# Comparison of Short Tone Burst-evoked and Click-evoked Vestibular Myogenic Potentials in Healthy Individuals

Huei-Jun Wu[1,2], An-Suey Shiao[1,3], Yih-Liang Yang[2], Guo-She Lee[2,3,4]*

*[1]Division of Otology, Department of Otolaryngology–Head and Neck Surgery, Taipei Veterans General Hospital, [2]Department of Speech and Hearing Disorders and Sciences, NTCN, [3]Faculty of Medicine, National Yang-Ming University School of Medicine, and [4]Department of Otolaryngology, Taipei City Hospital, Taipei, Taiwan, R.O.C.*

**Background:** Vestibular evoked myogenic potential (VEMP) is one of the clinical tools to evaluate vestibular function. The VEMP can be recorded from sternocleidomastoid muscle by auditory stimulation with various sound stimuli. The aim of this study was to compare the VEMP responses evoked by short tone burst (STB) with those evoked by click stimuli in healthy young individuals.

**Methods:** Twenty-two healthy volunteers (11 males, 11 females; 44 ears), with ages ranging from 17 to 30 years were enrolled in this study. Subjects were instructed to lie in supine position and elevate their heads unsupported. The VEMP was recorded using 500 Hz STB and then click sound stimuli to each ear. The latency p13, n23, peak-to-peak p13-n23 amplitude and VEMP asymmetry ratio (VAR) were obtained for further analysis.

**Results:** The VEMP responses were present in all subjects. The latencies p13 and n23 of STB-VEMP were significantly longer, and the p13-n23 amplitudes were significantly greater for STB-VEMP ($p < 0.05$, paired $t$ test), as well. The VAR, however, showed no significant difference between the 2 stimuli. The latency n23 of click VEMP in our study was significantly different from that of 1 of the other studies ($p < 0.05$).

**Conclusion:** The VEMP responses were significantly different between the stimuli of STB and click, and the norms of different stimuli should be established for clinical interpretations. For clinical diagnosis using VEMP, we recommend STB stimuli because the latencies and amplitudes of click were significantly different among several labs, including ours. [*J Chin Med Assoc* 2007;70(4):159–163]

**Key Words:** click, short tone burst, vestibular evoked myogenic potential

## Introduction

The human vestibular endorgans consist of utricles, saccules and semicircular canals. The saccules and utricles contain otoliths that are sensitive to gravity and are slightly sensitive to sounds, as well. Tullio's phenomenon refers to a patient who manifests vertigo, abnormal eye movements, and/or imbalance when the affected ear is exposed to loud sounds or pressure change within the external auditory meatus.[1] Clinically, this phenomenon is found in Meniere's disease, perilymphatic fistula, and superior canal dehiscence syndrome and it also provides a clue revealing the response of the vestibular system to sounds.[2–6] Vestibular evoked myogenic potential (VEMP) is a clinical test for vestibular disorders, and is deduced to be produced by the sacculo-collic reflex. VEMP is recorded from the ipsilateral tonically contracting sternocleidomastoid (SCM) muscle while monoaurally stimulating with loud short tone burst (STB) or click sounds.[7] The VEMP amplitudes are increased and thresholds are pathologically lowered in superior semicircular canal dehiscence presenting with Tullio's phenomenon.[8] A successful VEMP response depends on the adequate energy transfer of sound through the middle ear, oval window, and vestibule.[9,10] Then a reflex is generated by a disynaptic pathway, beginning in the saccule macula via the inferior vestibular nerve, lateral vestibular nucleus, medial

*Correspondence to: Dr Guo-She Lee, Faculty of Medicine, National Yang-Ming University School of Medicine, 155, Section 2, Linong Street, Beitou District, Taipei 112, Taiwan, R.O.C.
E-mail: guosheli@ms12.hinet.net • Received: August 4, 2006 • Accepted: March 12, 2007

vestibulospinal tract, and finally ending at the motor neurons of the SCM muscle.[9]

A typical VEMP response includes 2 biphasic waves.[9,10] The first wave is believed to be generated by vestibular afferents arising from the saccule and peaks at a latency near 13 ms (p13). The trough is approximately at 23 ms (n23). A second wave is elicited in 60% of healthy subjects and probably originates from cochlear afferents.[3] The second wave has a trough at the latency near 34 ms (n34) and peaks at about 44 ms (p44). Usually, clinical interpretation of a VEMP test includes latency p13, n23, peak-to-peak p13-n23 amplitude, and VEMP asymmetry ratio (VAR).[7,11]

Clinically, the sound stimuli of STB and click are used to induce VEMP response.[2–6] The wave morphology of the 2 stimuli is found to be similar during tonic contractions of the SCM muscle.[7,9,10] Clicks are believed to activate the hair cells of the saccule after energy transmission through the middle ear.[7] According to a previous study using click first and then STB to evoke VEMP, the click VEMP (C-VEMP) had a higher response rate (98%), a shorter latency, and larger amplitude than short tone burst VEMP (STB-VEMP).[12] However, the responses of the 2 stimuli were not significantly different in another study, and the 500-Hz STB could evoke the same VEMP response as click (88%).[7] We collected the VEMP responses using both STB and click stimuli in healthy young individuals to clarify the inconsistencies of the responses of the 2 stimuli. The results are presented and compared with those of other studies.

## Methods

### *Subjects*

Data were collected from healthy volunteers between January and April 2006 at the Department of Otolaryngology, Taipei Veterans General Hospital. Subjects' ages were less than 30 years, and all subjects passed the hearing-screening test of 20 dBHL from 250 to 8,000 Hz using a clinical pure tone audiometer. The tympanometry of the subjects were type A, and subjects with a medical history of ear disease and vestibular disorder were excluded from the study. Twenty-two healthy volunteers (11 males, 11 females; 44 ears) aged from 17 to 30 years (24.32 ± 4.29 years, mean ± SD) were finally included in our study. The power analysis of the sample size 10–20 was 0.99 to 0.93.

### *Procedures*

Subjects were instructed to lie in the supine position. The surface electromyographic (EMG) electrodes were placed at the symmetrical sites over the upper half of each SCM muscle. The reference electrodes were placed at the sternal notch, and the ground electrode was placed on the forehead. During recording, the subjects were instructed to elevate their heads unsupported and keep them steady as much as possible. The EMG activities were recorded with a commercial system (model Navigator Pro win AEP system, Bio-Logic, IL, USA) and were monitored at a level of 50 μV. The signals were amplified with a gain of 1,000 and were band-pass filtered at 30–3,000 Hz. The sound stimulus of STB was set to 95 dBnHL, rarefaction, 500 Hz, 1-ms rise/fall time and 2-ms plateau. The stimulus was transmitted through inserted earphones, and the repetition rate was 5 Hz. The analysis time was 40 ms and 200 consecutive runs were averaged for each trial. Two consecutive trials were collected for averaging and further analysis. Two minutes after the test of STB, click stimuli of 0.1 ms duration were used to elicit VEMP responses. The hardware settings and procedures were the same as for the STB stimuli. Similarly, 2 consecutive trials were collected for averaging to increase the reproducibility of data.

### *VEMP responses*

The latency p13 is defined as the positive polarity of the biphasic wave that appears at approximately 13 ms, and the latency n23 is defined as the negative polarity of the biphasic wave that appears at approximately 23 ms. The amplitude is defined as the peak-to-peak p13-n23 maximum energy in μV. VEMP asymmetry ratio (VAR) is defined as the ratio of the inter-aural amplitude difference to the sum of the amplitudes of both ears.[7,11]

### *Statistical analysis*

Power analysis of sample size was performed by 2-sample *t* test and an independent sample *t* test was used to test the equal variance of bilateral latencies and amplitudes. Comparisons between STB-VEMP and click VEMP were performed by paired *t* test. Comparisons with other studies were made by meta-analysis. Statistical significance was assumed when $p < 0.05$. The software used was SAS version 9.1 (SAS Institute Inc., Cary, NC, USA) for Windows. Values were expressed as mean ± SD or mean ± SE.

## Results

The VEMP response rates were 100% for both stimuli. The typical responses of STB-VEMP and C-VEMP are shown in Figure 1. The latencies of p13 and n23,

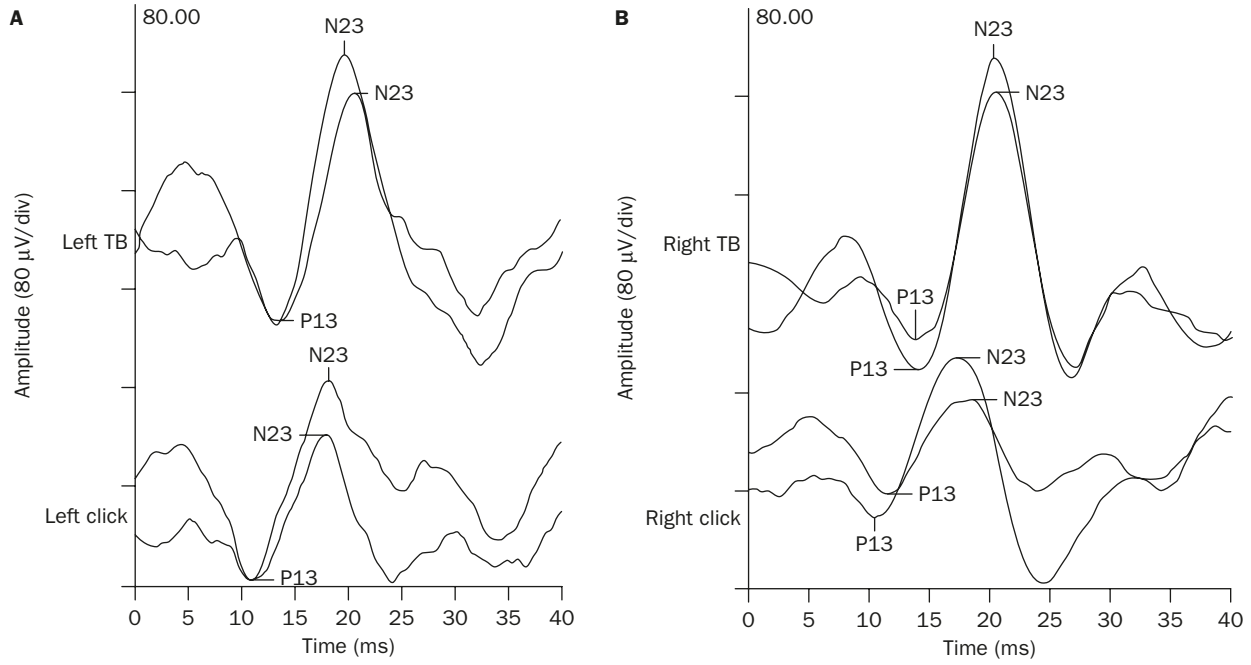


**Figure 1.** (A,B) The vestibular evoked myogenic potential (VEMP) evoked by short tone burst (STB) and click sounds in a healthy 17-year-old female.

**Table 1.** Comparison of vestibular evoked myogenic potential (VEMP) triggered by short tone burst (STB) and click*

| VEMP | Latency p13 (ms) | Latency n23 (ms) | Amplitude (μV) | VAR |
|---|---|---|---|---|
| STB | 14.83 ± 0.81 | 22.54 ± 1.30 | 198.53 ± 64.64 | 0.13 ± 0.12 |
| Click | 12.43 ± 1.01† | 19.85 ± 1.65† | 81.23 ± 32.56† | 0.20 ± 0.13 |

**Data are expressed as mean ± standard deviation; †p < 0.01 compared with STB-VEMP using paired t test.*

**Table 2.** Comparison of short tone burst vestibular evoked myogenic potential (STB-VEMP) with other studies*

| Study | *n* | Age (yr)† | Latency p13 (ms) | Latency n23 (ms) | VAR |
|---|---|---|---|---|---|
| Wu and Young (2002)[16] | 10 | 24–35 | 14.90 ± 0.5 | 20.13 ± 0.44 | 0.13 ± 0.12 |
| Cheng et al (2003)[12] | 29 | 17–43 | 12.49 ± 0.26 | 19.79 ± 0.33 | NA |
| Present study | 22 | 17–30 | 14.83 ± 0.17 | 22.54 ± 0.27 | 0.13 ± 0.02 |

**Data are expressed as mean ± standard error and comparisons between studies were made using meta-analysis; †age expressed as year range. VAR = VEMP asymmetry ratio; NA = not applicable.*

peak-to-peak p13-n23 amplitude, and VAR of STB-VEMP in healthy individuals were 14.83 ± 0.81 ms (mean ± SD), 22.54 ± 1.30 ms, 198.53 ± 64.64 μV, and 0.13 ± 0.12, respectively. The latencies of p13 and n23, peak-to-peak p13-n23 amplitude and VAR of C-VEMP in healthy individuals were 12.43 ± 1.01 ms, 19.85 ± 1.65 ms, 81.23 ± 32.56 μV and 0.2 ± 0.13, respectively.

The latencies p13, n23 and p13-n23 amplitude of STB-VEMP were significantly different from those of C-VEMP (Table 1) ($p < 0.05$, paired $t$ test). The VAR of STB-VEMP, however, was not different from C-VEMP (Table 1).

Table 2 shows the comparison of STB-VEMP responses with those of the other studies. The latencies p13, n23, and VAR were not significantly different from those of the other studies.[12,16] The comparison of C-VEMP responses with those of other studies are summarized in Table 3. The latency n23 of our study

**Table 3.** Comparison of click vestibular evoked myogenic potential (VEMP) with other studies*

| Study | *n* | Age (yr)† | Latency p13 (ms) | Latency n23 (ms) | VAR |
|---|---|---|---|---|---|
| Colebatch et al (1994)[9] | 10 | 29–63 | 13.3 ± 0.45 | 22.6 ± 0.57‡ | NA |
| Cheng et al (2003)[12] | 29 | 17–43 | 11.45 ± 0.28 | 19.17 ± 0.36 | NA |
| Su et al (2004)[11] | 19 | 21–40 | 11.47 ± 0.32 | 19.05 ± 0.39 | 0.19 ± 0.11 |
| Present study | 22 | 17–30 | 12.43 ± 0.21 | 19.85 ± 0.35 | 0.20 ± 0.02 |

**Data are expressed as mean ± standard error; †age expressed as year range; ‡$p < 0.05$ compared with the other 3 studies using meta-analysis. VAR = VEMP asymmetry ratio; NA = not applicable.*

was significantly different from that in 1 of the other studies ($p < 0.05$), although the latency p13 and VAR revealed no significant difference.[9,11,12] We did not know the exact cause of the difference. However, the comparisons of n23 between labs should be made with consideration to this difference.

## Discussion

In this study, the VEMP responses of 500-Hz STB and click sound stimuli were collected in 22 healthy volunteers. The latencies p13, n23 and p13-n23 amplitude were significantly different between the 2 stimuli, although the VAR did not show significant difference. A different database should be established before clinical application of VEMP for different stimuli.

The latencies p13 and n23 of STB-VEMP were longer than those of C-VEMP. The longer latency may result from a delay of STB stimulus to reach the maximum intensity in an 1-ms rise/fall time.[6] Moreover, the vestibular neurons may have double or triple firing to 1 tone-burst stimulus, and the latencies of VEMP responses might be delayed because of the second or third spikes.[12,13]

The stapedial reflex tenses the tympanic membrane to protect the hearing from damage of a loud acoustic stimulus and decreases the energy transfer of sound stimuli.[13–15] However, a shorter rise/fall time (0.3 ms, 1 ms or 3 ms) and plateau (2 ms) of click stimuli may evoke the VEMP response without inducing a stapedial reflex,[14] and thus the peak-to-peak p13-n23 amplitudes of the STB-VEMP were significantly larger than those of C-VEMP.

In each subject of this study, the STB-VEMP was performed first and was followed 2 minutes later by C-VEMP. Thus, the p13-n23 amplitude might be decreased because of the fatigue of the SCM muscle. According to the results of the studies,[9,11] the peak-to-peak p13-n23 amplitudes of 95 dBnHL click had also shown relatively larger variations (18.3–137.1 μV) even by the stimulations of STB and click in randomized order.[9] Nevertheless, the VAR of C-VEMP was not significantly different from that of STB-VEMP in this study (Table 1) and other studies (Table 3).[11,16] With these findings, we conclude that VEMP amplitude, but not VAR, might change significantly if the time interval between 2 sequential tests is less than 2 minutes. The latencies, however, seem not to be significantly affected by the order of tests.

In conclusion, the VEMP responses were significantly different between the stimuli of STB and click. The STB-VEMP had longer latencies p13 and n23 than C-VEMP. The norms of different stimuli should be established for clinical interpretations. For clinical diagnosis using VEMP, we recommend STB stimuli because the latencies and amplitudes of click were significantly different among several labs, including ours.

## References


1. Watson SR, Halmagyi GM, Colebatch JG. Vestibular hypersensitivity to sound (Tullio phenomenon): structural and functional assessment. *Neurology* 2000;54:722–8.
2. Ishizaki H, Pyykko I, Aalto H, Starck J. The Tullio phenomenon in patients with Meniere's disease as revealed with posturography. *Acta Otolaryngol Suppl* 1991;481:593–5.
3. Ildiz F, Dundar A. A case of Tullio phenomenon in a subject with oval window fistula due to barotrauma. *Aviat Space Environ Med* 1994;65:67–9.
4. Pyykko I, Ishizaki H, Aalto H, Starck J. Relevance of the Tullio phenomenon in assessing perilymphatic leak in vertiginous patients. *Am J Otol* 1992;13:339–42.
5. Fox EJ, Balkany TJ, Arenberg IK. The Tullio phenomenon and perilymph fistula. *Otolaryngol Head Neck Surg* 1988;98:88–9.
6. Ostrowski VB, Byskosh A, Hain TC. Tullio phenomenon with dehiscence of the superior semicircular canal. *Otol Neurotol* 2001; 22:61–5.
7. Murofushi T, Matsuzaki M, Wu CH. Short tone burst-evoked myogenic potentials on the sternocleidomastoid muscle: are these potentials also of vestibular origin? *Arch Otolaryngol Head Neck Surg* 1999;125:660–4.
8. Welgampola MS, Colebatch JG. Characteristics and clinical applications of vestibular-evoked myogenic potentials. *Neurology.* 2005;64:1682–8.
9. Colebatch JG, Halmagyi GM, Skuse NF. Myogenic potentials generated by a click-evoked vestibulocollic reflex. *J Neurol Neurosurg Psychiatry* 1994;57:190–7.

10. Rauch SD, Zhou G, Kujawa SG, Guinan JJ, Herrmann BS. Vestibular evoked myogenic potentials show altered tuning in patients with Meniere's disease. *Otol Neurotol* 2004;25: 333–8.
11. Su HC, Huang TW, Young YH, Cheng PW. Aging effect on vestibular evoked myogenic potential. *Otol Neurotol* 2004;25: 977–80.
12. Cheng PW, Huang TW, Young YH. The influence of clicks versus short tone bursts on the vestibular evoked myogenic potentials. *Ear Hear* 2003;24:195–7.
13. Cheng PW, Murofushi T. The effects of plateau time on vestibular-evoked myogenic potentials triggered by tone bursts. *Acta Otolaryngol* 2001;121:935–8.
14. Cheng PW, Murofushi T. The effect of rise/fall time on vestibular-evoked myogenic potential triggered by short tone bursts. *Acta Otolaryngol* 2001;121:696–9.
15. Salomon G. Middle ear muscle activity. *Proc R Soc Med* 1966; 59:966–71.
16. Wu CC, Young YH. Vestibular evoked myogenic potentials are intact after sudden deafness. *Ear Hear* 2002;23:235–8.