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The Influence of Unilateral Versus Bilateral Clicks on the Vestibular-Evoked Myogenic Potentials

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Objective: Because a continuous muscular effort is required during recording of vestibular-evoked myogenic potentials, we assume vestibular-evoked myogenic potentials elicited by simultaneous bilateral clicks can be used as a more convenient mode compared with respective unilateral clicks. To investigate whether bilateral clicks provide the same information as unilateral clicks, we examined whether the responses are different between them in normal subjects and whether bilateral clicks have the same diagnostic value as vestibular-evoked myogenic potentials elicited by unilateral clicks in detecting retrolabyrinthine lesions.
Study Design: Prospective study.
Setting: Academic tertiary referral center.
Subjects: Fourteen healthy volunteers and four patients with unilateral cerebellopontine angle tumors were enrolled in this study.
Interventions: Recordings of vestibular-evoked myogenic potential responses.
Main Outcome Measures: The latency of each peak (p13, n23), the peak-to-peak interval, and amplitude (p13–n23).
Results: Both unilateral and bilateral click stimulation of 28 ears (100%) produced vestibular-evoked myogenic potentials in normal subjects. The mean latencies of p13 and n23, peak-to-peak interval, and amplitude of vestibular-evoked myogenic potentials elicited with unilateral clicks were 11.62 ± 0.99 ms, 19.74 ± 1.30 ms, 8.12 ± 1.66 ms, and 110.79 ± 61.37 μV, respectively, whereas those elicited with bilateral clicks were 11.16 ± 0.51 ms, 19.22 ± 1.61 ms, 8.06 ± 1.66 ms, and 111.77 ± 40.98 μV, respectively. There was a significant difference ($p < 0.05$) in the latencies, but not for the interval and amplitude ($p > 0.05$). Four patients with unilateral cerebellopontine angle tumors and prolonged latencies of unilateral clicks vestibular-evoked myogenic potentials also showed latency prolongation in bilateral clicks vestibular-evoked myogenic potentials.
Conclusion: Although the use of bilateral acoustic stimulation shortens the vestibular-evoked myogenic potential latencies in normal subjects, it does not affect the bilateral clicks vestibular-evoked myogenic potential ability to detect retrolabyrinthine lesions. Bilateral clicks vestibular-evoked myogenic potentials are a more convenient mode with which to help diagnose both labyrinthine and retrolabyrinthine lesions than unilateral clicks vestibular-evoked myogenic potentials.
Key Words: Amplitude—Interval—Latency—Sacculocollic reflex—Wave p13-n23.
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Vestibular-evoked myogenic potentials (VEMPs) are a new physiologic test for exploring the integrity of the sacculocollic reflex (1–3). Any lesions in this reflex pathway may display with abnormal VEMP responses in terms of the latency, amplitude, interaural amplitude difference (IAD) ratio, or the sound threshold required to activate them. For example, latencies are prolonged in retrolabyrinthine lesions, such as acoustic neuroma (4) and multiple sclerosis (5); the amplitudes on the lesioned side or IAD ratios were abnormal in peripheral vestibular disorders, such as vestibular neurolabyrinthitis (2) and Ménière's disease (6); the threshold was reduced in superior semicircular canal dehiscence (7) and the Tullio phenomenon (8).

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Although VEMPs can be evoked by sound (air-conducted or bone-conducted), vibration (head tapping) or galvanic stimuli (1,9–12), air-conducted VEMPs have been set as a screening test in our clinics in patients without conductive hearing loss because of their relatively better waveform morphology and less discomfort than the other methods to obtain VEMPs. Air-conducted VEMPs can be elicited by clicks and by short tone bursts; however, our previous report suggested that the former seem superior to the latter for yielding VEMP responses in healthy subjects (13).

Because a continuous muscular effort is required during recording, we assume VEMPs elicited by simultaneous bilateral stimulation with bilateral recording can be used as a more convenient mode compared with two sequential monaural recordings triggered by respective unilateral stimulation. Thus, in this study, we continue using clicks to evoke VEMPs by unilateral and bilateral stimulation to clarify whether the responses are

different between them in normal subjects and whether the latter render the same diagnostic value as the former in detecting retrolabyrinthine lesions in patients with cerebellopontine angle (CPA) tumors.

PATIENTS AND METHODS

Fourteen healthy volunteers (nine men and five women; age range, 24–41 yr; mean age, 31 yr) underwent VEMP tests. All subjects denied any history of previous ear disorders. VEMPs were evoked by unilateral click stimulation of each ear separately with two sequential ipsilateral recording (UC-VEMPs) and by simultaneous bilateral click stimulation with bilateral recordings (BC-VEMPs). Seven subjects with odd registration numbers received an initial UC-VEMP test and subsequent BC-VEMP test, whereas seven subjects with even registration numbers underwent the BC-VEMP test initially followed by the UC-VEMP test.

Surface electromyographic (EMG) activity was recorded in a supine subject using an active electrode on the upper half of sternocleidomastoid muscle and a reference electrode on the lateral end of the upper sternum. During the recording, the subject was instructed to hold his or her head slightly raised to activate the sternocleidomastoid muscle. EMG activity was monitored on the display to maintain it at a relatively constant level (50–200 μV) in individual testing ears. EMG signals were amplified and band-filtered between 20 and 2,000 Hz (Medelec Synergy, Surrey, U.K.). Rarefaction clicks at 0.1-ms duration were given through a headphone. The stimulation rate was 5 Hz and the stimulus intensity was 105 dB normal hearing level. The analysis time for each stimulus was 50 ms. In total, 128 consecutive trials of stimuli were averaged for each run. Two reproducible runs were averaged as the final response.

The initial positive/negative polarity of a waveform with peaks, termed p13 and n23 based on their latencies, was used to determine the presence or absence of wave p13–n23. The latency of each peak (p13, n23), the peak-to-peak interval, and the amplitude (p13–n23) were measured by a computer. Comparative analysis between UC-VEMPs and BC-VEMPs was conducted using the two-tailed paired *t* test and the Wilcoxon signed-rank test (14). The level of significance was set at 0.05.

When the latency of p13 or n23 was longer than the mean latency plus 2 standard deviations (SDs) of healthy volunteers, we regarded the latency as prolonged. Another four patients with unilateral CPA tumors and prolonged latencies of the affected ear of UC-VEMPs also underwent BC-VEMP testing.

RESULTS

All 14 healthy volunteers (28 ears) completed VEMP tests. Typical configurations of wave p13–n23 were found in all UC-VEMPs and BC-VEMPs.

The mean and SDs of the latencies of p13 and n23, the peak-to-peak interval, and the amplitude of UC-VEMPs were 11.62 ± 0.99 ms, 19.74 ± 1.30 ms, 8.12 ± 1.66 ms, and 110.79 ± 61.37 μV, respectively, whereas those of BC-VEMPs were 11.16 ± 0.51 ms, 19.22 ± 1.61 ms, 8.06 ± 1.66 ms, and 111.77 ± 40.98 μV, respectively. There was a significant difference in the latencies (paired *t* test, $p < 0.05$), but not for the interval and the amplitude (paired *t* test, $p > 0.05$) (Table 1). Because the tonic EMG activities were maintained at a constant level only in individual ear recordings, Wilcoxon signed-ranks in amplitudes of UC-VEMPs minus BC-VEMPs on the same testing ears, rather than the absolute amplitudes, were used for analysis. Thus, the amplitudes of UC-VEMPs were no different from those of BC-VEMPs (Wilcoxon signed-rank test, $p > 0.05$) (Table 1).

Four patients with unilateral CPA tumors and prolonged latencies of the affected ear of UC-VEMPs also had clear responses of wave p13–n23 in BC-VEMPs (Fig. 1). The mean ± SD latencies of p13 and n23 of BC-VEMPs in normal subjects were 11.16 ± 0.51 and 19.22 ± 1.61 ms, respectively. Therefore, the latency of p13 or n23 of BC-VEMPs longer than 12.18 ms (p13) or 22.45 ms (n23) was regarded as prolonged. All four patients exhibited prolongation of p13, and two of four patients also showed prolongation of n23 in the affected ear of BC-VEMPs; besides, two of four patients displayed prolongation of p13 in the unaffected ear of BC-VEMPs (Table 2).

DISCUSSION

In the past, researchers used to trigger UC-VEMPs rather than BC-VEMPs to test the sacculocollic reflex for clinical use. Because VEMPs are myogenic potentials in origin, the examinee needs to maintain tonic contraction of his or her neck muscle sufficiently to generate good waveform morphology (15). Meanwhile, multiple sweeps of stimuli have to be averaged to increase the signal-to-noise ratio of VEMP response. Subjects receiving UC-VEMP tests have to keep their muscles contracted twice as long as those receiving BC-VEMP tests. The longer the muscle contracts, the easier it is fatigued. Both insufficient EMG activity sustained and involuntary movement of the head because of exhaustion will decrease the signal-to-noise ratio of response and result in poor waveform propagation. Considering this aspect, bilateral acoustic stimulation seems better than unilateral acoustic stimulation for eliciting constant and prominent VEMP responses, especially for those with inadequate maintenance of tonic muscle contraction.

VEMPs are thought to originate from the saccular macula, then via the inferior vestibular nerve, lateral vestibular nucleus, medial vestibulospinal tract ipsilaterally, and finally terminating to the motor neurons innervating the neck muscles (1,16–19). Our results disclosed that either UC-VEMPs or BC-VEMPs could evoke 100% typical responses in all tested ears. Although the p13–n23 wave was predominantly generated by afferents from the ipsilateral saccule, our data revealed that both p13 and n23 latencies of BC-VEMPs were significantly shorter than those of UC-VEMPs in normal volunteers and that two of four CPA tumor patients displayed p13 prolongation in the unaffected ear of BC-VEMPs in contrast to that of UC-VEMPs with a normal p13 latency. Both of them might indicate that there exists a minor cross-pathway in addition to a major

TABLE 1. *Comparison of vestibular-evoked myogenic potentials triggered by unilateral and bilateral clicks in normal subjects*

VEMPs	Latency, p13 (ms)	Latency, n23 (ms)	Interval (p13–n23) (ms)	Amplitude (p13–n23) (μV)
UC-VEMPs	11.62 ± 0.99[a]	19.74 ± 1.30[b]	8.12 ± 1.66[c]	110.79 ± 61.37[d]
BC-VEMPs	11.16 ± 0.51[a]	19.22 ± 1.61[b]	8.06 ± 1.66[c]	111.77 ± 40.98[d]

[a]$p < 0.05$; [b]$p < 0.01$; [c]$p > 0.05$ (two-tailed paired t test); [d]$p > 0.05$ (two-tailed paired *t* test; Wilcoxon signed-rank test). Data are expressed as mean ± SD.

UC-VEMPs, vestibular-evoked myogenic potentials triggered by unilateral clicks; BC-VEMPs, vestibular-evoked myogenic potentials triggered by bilateral clicks; SD, standard deviation.

non–cross-pathway in the sacculocollic reflex of VEMP response (1).

The amplitude showed no significant difference between UC-VEMPs and BC-VEMPs. This might mean that when interpreting VEMPs by amplitudes or IAD ratio, BC-VEMPs could substitute UC-VEMPs for clinical use, especially for those patients with labyrinthine disorders. In contrast to the amplitude, prolonged latencies in UC-VEMPs have value in diagnosing retrolabyrinthine lesions (4,5). Prolonged p13 and n23 latencies have been observed in association with central vestibulopathy (20). VEMPs provide a useful new diagnostic method for identifying lower brainstem lesions compared with auditory brainstem responses for upper brainstem lesions (21). VEMPs might be a more sensitive test than other physiologic examinations for the lesions affecting only the sacculocollic reflex pathway. Although the use of bilateral acoustic stimulation shortens latencies in normal subjects, retrolabyrinthine lesions still could be detected by prolonged latencies of BC-VEMPs in addition to UC-VEMPs as shown in the current study. However, the question might be raised of why prolonged p13 but normal n23 latencies in BC-VEMPs were encountered in the affected or unaffected ears of unilateral CPA tumor cases. To clarify this point, we can consider two possibilities. First, as we showed, the SD of n23 was greater than that of p13, resulting in a wider normal range of n23 than p13. Second, the p13-n23 waves are myogenic

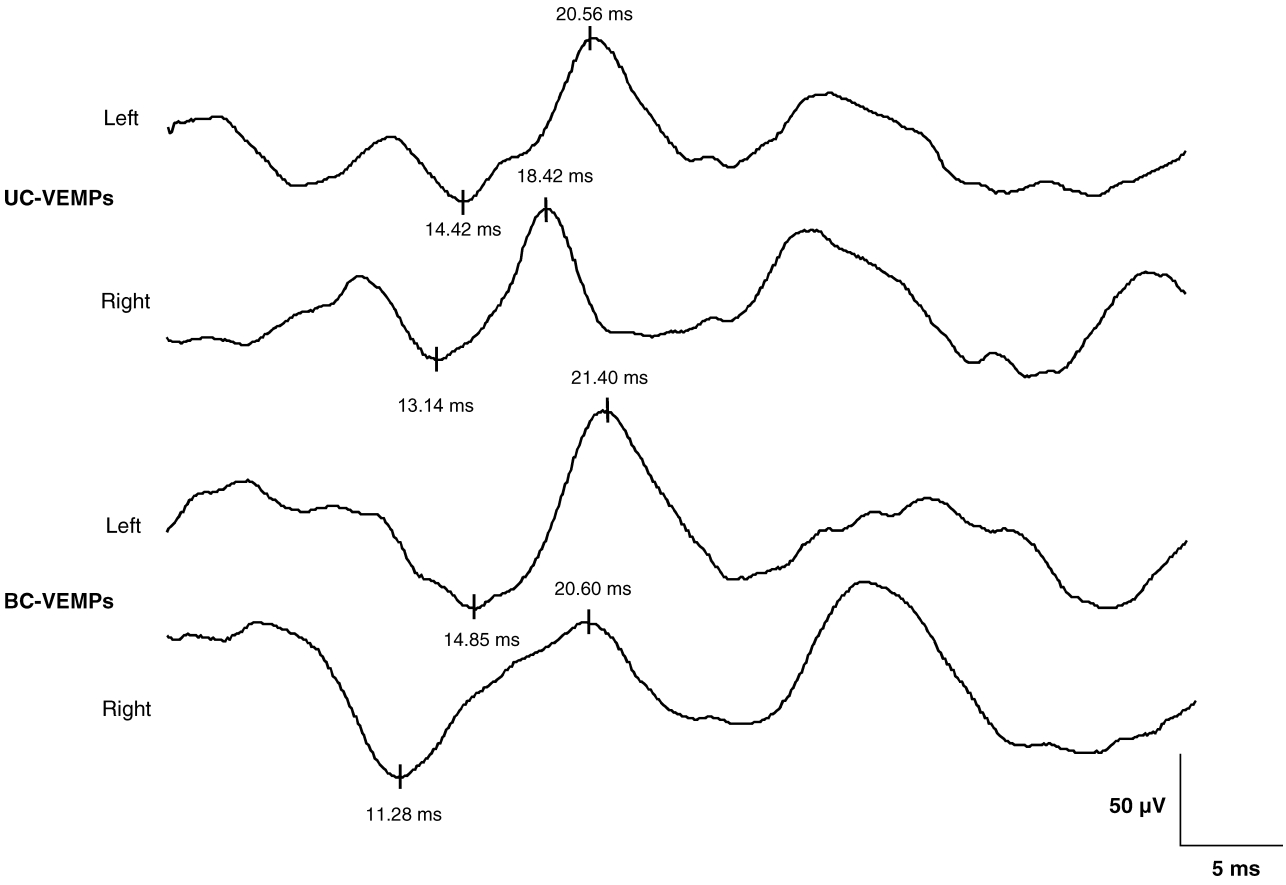

FIG. 1. Vestibular-evoked myogenic potentials of Patient 2, a 48-year-old man with left-sided vestibular schwannoma, elicited by unilateral click stimulation (UC-VEMPs) and by simultaneous bilateral click stimulation (BC-VEMPs). Both UC-VEMPs and BC-VEMPs showed significantly prolonged p13 latency on the left.

TABLE 2. *Prolonged p13 and/or n23 latencies of vestibular-evoked myogenic potentials triggered by bilateral clicks in patients with cerebellopontine angle tumors*

Patient	Sex/age (yr)	Latency (affected/unaffected ear)		Final diagnosis[a]
		p13(ms)	n23(ms)	
1	F/66	12.68[b]/11.27	20.80/19.57	Vestibular schwannoma
2	M/48	14.85[b]/11.28	21.40/20.60	Vestibular schwannoma
3	M/43	13.95[b]/12.45[b]	26.25[b]/21.53	Vestibular schwannoma
4	F/24	13.78[b]/12.20[b]	22.80[b]/22.13	Epidermoid cyst

[a]Final diagnosis of cerebellopontine angle tumors were made by neurosurgery and histopathology.
[b]Prolonged latencies.
F, female; M, male.

potentials in origin instead of neurogenic potential. Therefore, p13 is a better parameter for evaluation of the latency of VEMPs. Because UC-VEMPs demonstrated longer latencies than BC-VEMPs in normal subjects, it was important to remember that the defined criteria of prolonged latencies were variable according to different acoustic stimulation.

CONCLUSION

BC-VEMPs provide responses of shorter latencies, whereas amplitudes and interpeak intervals are similar to those of UC-VEMPs. The diagnostic value of prolonged latencies in UC-VEMPs also holds true in BC-VEMPs. Compared with UC-VEMPs, BC-VEMPs could be a more convenient mode for evaluating both labyrinthine and retrolabyrinthine lesions when testing children, elders, or patients without sufficient support of tonic EMG activity. However, the defined criteria of prolonged latencies are variable, based on UC-VEMPs or BC-VEMPs.

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