly from 44.4% to 77.8% postoperatively. The significant improvement of postoperative p13 and VEMP response rate in these subjects implies that a reconstructed middle ear transfers more energy for VEMP than auditory perceptions. The sound energy of lower frequencies can stimulate the vestibular system although they might not result in auditory perception.

Conclusion

The VEMP response is significantly affected by the middle ear pathology of COM. The VEMP was either non-responsive or significantly delayed both preoperatively and postoperatively, although the 500 Hz ABG was significantly reduced after surgery. The persistent delay of postoperative p13 latencies and insignificant correlation between appearance of VEMP and 500 Hz ABG may imply a pathology of COM that delays but does not reduce the energy transfer of sound stimulus to the inner ear. The significant improvement of VEMP response in the subjects with no or negative postoperative gain of 500 Hz ABG also suggests that the sound energy transfer inducing a VEMP could be different from the energy transfer producing an auditory perception.

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