AIR- AND BONE-CONDUCTION VESTIBULAR EVOKED MYOGENIC POTENTIALS IN CHRONIC SUPPURATIVE OTITIS MEDIA, PRE- AND POST-OPERATIVELY

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Abstract

Background: Vestibular evoked myogenic potentials (VEMPs) are reflex myogenic potentials of the neck muscles elicited by stimulating the vestibular system with a click or tone burst sound stimulus. VEMP responses depend on good energy transfer of sound from the middle ear to the inner ear and are presumed absent in the presence of a conductive hearing loss (CHL) of more than 20 dB air-bone gap (ABG). The aim of this study was to evaluate VEMPs in patients with chronic suppurative otitis media (CSOM) before and after surgery.

Material and methods: The study was conducted on 20 patients with CSOM preoperatively and postoperatively and on 20 controls. Their ages ranged from 20 to 50 years. Each subject underwent history taking, otologic examination, basic audiological evaluation, and air- and bone-conducted VEMP testing.

Results: All perforated ears showed a lost air conduction VEMP response pre-operatively without any post-operative improvement. This can be attributed to the absence of any statistically significant differences between the pre-operative and post-operative ABGs at all tested frequencies. Bone conduction VEMP was preserved in all CSOM cases pre-operatively and post-operatively. There were no statistically significant differences between the air conduction and bone conduction VEMP parameters in the controls except for a significantly smaller P13–N23 amplitude of bone conduction VEMP compared to air conduction VEMP. There was no statistically significant differences between the pre-operative perforated ears of CSOM cases and their controls regarding bone conduction P13, N23 latencies, or P13–N23 amplitude. There was a significantly delayed P13 latency and greater P13–N23 amplitude of bone conduction VEMP post-operatively compared to pre-operatively. But there was no statistically significant difference between pre-operative and post-operative bone conduction N23 VEMP latency or interaural amplitude difference. Bone conduction VEMP results were pre-operatively affected by the ABG and bone conduction, but not post-operatively.

Conclusions: Air conduction VEMP in patients with CSOM showed a zero-percent response rate pre-operatively that did not change post-operatively, whereas bone conduction VEMP showed a 100% response rate pre- and post-operatively. We therefore recommend using bone rather than air conduction VEMP for assessment of the sacculo-collic reflex in patients with CSOM who complain of balance problems.

Keywords: hearing loss • conductive • otitis media • suppurative • vestibular evoked myogenic potentials

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ESTUDIO DE LOS POTENCIALES VESTIBULARES MIOGÉNICOS EVOCADOS PARA LA CONDUCCIÓN AÉREA Y ÓSEA EN LA OTITIS MEDIA CRÓNICA SUPURATIVA ANTES Y DESPUÉS DE LA INTERVENCIÓN CIRÚGICA

Resumen

Introducción: Los potenciales vestibulares miogénicos evocados (VEMP) son potenciales miogénicos automáticos de los músculos cervicales que aparecen a consecuencia de la estimulación del sistema vestibular con un chasquido o un tono corto. Una buena transferencia de la energía de la señal acústica del oído medio al oído interno influye en las respuestas de VEMP.

Se supone, que las respuestas VEMP no aparecen en el caso de la pérdida auditiva de conducción en la reserva coclear (ABG) superior a 20 dB. El objetivo de este estudio es la evaluación de VEMP en los pacientes con la otitis media crónica supurativa (CSOM) antes y después de la cirugía.

Materiales y métodos: El estudio ha sido realizado en 20 pacientes con CSOM antes y después de la intervención cirúgica y en un grupo de control de 20 personas. La edad de los participantes de la prueba es de 20 hasta 50 años. Se ha realizado el historial médico de cada participante, y todos han sido sometidos a los exámenes otológicos, evaluaciones audiológicas y las pruebas VEMP para la conducción aéra y ósea.

Resultados: Todos los oídos con una perforación de la membrana timpánica han demostrado una pérdida de respuesta VEMP para la conducción aérea, sin mejoría después de la intervención cirúgica. Esta situación está relacionada con la falta de una diferencia estadísticamente significativa entre el ABG antes y después de la cirugía para todas las frecuencias estudiadas. Los potenciales VEMP para la conducción ósea han sido conservados en todos los casos de CSOM antes y después de la cirugía. No se han observado diferencias estadísticamente significativas entre los parámetros VEMP para la conducción aérea y ósea en el grupo de control, a parte de una amplitud mucho menor P13–N23 para VEMP para la conducción ósea en compraración con VEMP para la conducción aérea. No se han producido diferencias estadísticamente significativas en referencia a la conducción ósea P13, latencia N23 y la amplitud P13–N23 entre el oído con la perforación de la membrane timpánica antes de la opración entre el grupo con CSOM y el grupo de control. Se ha observado una latencia P13 considerablemente retrasada y una mayor amplitud P13-N23 VEMP para la conducción ósea después de la cirugía en comparación con la situación anterior a la cirugía. Sin embargo, no se han observado diferencias estadísticamente significativas entre la latencia N23 VEMP para la conducción ósea antes y después de la cirugía, ni la diferencica en la amplitud interaural. ABG y la conducción ósea afectan los resultados de VEMP para la conducción ósea en el caso previo a la cirugía, pero no después de ella.

Conclusiones: VEMP para la conducción aérea en los pacientes con CSOM han demostrado una tasa de respuesta zeroporcentual antes de la operación y esta no ha cambiado después de la cirugía; sin embargo, VEMP para la conducción ósea ha demostrado una tasa de cien por ciento, tanto antes, como y después de la cirugía. Por lo tanto, para evaluar el reflejo de sáculo a cervicales en los pacientes con CSOM, que aquejan problemas de coordinación, se recomienda utilizar VEMP para la conducción ósea (y no aérea).

Palabras clave: pérdida auditiva de conducción • otitis media crónica supurativa • potenciales vestibulares miogénicos evocados

ТЕСТ ВЫЗВАННЫХ ВЕСТИБУЛЯРНЫХ МИОГЕННЫХ ПОТЕНЦИАЛОВ ДЛЯ ВОЗДУШНОЙ И КОСТНОЙ ПРОВОДИМОСТИ ПРИ ХРОНИЧЕСКОМ ГНОЙНОМ СРЕДНЕМ ОТИТЕ ДО И ПОСЛЕ ОПЕРАЦИИ

Изложение

Введение: Вызванные вестибулярные миогенные потенциалы (VEMP) это миогенные рефлекторные потенциалы мышц шеи, возникающие в результате стимуляции вестибулярного аппарата с помощью щелчка или короткого тона. Хорошая передача энергии звукового сигнала из среднего во внутреннее ухо оказывает влияние на ответы VEMP. Предполагается, что ответы VEMP не появляются в случае кондуктивной тугоухости при улитковом резерве (ABG), превышающем 20 дБ. Целью данного исследования является оценка VEMP у пациентов с хроническим гнойным средним отитом (CSOM) до и после хирургической процедуры.

Материал и методы: Исследование было проведено на 20 пациентах с CSOM до операции и после нее, а также на состоящей из 20 человек контрольной группе. Возраст лиц, принимающих участие в исследовании, составлял от 20 до 50 лет. У каждого отдельного участника был собран анамнез, а также каждый участник был подвергнут отологическому осмотру, аудиологическим оценкам и исследованиям VEMP для воздушной и костной проводимости.

Результаты: Все уши с перфорацией барабанной перепонки проявляли потерю ответов VEMP для воздушной проводимости без улучшения после операции. Это состояние вещей связано с отсутствием статистически значимых различий между ABG до и после операции на всех исследуемых частотах. Потенциалы VEMP для костной проводимости сохранились во всех случаях CSOM как до, так и после операции. Не было отмечено статистически значимых различий между параметрами VEMP для воздушной и костной проводимости в контрольной группе кроме значительно меньшей амплитуды комплекса P13–N23 для VEMP для костной проводимости по сравнению с VEMP для воздушной проводимости. Не было отмечено статистически значимого различия для костной проводимости P13, латенции N23 и амплитуда P13–N23 между ушами с перфорацией барабанной перепонки до операции в случае CSOM и контрольной группой. Была отмечена существенно удлиненная латенция P13 и более высокая амплитуда P13–N23 VEMP для костной проводимости после операции по сравнению с ситуацией до операции. Однако не было отмечено статистически значимых различий между латенцией N23 VEMP для костной проводимости до операции и после нее, а также различия в области межушной амплитуды. ABG и костная проводимость оказали влияние на результаты VEMP для костной проводимости в случае до операции, но не после операции.

Результаты: В случае VEMP для воздушной проводимости у пациентов с CSOM был отмечен нулевой показатель для ответов до операции и результаты не изменились после операции, зато в случае VEMP для костной проводимости был отмечен стопроцентный показатель как до, так и после операции. Поэтому для оценки саккуло-шейного рефлекса у пациентов с CSOM, которые жалуются на проблемы с равновесием, рекомендуется использовать VEMP для костной (не воздушной) проводимости.

Ключевые слова: кондуктивная тугоухость • гнойный средний отит • вызванные вестибулярные миогенные потенциалы

BADANIE MIOGENNYCH PRZEDSIONKOWYCH POTENCJAŁÓW WYWOŁANYCH DLA PRZEWODNICTWA POWIETRZNEGO I KOSTNEGO W CHRONICZNYM ROPNYM ZAPALENIU UCHA ŚRODKOWEGO PRZED I PO OPERACJI

Streszczenie

Wstęp: Miogenne przedsionkowe potencjały wywołane (VEMP) są miogennymi potencjałami odruchowymi mięśni szyi powstającymi w wyniku stymulacji systemu przedsionkowego za pomocą trzasku lub krótkiego tonu. Dobry transfer energii sygnału dźwiękowego z ucha środkowego do ucha wewnętrznego wpływa na odpowiedzi VEMP. Zakłada się, że odpowiedzi VEMP nie pojawią się w obecności niedosłuchu przewodzeniowego przy rezerwie ślimakowej (ABG) większej niż 20 dB. Celem tego badania jest ocena VEMP u pacjentów z chronicznym ropnym zapaleniem ucha środkowego (CSOM) przed zabiegiem chirurgicznym i po nim.

Materiał i metody: Badanie zostało przeprowadzone na 20 pacjentach z CSOM przed operacją i po niej oraz na 20-osobowej grupie kontrolnej. Wiek osób biorących udział w badaniu to 20 do 50 lat. Z każdą osobą przeprowadzono wywiad chorobowy oraz poddano je badaniom otologicznym, ocenom audiologicznym oraz badaniom VEMP dla przewodnictwa powietrznego i kostnego.

Wyniki: Wszystkie uszy z perforacją błony bębenkowej wykazały utratę odpowiedzi VEMP dla przewodnictwa powietrznego bez poprawy po operacji. Ten stan rzeczy związany jest z brakiem statystycznie istotnej różnicy pomiędzy ABG przed operacją i po niej na wszystkich badanych częstotliwościach. Potencjały VEMP dla przewodnictwa kostnego zostały zachowane we wszystkich przypadkach CSOM przed operacją i po niej. Nie było statystycznie istotnych różnic pomiędzy parametrami VEMP dla przewodnictwa powietrznego i kostnego w grupie kontrolnej oprócz znacząco mniejszej amplitudy P13–N23 dla VEMP dla przewodnictwa kostnego w porównaniu z VEMP dla przewodnictwa powietrznego. Nie było statystycznie istotnej różnicy w kwestii przewodnictwa kostnego P13, latencji N23 oraz amplitudy P13–N23 pomiędzy uszami z perforacją błony bębenkowej przed operacją w przypadkach CSOM a grupą kontrolną. Zaobserwowano istotnie opóźnioną latencję P13 i większą amplitudę P13–N23 VEMP dla przewodnictwa kostnego po operacji w porównaniu z sytuacją przed operacją. Jednakże nie było statystycznie istotnych różnic pomiędzy latencją N23 VEMP dla przewodnictwa kostnego przed operacją i po niej ani różnicy w amplitudzie międzyusznej. ABG oraz przewodnictwo kostne, miały wpływ na wyniki VEMP dla przewodnictwa kostnego w przypadku przedoperacyjnym, ale nie pooperacyjne.

Wnioski: VEMP dla przewodnictwa powietrznego u pacjentów z CSOM wskazały zeroprocentowy wskaźnik odpowiedzi przed operacją i nie zmieniły się po operacji, natomiast VEMP dla przewodnictwa kostnego wskazały stuprocentowy wskaźnik zarówno przed operacją jak i po niej. Dlatego też dla oceny odruchu woreczkowo-szyjnego u pacjentów z CSOM, którzy skarżą się na problemy z równowagą, zaleca się korzystanie z VEMP na przewodnictwo kostne (nie powietrzne).

Słowa kluczowe: niedosłuch przewodzeniowy • ropne zapalenie ucha środkowego • miogenne przedsionkowe potencjały wywołane

Background

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

VEMP responses depend on good energy transfer of sound from the middle ear to the inner ear. The VEMP is virtually absent in the presence of conductive hearing loss (CHL) of more than 20 dB air-bone gap (ABG) [6].

Wang and Lee [7] found that VEMP responses were significantly affected by middle ear effusion (MEE). The VEMP was either non-responsive or significantly delayed. The VEMP response rate significantly increased and p13 latencies returned to the normal range after the CHL was reduced by tympanic aspiration. The VEMP latencies and asymmetry ratios returned to the range of healthy controls. In addition, recovery was prompt and immediate [7].

Chronic suppurative otitis media (CSOM) is defined as a chronic inflammation of the middle ear and mastoid cavity, which presents with recurrent ear discharges or otorrhoea through a tympanic perforation [8]. A VEMP response was also elicited in subjects with chronic otitis media (COM) [9]. The degree of ABG did not significantly correlate with the appearance of a VEMP response [9]. The middle ear pathology in COM can be removed and reconstructed surgically with tympanoplasty. After surgery, the 500-Hz ABG decreased significantly and the VEMP response rate increased significantly from 41.7% to 66.7% [10].

VEMP has been recorded using bone-conducted stimuli [11]. Results of bone-conducted VEMP (B-VEMP) are identical to those of the air-conducted VEMP (A-VEMP), at least in patients without CHL [12]. Bone-conducted stimuli are not affected by pathologic changes in the middle ear; thus, B-VEMP might be useful to evaluate vestibular function even in patients with CHL [12]. B-VEMPs showed high specificity for the presence of vertigo in patients with unilateral COM. The ear with COM showed lower responses than the intact ear in all subjects who had abnormal results [13].

Rationale

VEMP is a good test for evaluating the sacculocolic reflex, but unfortunately the presence of a CHL results in an absent VEMP despite an intact reflex pathway. However, its presence in certain cases of OM raises interest in investigating whether a large ABG in the CHL, or the pathology of the CHL itself before surgery, affect the air-conducted VEMP reflex pathway and whether VEMP reappearance or improved latency after surgery (if ever it does occur) is due to changes in the ABG or due to the healed pathology.

The aim of this study was to evaluate vestibular evoked myogenic potentials (VEMPs) using air- and bone-conducted stimuli in patients with chronic suppurative otitis media before and after surgical management, and to compare the results to controls.

Material and methods

This study included 20 cases and 20 controls. The cases comprised 20 patients having chronic suppurative otitis media (with unilateral and bilateral conductive hearing loss, CHL). Bilateral perforation occurred in 10 of them, 2 had unilateral perforation and an intact graft on the opposite side, and 8 had unilateral perforation and a normal tympanic membrane on the opposite side. Each of the 20 patients then had a single tympanoplasty and the ear that was operated upon was re-tested after surgical intervention. The CSOM group had 20 cases with unilateral and bilateral CHL. However, this was still a homogenous group, as we compared one side only for the cases (i.e. 20 ears with 20 control ears). IAAD was calculated only for those who had unilateral perforation. The cases included 15 females and 5 males while the controls comprised 16 females and 4 males. Their age ranged from 20 to 50 years. The study took place in the Audiology unit, Cairo University Hospitals, from May 2012 to October 2013. Exclusion criteria included any of the following: sensorineural hearing loss or inner ear labyrinthine disease or presence of dizziness or vertigo; conductive hearing loss due to other middle ear pathology; hypertension; diabetes; or neurological disease. Controls were taken from relatives of patients attending the Audiology unit and E.N.T. unit, Cairo University Hospitals. They comprised 20 healthy adult subjects, with normal hearing sensitivity, i.e. their hearing threshold level was <25 dB HL with no history of any general or ear disease. They were well-matched to the cases in terms of age and gender.

All subjects underwent: 1) Full history-taking. 2) Otological examination including otoscopic examination to evaluate the condition of the tympanic membrane and the type of perforation. 3) Basic audiological evaluation: A) *pure tone audiometry (PTA)* to detect air-conduction threshold over the frequency range 250–8000 Hz at octave intervals, and bone-conduction thresholds over the frequency range 500–4000 Hz at octave intervals. The hearing loss was divided according to PTA average into mild (25–40 dBHL); moderate (41–55 dBHL); moderately severe (56–70 dBHL); and severe (71–90 dBHL). CHL was diagnosed when there was an air-bone gap of at least 10 dB at all tested frequencies or a 15 dB or more air-bone gap at one or more tested frequency, provided the bone conduction threshold was better than 25 dBHL at all tested frequencies, otherwise a mixed hearing loss was defined. The amount of air-bone gap was calculated pre and post-operatively. B) *Speech audiometry*: speech reception threshold (SRT), using Arabic spondaic words [14]; and word discrimination score (WDS), using Arabic phonetically balanced words [15]. Audiometry was done in a sound treated room, an Amplisilence Model E, and used a Madsen Itera II clinical diagnostic audiometer, GN Otometrics, Denmark, calibrated according to ANSI S3.6 standards. C) *Immittancemetry for the non-perforated ears*: single-component, single-frequency tympanometry with a probe tone of 226 Hz and testing of the acoustic reflex threshold for the ipsilateral and contralateral elicited reflexes, using pure tones at frequencies of 500, 1000, 2000, and 4000 Hz. This was done using an immittancemeter (Madsen Zodiac 901 tympanometer), calibrated according to ANSI standards. 4) *Vestibular evoked myogenic potentials (VEMPs)* were recorded with a Bio-Logic Navigator Pro (Natus Medical Incorporated, San Carlos, CA, USA) while the subject was in an upright sitting position (before applying electrodes the skin was first cleaned to ensure impedance was less than 5 kΩ). Recording electrodes were placed with the active electrode on the middle-third of the sternocleidomastoid (SCM) muscle of the tested side, the reference electrode was fixed at the suprasternal notch, and the ground electrode was placed on the subject's forehead. The subject was instructed to tense the muscle by turning their chin to the contralateral shoulder during runs of acoustic stimulation, and was instructed to relax inbetween runs to avoid fatigue. BC potentially stimulates both ears, and so BC VEMP is not lateralised to one side; patients were therefore chosen to have symmetrical BC thresholds in both ears to eliminate the possibility of stimulating the better cochlea when recording ipsilateral responses. Stimuli were short tone bursts (1000 Hz, rise/fall time 2 ms, plateau time 2 ms), presented by air conduction through TDH 39 headphones. Bone conducted stimuli were 1000 Hz tone bursts (duration 8 ms, rise/fall time 2 ms), delivered by a bone vibrator radio ear B 71

Table 1. Mean, SD, and range of the air and bone conduction pure tone thresholds (AC and BC in dBHL) and the air-bone gap (ABG) at different frequencies in the perforated ear of the cases pre-and post-operatively

	Pre-op				Post-op				*t*	*p*
	Mean	SD	Min	Max	Mean	SD	Min	Max		
AC threshold										
250 Hz	49.25	16.65	15	80	49.25	15.92	15	70	0	1
500 Hz	47.5	19.09	20	80	46.25	17.54	20	70	0.665	0.514
1000 Hz	40.75	19.01	15	70	41.25	19.12	15	70	–0.261	0.797
2000 Hz	37.00	15.76	10	75	38.5	15.9	15	70	–0.73	0.474
4000 Hz	42.25	13.81	15	70	37.25	14.00	5	60	1.723	0.101
8000 Hz	50.75	22.44	20	100	46.75	22.90	20	100	2.707	0.014
BC threshold										
500 Hz	19.25	7.12	5	30	19.75	7.69	5	35	–0.567	0.577
1000 Hz	14.50	7.05	5	30	16.50	6.90	5	30	–2.629	0.017
2000 Hz	20.00	8.27	5	40	20.25	8.03	5	40	–0.237	0.815
4000 Hz	20.00	7.43	10	40	19.25	7.30	10	40	0.679	0.505
ABG										
500 Hz	28.25	15.41	10	60	26.50	13.39	10	50	0.960	0.349
1000 Hz	26.25	13.85	5	45	24.75	14.19	5	55	0.922	0.368
2000 Hz	17.00	10.81	0	35	18.25	10.67	0	40	–0.773	0.449
4000 Hz	22.25	11.41	0	45	19.50	9.16	0	35	1.636	0.118

placed on the ipsilateral mastoid process of the stimulated ear. Stimuli were presented monaurally at 95 dB nHL for air conduction VEMP and 60 dB nHL for bone conduction VEMP at a frequency of 5 Hz. At least 100 sweeps within the acceptance criteria were averaged, and two trials of averaged signals were obtained at each intensity to ensure reproducibility. The time window for analysis was 50 ms. Response waves were judged as being present or absent. The biphasic P13–N23 wave was defined as an initial positive polarity (P13) occurring at approximately 13 ms after stimulation onset, and a subsequent negative polarity (N23) at nearly 23 ms after stimulus onset. When the biphasic P13–N23 was present, P13 and N23 latencies and P13–N23 peak-to-peak amplitude were assessed. The asymmetry ratio or the inter-aural amplitude difference (IAAD) is the P13–N23 peak-to-peak amplitude difference between the two ears divided by the total amplitude of both ears: IAAD=(R–L)/(R+L). An IAAD >0.36 was considered abnormal. The patients were tested pre-operatively and 3 months post-operatively, while the controls were tested once.

Statistical analyses

The data collected were saved in Excel software on a PC. Data were tabulated and statistically analyzed to evaluate the difference between the groups under study with regard to the various parameters. Calculations were done by means of the statistical software package SPSS version 15 (SPSS Inc., Chicago, IL). For quantitative variables, the statistical analysis included the arithmetic mean and standard deviation. Statistical comparative analyses were made in different groups using the independent *t*-test, paired *t*-test, Chi-square test, and ANOVA test. Pearson correlation coefficient (r) was used for correlations between the essential studied parameters. A difference was considered to be statistically significant (S) when the probability (p) value was ≤0.05 and non-statistically significant (NS) when p was >0.05.

Results

The mean duration of hearing loss was 5.88±4.51 years (ranging from 1–15 years). The mean age of the cases was 29.25±9.98 yrs; the mean age of the controls was 32.55±9.92 yrs. There was no statistically significant difference between the 2 groups with regard to their age (t=–1.049; p=0.30) or gender (χ^2=40.14; p=0.71).

All controls had normal bilateral thresholds at all tested frequencies. All subjects had excellent speech discrimination. All controls and the 8 ears of unilateral CSOM cases had type A tympanograms and normal acoustic reflex thresholds.

Table 1 shows the air and bone conduction pure tone thresholds in (dBHL) and the air-bone gap at different frequencies in the perforated ear of the cases pre-and post-operatively.

Table 2. Mean, SD, and range of the air-bone gap improvement post-operatively at different frequencies in the perforated ear of the cases

Frequency	ABG improvement post-op			
	Mean	SD	Min	Max
500 Hz	5.75	5.911	0	20
1000 Hz	5.00	5.380	0	15
2000 Hz	5.25	4.990	0	20
4000 Hz	4.75	3.800	0	10

Table 3. Distribution of the air-bone gap change post-operatively at different frequencies in the perforated ear of the cases

Air-bone gap change	500 Hz		1000 Hz		2000 Hz		4000 Hz	
	No	%	No	%	No	%	No	%
Decreased	9	45	8	40	10	50	10	50
Increased	5	25	3	15	5	25	4	20
Same	6	30	9	45	5	25	6	30
Total	**20**	**100**	**20**	**100**	**20**	**100**	**20**	**100**

Table 4. Comparison between air conduction and bone conduction VEMP parameters in controls

		Air conduction VEMP		Bone conduction VEMP		*t*	*p*
		Mean	SD	Mean	SD		
P13 latency (ms)	R	13.65	1.25	13.02	1.23	1.580	0.131
	L	13.15	1.29	12.85	1.35	0.694	0.473
N23 latency (ms)	R	21.57	1.86	21.21	1.57	4.688	0.496
	L	21.87	2.55	21.21	1.57	0.733	0.343
P13-N23 amplitude (μV)	R	50.69	31.75	26.32	23.80	0.973	**0.000**
	L	46.38	31.84	27.81	17.21	3.259	**0.004**
IAAD (%)		16.58	8.97	15.14	10.35	0.433	0.670

There were no statistically significant differences regarding the pre-operative and post-operative air or bone conduction pure tone thresholds or air-bone gaps at any of the tested frequencies except for a statistically lower mean air conduction pure tone threshold at 8 kHz post-operatively than pre operatively, but both were in the moderate degree, and a statistically higher mean bone conduction pure tone threshold at 1 kHz post-operatively than pre-operatively but both were within the normal threshold.

Table 2 shows the air-bone gap improvement post-operatively at different frequencies in the perforated ear of the cases. Table 3 shows the distribution of the air-bone gap change post- operatively at different frequencies in the perforated ear of the cases.

Air conduction VEMP

All cases had lost air conduction VEMP in the perforated ear pre-operatively, while all controls had preserved VEMP. None of the cases showed any post-operative appearance of air conduction VEMP.

Our normal values regarding air conduction VEMP were: 13.15±1.29 ms for P13 latency; 21.88±2.55 ms for N23 latency, 46.38±31.84 μV for P13–N23 amplitude, and 16.58±8.97 for the IAAD.

Bone conduction VEMP

There were no statistically significant differences between the air conduction and bone conduction VEMP parameters in the controls except P13–N23 amplitude (Table 4).

Bone conduction VEMP was preserved in all CSOM cases pre-operatively and post-operatively and in the controls. Figure 1 shows air and bone conducted VEMP traces respectively in one in the controls. Figures 2 and 3 show air and bone conducted VEMP traces in one of the cases pre- and post-operatively respectively. Our

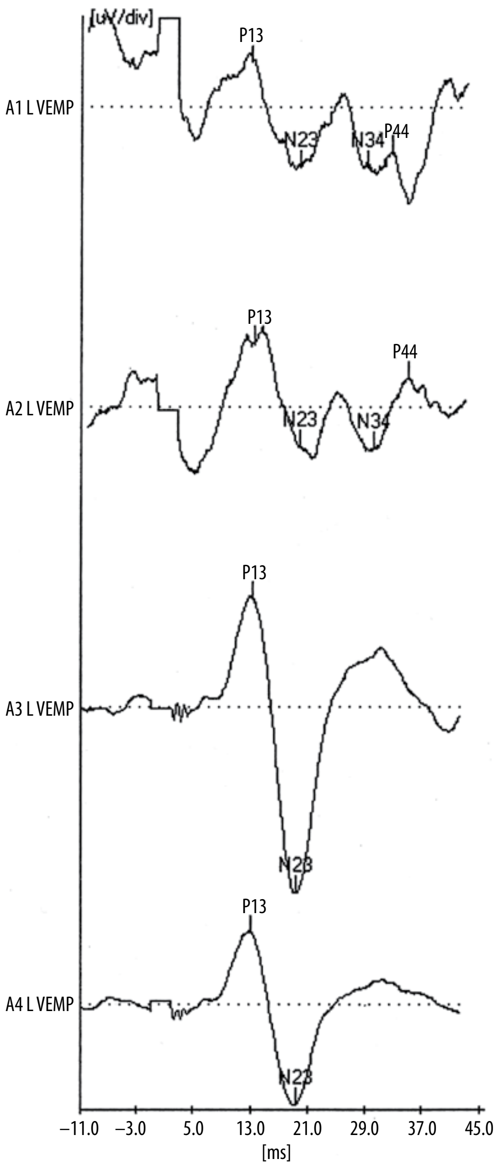

Figure 1. Bone conducted VEMP (traces A1 and A2) and air conducted VEMP (A3 and A4) in one of the controls

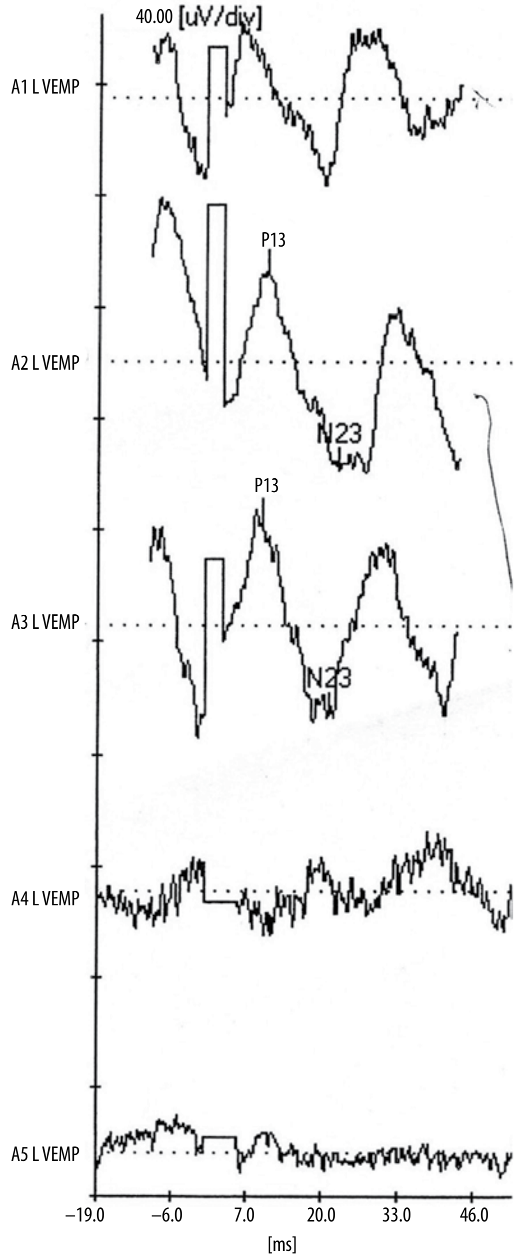

Figure 2. Bone conducted VEMP (traces A1, A2, and A3) and air conducted VEMP (A4 and A5) in one of the cases with chronic otitis media pre-operatively

normal values regarding bone conduction VEMP parametersin the R and L ears are shown in Table 5. In comparison to normative values, 15/20 CSOM patients (75%) had normal bilateral IAAD pre-operatively, 3/20 CSOM patients (15%) had abnormal amplitude in the intact ear, and 2/20 (10%) had abnormal amplitude in the perforated ear.

There was no statistically significant difference between the pre-operative perforated ears of the CSOM cases and their controls regarding bone conduction P13, N23 latencies, or P13–N23 amplitude (Table 5). There was no statistically significant difference between the post-operative perforated ears of CSOM cases and their controls regarding bone conduction P13 or N23 latencies, but the post-operative P13–N23 amplitude was statistically significantly greater than the controls (Table 6).

In CSOM cases there was a statistically significant difference between pre-operative and post-operative bone conduction VEMP P13 latency and P13–N23 amplitude. But there was no statistically significant difference between pre-operative and post-operative bone conduction VEMP N23 latency or IAAD (Table 7).

Effect of perforation site on bone conducted VEMP

The perforation was central in 12 cases, posterior in 4 cases, subtotal in 2 cases, anterior in 1 case, and superior in 1 case. There was no statistically significant difference among the different sites of perforations regarding

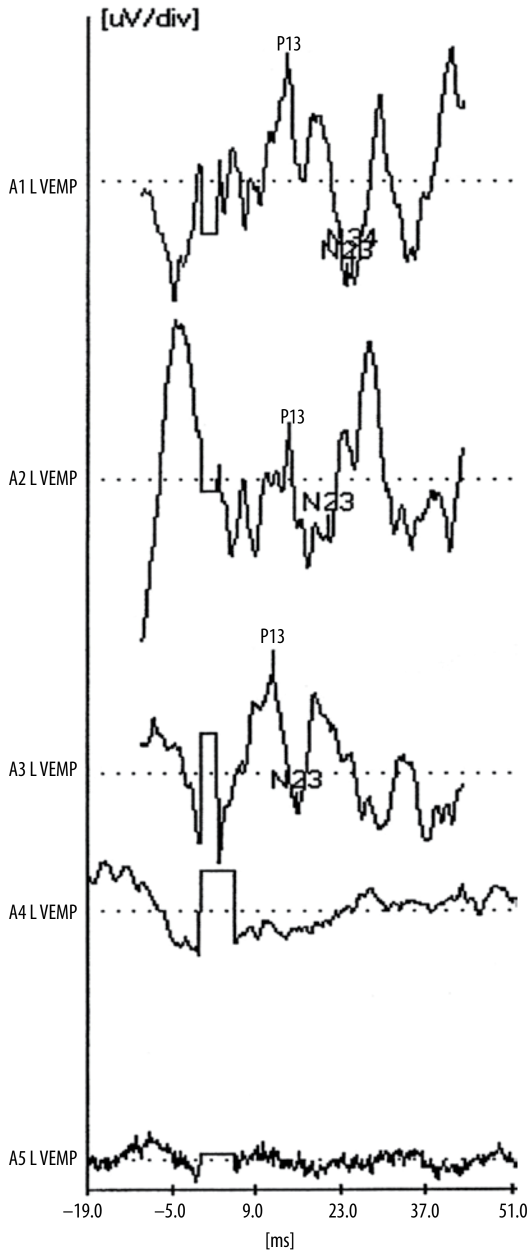

Figure 3. Bone conducted VEMP (traces A1, A2, and A3) and air conducted VEMP (A4 and A5) in the same case with chronic otitis media (Figure 2) post-operatively

P13, N23 latency, or P13–N23 amplitude and the IAAD whether pre- or post-operatively.

Effect of air and bone conduction thresholds and air-bone gap (ABG) on pre-operative bone conducted VEMP

There was no statistically significant difference between the ears with pre-operative 20 or less ABG and ears with greater than 20 ABG at 500, 1000, 2000, and 4000 Hz of the cases regarding P13 latency or P13–N23 amplitude, but there was a statistically significant delayed N23 pre-operative 20 or less compared to ABG greater than 20 dB at 500 Hz (Table 8).

There was no statistically significant difference between the ears with pre-operative 25 dB or less ABG and ears with greater than 25 dB ABG at 500, 1000, 2000, and 4000 Hz of the cases regarding P13 latency, N23 latency, or P13–N23 amplitude of the pre-operative bone conducted VEMP. But there was a statically significant difference between the ears with pre-operative 25 dB or less ABG and ears with greater than 25 dB ABG at 2000 Hz regarding P13–N23 amplitude (Table 9).

There was a statistically significant negative correlation between the air-bone gap at 500 Hz and 4000 Hz and the bone conduction VEMP P13–N23 amplitude pre-operatively. But there were no statistically significant correlations between other pure tone audiogram parameters and the bone conduction VEMP parameters (Table 10).

Effect of air and bone conduction thresholds and air-bone gap (ABG) on post-operative bone conducted VEMP

There was no statistically significant difference between the ears with post-operative 20 dB or less ABG and ears with greater than 20 dB ABG at 500, 1000, 2000, and 4000 Hz of the cases regarding P13 or N23 latency or P13–N23 amplitude of the post-operative bone conducted VEMP (Table 11).

There was no statistically significant difference between the ears with post-operative 25 dB or less ABG and ears with greater than 25 dB ABG at 500Hz of the cases regarding P13 latency, N23 latency, or P13–N23 amplitude of the post-operative bone conducted VEMP (Table 12).

Table 5. Comparison between CSOM cases pre-operatively and R and L ears of controls regarding bone conduction VEMP parameters

Bone conducted VEMP	CSOM patients (*n*=20 ears)		Controls, R ears (*n*=20 ears)		Controls, L ears (*n*=20 ears)		*F*	*p*
	Mean	SD	Mean	SD	Mean	SD		
P13 latency (ms)	12.17	1.61	13.02	1.23	12.73	1.43	1.839	0.168
N23 latency (ms)	20.89	1.81	21.21	1.57	21.47	1.5	0.629	0.537
P13–N23 amplitude (µV)	29.29	19.18	26.32	23.8	27.81	17.21	0.107	0.898

Table 6. Comparison between CSOM cases post-operatively and R and L ears of controls regarding bone conduction VEMP parameters

Bone conducted VEMP	CSOM patients post op. (*n*=20 ears)		Controls Rt ears (*n*=20 ears)		Controls' Lt ears (*n*=20 ears)		*F**	*p*
	Mean	SD	Mean	SD	Mean	SD		
P13 latency (ms)	13.44	0.94	13.02	1.23	12.73	1.43	1.718	0.189
N23 latency (ms)	20.46	2.32	21.21	1.57	21.47	1.50	1.643	0.202
P13–N23 amplitude (µV)	46.50	23.45	26.32	23.8	27.81	17.21	5.374	**0.007**

* F of ANOVA. CSOM patients: R control ears (*t*=2.702; p=**0.010**) for P13–N23 amplitude; CSOM patients: L control ears (*t*=2.874; p=**0.007**) for P13–N23 amplitude

Table 7. Comparison between pre-operative and post-operative bone conduction VEMP parameters in CSOM cases

Bone conducted VEMP	Pre-operative				Post-operative				Paired *t*-test	*p*
	Mean	SD	Min	Max	Mean	SD	Min	Max		
P13 latency (msec)	12.17	1.61	9.78	15.46	13.44	0.94	10.92	14.98	–2.821	**0.011**
N23 latency (msec)	20.89	1.81	17.59	24.15	20.46	2.32	17.17	24.67	0.633	0.534
P13–N23 amplitude (µV)	29.29	19.18	7.18	76.76	46.5	23.45	12.66	92.02	–2.471	**0.023**
IAAD (%)	26.55	17.46	6.39	65.38	40.43	22.45	3.92	73.16	–1.256	0.249

Table 8. Comparison between ABG less than 20 dB and ABG greater than 20 dB at 500, 1000, 2000, and 4000 Hz regarding bone conduction VEMP parameters pre-operatively

Pre-operative bone conducted VEMP	ABG 20 or less		ABG greater than 20		*t*-test	
	Mean	SD	Mean	SD	*t*	*p*-value
At 500 Hz						
P13 latency (ms)	11.69	1.79	12.48	1.47	–1.074	0.297
N23 latency (ms)	22.05	1.56	20.13	1.57	2.68	**0.015**
P13–N23 amplitude (µV)	35.33	18.00	25.26	19.61	1.161	0.261
At 1000 Hz						
P13 latency (ms)	11.72	1.61	12.61	1.56	–1.244	0.23
N23 latency (ms)	21.29	2.11	20.50	1.45	0.978	0.341
P13–N23 amplitude (µV)	34.66	16.24	23.92	21.17	1.273	0.219
At 2000 Hz						
P13 latency (ms)	11.84	1.60	12.93	1.49	–1.431	0.17
N23 latency (ms)	21.06	2.05	20.51	1.13	0.609	0.55
P13–N23 amplitude (µV)	30.21	16.08	27.13	26.78	0.321	0.752
At 4000 Hz						
P13 latency (ms)	11.82	1.66	12.45	1.59	–0.856	0.403
N23 latency (ms)	21.41	1.91	20.47	1.68	1.168	0.258
P13–N23 amplitude (µV)	29.11	12.25	29.43	24.05	–0.036	0.972

Table 9. Comparison between ears with ABG less than 25 dB and ABG greater than 25 dB at different frequencies, regarding the bone conduction VEMP parameters pre-operatively

Pre-operative bone conducted VEMP	ABG 25 dB or less		ABG greater than 25 dB		*t*-test	
	Mean	SD	Mean	SD	*t*	*p*-value
At 500 Hz						
P13 latency (ms)	11.78	1.70	12.48	1.54	–0.961	0.349
N23 latency (ms)	21.62	1.94	20.30	1.52	1.704	0.106
P13–N23 amplitude (µV)	35.69	24.05	16.87	20.09	1.384	0.183
At 1000 Hz						
P13 latency (ms)	11.70	1.53	12.73	1.61	–1.46	0.162
N23 latency (ms)	21.18	2.04	20.55	1.53	0.763	0.455
P13–N23 amplitude (µV)	32.16	17.50	25.78	21.57	0.731	0.474
At 2000 Hz						
P13 latency (ms)	12.02	1.57	12.74	1.87	–0.786	0.442
N23 latency (ms)	20.86	2.01	21.01	0.69	–0.143	0.888
P13–N23 amplitude (µV)	33.57	18.97	12.16	6.38	2.187	**0.042**
At 4000 Hz						
P13 latency (ms)	11.95	1.58	12.67	1.70	–0.913	0.373
N23 latency (ms)	21.31	1.79	19.92	1.58	1.644	0.117
P13–N23 amplitude (µV)	28.71	16.94	30.63	25.46	–0.199	0.845

Table 10. Correlation between the pre-operative air and bone conduction thresholds, and pre-operative air bone gap with VEMP parameters

Pre-operative audiogram parameters	Pre-operative bone conduction VEMP parameters					
	P13 latency (ms)		N23 latency (ms)		P13–N23 amp (µV)	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value
AC at 250 Hz	0.002	0.994	–0.173	0.466	–0.26	0.269
AC at 500 Hz	0.029	0.903	–0.393	0.086	–0.371	0.108
AC at 1000 Hz	0.087	0.717	–0.166	0.485	–0.321	0.167
AC at 2000 Hz	0.091	0.703	–0.199	0.401	–0.248	0.292
AC at 4000 Hz	0.167	0.481	–0.271	0.249	–0.293	0.210
AC at 8000 Hz	0.179	0.45	–0.116	0.626	–0.378	0.100
BC at 500 Hz	–0.12	0.615	–0.271	0.248	–0.453	**0.045***
BC at 1000 Hz	–0.049	0.839	–0.147	0.535	–0.412	0.071
BC at 2000 Hz	0.01	0.966	–0.288	0.218	–0.175	0.459
BC at 4000 Hz	–0.064	0.789	–0.228	0.334	–0.545	**0.013***
ABG at 500 Hz	0.091	0.702	–0.362	0.117	–0.25	0.288
ABG at 1000 Hz	0.144	0.546	–0.152	0.521	–0.231	0.328
ABG at 2000 Hz	0.125	0.601	–0.069	0.771	–0.227	0.336
ABG at 4000 Hz	0.244	0.3	–0.179	0.45	0	0.999

Table 11. Comparison between ABG less than 20 dB and ABG greater than 20 dB at 500 Hz, regarding the bone conduction VEMP parameters post-operatively

Post-operative bone conducted VEMP	ABG 20 dB or less		ABG greater than 20 dB		*t*-test	
	Mean	SD	Mean	SD	*t*	*p*-value
At 500 Hz						
P13 latency (ms)	13.66	0.57	13.21	1.20	1.067	0.300
N23 latency (ms)	20.57	2.47	20.35	2.28	0.208	0.838
P13–N23 amp (µV)	48.13	25.86	44.88	22.05	0.303	0.765
At 1000 Hz						
P13 latency (ms)	13.35	0.92	13.55	1.00	–0.477	0.639
N23 latency (ms)	20.25	2.56	20.71	2.10	–0.435	0.668
P13–N23 amp (µV)	41.50	23.77	52.62	22.88	–1.058	0.304
At 2000 Hz						
P13 latency (ms)	13.31	0.99	13.67	0.86	–0.823	0.421
N23 latency (ms)	20.35	2.54	20.67	2.00	–0.29	0.775
P13–N23 amp (µV)	47.45	22.81	44.75	26.37	0.24	0.813
At 4000 Hz						
P13 latency (ms)	13.38	0.99	13.53	0.92	–0.339	0.738
N23 latency (ms)	20.73	2.62	20.05	1.87	0.638	0.531
P13–N23 amp (µV)	44.36	22.28	49.72	26.32	–0.491	0.629

Table 12. Comparison between ABG less than 25 dB and ABG greater than 25 dB at 500 Hz, regarding the bone conduction VEMP parameters post-operatively

Post-operative bone conducted VEMP	ABG 25 dB or less		ABG greater than 25 dB		*t*-test	
	Mean	SD	Mean	SD	*t*	*p*-value
At 500 Hz						
P13 latency (ms)	13.66	0.57	13.21	1.20	1.067	0.306
N23 latency (ms)	20.57	2.47	20.35	2.28	0.208	0.838
P13–N23 amp (µV)	48.13	25.86	44.88	22.05	0.303	0.765
At 1000 Hz						
P13 latency (ms)	13.45	0.95	13.42	0.99	0.055	0.957
N23 latency (ms)	20.18	2.46	20.88	2.18	–0.658	0.519
P13–N23 amp (µV)	44.59	25.06	49.37	22.13	–0.437	0.668
At 2000 Hz						
P13 latency (ms)	13.31	0.93	13.82	0.95	–1.045	0.310
N23 latency (ms)	20.14	2.42	21.42	1.85	–1.078	0.295
P13–N23 amp (µV)	48.49	25.42	40.53	17.04	0.647	0.526
At 4000 Hz						
P13 latency (ms)	13.30	0.93	13.97	0.90	–1.286	0.215
N23 latency (ms)	20.55	2.54	20.09	1.23	0.349	0.731
P13–N23 amp (µV)	43.71	23.21	57.69	24.10	–1.07	0.299

Table 13. Correlation between the post-operative air and bone conduction thresholds, and post-operative air bone gap with VEMP parameters

Post-operative audiogram parameters	Post-operative bone conduction VEMP parameters					
	P13 latency (ms)		N23 latency (ms)		P13–N23 amplitude (μV)	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value
AC at 250 Hz	0.073	0.758	–0.031	0.898	–0.089	0.710
AC at 500 Hz	0.004	0.987	0.072	0.764	–0.028	0.907
AC at 1000 Hz	0.025	0.917	0.043	0.856	0.210	0.375
AC at 2000 Hz	0.177	0.456	0.209	0.377	0.063	0.793
AC at 4000 Hz	0.218	0.356	0.154	0.518	0.189	0.424
AC at 8000 Hz	0.177	0.456	0.079	0.740	0.029	0.905
BC at 500 Hz	–0.104	0.662	–0.065	0.785	0.036	0.880
BC at 1000 Hz	0.120	0.614	0.085	0.722	0.202	0.394
BC at 2000 Hz	0.009	0.970	0.112	0.638	0.106	0.658
BC at 4000 Hz	0.059	0.804	0.176	0.458	0.067	0.779
ABG at 500 Hz	0.065	0.786	0.132	0.580	–0.057	0.810
ABG at 1000 Hz	–0.025	0.917	0.017	0.943	0.184	0.436
ABG at 2000 Hz	0.257	0.275	0.227	0.337	0.014	0.953
ABG at 4000 Hz	0.092	0.700	0.090	0.705	–0.013	0.956
ABG improvement at 500 Hz	0.136	0.567	0.155	0.513	–0.225	0.341
ABG improvement at 1000 Hz	–0.146	0.539	–0.384	0.095	0.032	0.894
ABG improvement at 2000 Hz	0.280	0.231	–0.058	0.808	0.169	0.478
ABG improvement at 4000 Hz	–0.212	0.369	0.133	0.575	–0.375	0.103

There were no statistically significant correlations between the pure tone audiogram parameters and the bone conduction VEMP parameters post-operatively (Table 13).

Discussion

In our study, the perforated ears showed an average of mild to moderate conductive hearing loss pre-operatively, and an average of mild conductive hearing loss post-operatively. Regarding the distribution of VEMP results, all cases had lost air conduction VEMP in the perforated ear pre-operatively, while all controls had preserved VEMP. Regarding the VEMP parameters, our normal values regarding air conduction VEMP parameters were in accordance with Wang et al. [10] who found that the latency of P13 for a healthy control subject was 12.98±1.13 ms and the latency of N23 was 19.46±4.08 ms.

Halmagyi et al. [6] reported that VEMP responses are typically absent in cases of conductive hearing loss with an air-bone gap greater than 20 dB. Middle ear status can affect the VEMP [16]. Yang and Young [9] observed positive VEMP responses in 59% of subjects with COM using ipsilateral tone burst stimulation. They concluded that neither tympanic membrane perforation nor 500 Hz ABG would predict the presence of a VEMP response. El-Khousht et al. [17] reported that in CHL in patients with CSOM, the percentage of VEMP responses by AC stimulation was 20% (4/20 ears). None of the cases in our study showed any air conducted VEMP response post-operatively. In comparison, Wang et al. [10] found that the preoperative VEMP response of subjects with CSOM was either non-responsive or significantly delayed. With surgery, the VEMP response rate increased significantly from 41 to 67%, although there was no significant improvement in 500 Hz ABG. Wang et al. [10] stated that after tympanoplasty, hearing threshold improved significantly, and the 500 Hz ABG also improved significantly from 38.1 to 31.7 dB. But in our study, there were no statistically significant differences regarding the pre-operative and post-operative air or bone conduction pure tone thresholds at any of the tested frequencies.

Lee et al. [18] found that the VEMP response rate on ipsilateral stimulation was 64% and it increased to 86% after a paper patch was applied. After paper patching, they found a positive correlation between normalizing of VEMP parameters, such as P13 and VEMP asymmetry ratio, and reduction of air-bone gap in patients with COM. The VEMP response in patients with COM with intact ossicles and clean mucosa was more normalized compared with those in patients with COM with different middle ear conditions. VEMP responses require good energy transfer to the inner ear, meaning that an intact middle ear is necessary [18]. Lee et al. [18] defined the small-to-moderate-sized group as those patients having a perforation size of less than 50% relative to the entire TM, and large-sized group as patients having a perforation greater than 50%. They found that VEMP parameters did not show any significant change after paper patching in the small to- moderate-sized perforation group. However, in the patients with large-sized perforations, the P13 latency significantly decreased.

Wang and Lee [7] concluded that the VEMP responses were significantly affected by middle ear dysfunction of middle ear effusion. The VEMP was either non-responsive or significantly delayed, and the VEMP asymmetry ratio was significantly increased. However, after middle ear effusion was cleared, the VEMP latencies and asymmetry ratio returned to the range of healthy controls. The recovery of VEMP response was prompt and immediate after middle ear pathology was removed.

This disagrees with our results, which show no air conduction VEMP pre-operatively or post-operatively. The absence of VEMP response in our cases pre-operatively may be due not only to middle ear pathology, but the presence of an air-bone gap still abolished the air conduction VEMP pre and post-operatively.

In our study, there were no statistically significant differences regarding the pre-operative and post-operative air-bone gaps at any of the tested frequencies. But there were air-bone gap improvements varying between 4.75 and 5.75 dB. However comparing individual cases, improvement of ABG was found in 40–50% of cases at different frequencies.

In our study, we have excluded any patients complaining of vertigo or dizziness, to exclude that the saccule has been affected by middle ear pathology, in order to study the effect of conductive pathology only on the VEMP. Despite that surgery had corrected the chronic suppurative otitis media, in our study the remaining air-bone gap post-operatively also abolished the air conduction VEMP. So the large ABG in the CHL, and not the pathology of the CHL itself before surgery, affected the air-conducted VEMP reflex pathway.

Wang et al. [10] stated that because of chronic infections of the 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.

COM can lead to cochlear damage and SNHL [19,20]. The mechanism is believed to be that middle ear inflammatory mediators damage the inner ear through the round window and oval window [21]. The saccule is anatomically nearer the oval window than the cochlea and the semicircular canal, therefore VEMP is influenced to a greater extent in advanced COM [13].

Ho et al. [22] found that 73% of patients with unilateral simple COM had abnormal VEMP test results. They demonstrated through vestibular function tests that most patients with COM suffered from vestibular abnormalities; however, there was no significant correlation between the results of vestibular function tests and symptoms of dizziness/vertigo. It was suspected that the mechanism of central compensation occurred due to the chronic process of otitis media. In consequence, patients with COM did not suffer from an episode of dizziness/vertigo despite the abnormal vestibular function test results.

Bone conduction VEMP was preserved in all CSOM cases pre-operatively and post-operatively and in controls. Bone conduction VEMP results in our study controls agreed with Seo et al. [13] who showed that bone conduction VEMP (B-VEMP) response could be recorded in all subjects in their control group, where the mean latency of the P13 wave was 15.6 ms (SD 2.0), and that of N23 was 23.6 ms (SD 2.1). The mean IAR was 16.6% (SD 12.1); thus, the upper limit of the normal range of IAR was defined as 40.7%.

Seo et al. (13) found that the P13–N23 biphasic wave of B-VEMP was detected in all intact ears but not detected in 10 of 25 COM ears (40%) in the disequilibrium group, and 52% of the disequilibrium group showed abnormal results. Subjects showing abnormal B-VEMP results complained of balance problems. They stated accordingly that B-VEMP has a high specificity for balance problems and that B-VEMP can be used to evaluate vestibular function, even in patients with CHL. Seo et al. [13] found that there was no difference between the COM ear and intact ear in the mean latency of the P13 and N23 waves and peak-to-peak amplitude of bone conduction VEMP in the non-disequilibrium group.

El-Khousht et al. [17] reported that in CHL in patients with CSOM, a response percentage of present VEMP waves by BC stimulation increased compared to AC VEMP, to 75% (15/20 ears) with no significant difference in latency from healthy ears.

VEMPs have been recorded using bone conduction stimuli [11]. Miyamoto et al. [12] have reported that results of bone conduction VEMP are identical to those of air conduction VEMP, at least without CHL. Similarly, in our study, there was no statistically significant difference between the air conduction and bone conduction VEMP parameters in the controls except for statistically significant smaller P13–N23 amplitudes of bone conduction VEMP compared to air conduction VEMP.

Comparison between pre-operative and post-operative bone conduction VEMP parameters in CSOM cases revealed that there was a statistically significant delayed P13 latency and statistically significant greater P13–N23 amplitude post-operatively. But there was no statistically significant difference between pre-operative and post-operative bone conduction VEMP N23 latency. Improvement in amplitude could reflect the osseo-tympanic bone conduction theory whose effectiveness was increased by the tympanic membrane grafting surgery increasing the energy transfer by bone conduction to the saccule. And IAAD in the unilateral CSOM cases did not statistically significant differ pre-operatively compared to post-operatively.

P13 and N23 latencies or P13–N23 amplitudes in this study did not differ in a statistically significant way between controls and the pre-operative perforated ears of CSOM cases. This reflects that bone conducted VEMP can be well used in CSOM cases as it is not affected by middle ear pathology.

There was a statistically significant difference between pre-operative IAAD of the unilateral CSOM patients and the controls. Although the post-operative bone conduction VEMP P13–N23 amplitude was statistically significantly greater post-operatively than pre-operatively, the bone conduction VEMP IAAD in the unilateral CSOM patients did not change post-operatively. This reflects the stability of bone conduction VEMP.

In our study, there were no statistically significant differences among the different sites of perforations whether central, posterior, anterior, subtotal, or superior regarding P13 and N23 latencies or P13–N23 amplitude and the IAAD whether pre- or post-operatively.

There was a statistically significant delayed N23 latency with pre-operative ABG 20 dB or less compared to ABG greater than 20 dB at 500 Hz and statistically significant greater P13–N23 amplitude with pre-operative 25 dB or less ABG compared to ABG greater than 25 dB at 2000 Hz. As the bone conduction thresholds at 500 Hz and 4000 Hz were smaller (better), the bone conduction VEMP P13–N23 amplitude was larger pre-operatively. ABG and bone conduction thresholds had no effect on post-operative bone conducted VEMP.

In this study, the pre-operative VEMP results were associated with the worse ABG and bone conduction thresholds, but the absence of such a correlation post-operatively reflects the osseo-tympanic bone conduction mechanism, the effectiveness of which was diminished by tympanic membrane perforation but corrected by surgery.

In comparison to our results, Trivelli et al. [23] have reported that, pre-operatively, AC- and BC-VEMPs could be recorded in 9 (21.4%) and 16 (38.1%) of otosclerotic ears respectively in ears with mean ABG of 27.2 (±0.3) dBHL. Lower ABG was detected in patients with AC-VEMPs in comparison to those in whom air-conducted potentials (p=0.032) could not be elicited. At 12-month post-operative follow-up, AC-VEMPs were present in 11 (26.2%) ears, while BC-VEMPs could be elicited in 15 (35.7%) cases. Reduced bone-conduction 4-frequency pure tone average (4-PTA) at 500, 1000, 2000, and 3000 Hz was observed in patients with BC-VEMPs in comparison to those without recordable bone-conducted potentials pre- and post-operatively (p=0.003 and 0.005, respectively). A significantly lower (p=0.022) air-conducted 4-PTA was measured post-stapedotomy in patients with BC-VEMPs in comparison to those without elicitable bone-conducted potentials. They concluded that reduced elicitability of VEMPs in otosclerosis is likely due to CHL and inner ear impairment.

Conclusions and recommendations

All the perforated ears showed lost air conduction VEMP pre-operatively, which remained absent post-operatively. Bone conduction VEMP was preserved in all CSOM cases pre-operatively and post-operatively. There was no statistically significant difference between the pre-operative perforated ears of CSOM cases and their controls regarding bone conduction P13 and N23 latencies or P13–N23 amplitudes. There was a statistically significant delayed bone conduction P13 latency and statistically significant greater P13–N23 amplitude, but not bone conduction VEMP N23 latency post-operatively compared to pre-operatively. The different sites of perforations did not affect pre-operative bone conducted VEMP. Bone conduction VEMP results were pre-operatively affected by the ABG and bone conduction, but not post-operatively. Bone conduction VEMP was more reliable than air conduction VEMP in assessing the sacculocollic reflex cases of CSOM. So we recommend using bone conduction vestibular evoked myogenic potentials (VEMPs) for vestibular assessment of the sacculocollic reflex in patients with CSOM who complain of balance problems, and to avoid using air conduction VEMP, even if the air-bone gap is small.

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