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A study on vestibular-evoked myogenic potentials via galvanic vestibular stimulation in normal people

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Abstract

Objectives: The aim of our study is to examine vestibular-evoked myogenic potentials (VEMPs) elicited by the galvanic vestibular stimulation in the sternocleidomastoid muscle (SCM) in healthy subjects for clinical applications of auditory neuropathy or vestibular neuropathy in the future.
Methods: We enrolled sixteen healthy subjects to record the average responses of SCM to galvanic vestibular stimulation (GVS) [current 3 mA; duration 1 ms] by electromyography (EMG). SPSS18.0 software was used to analyze the obtained data for mean and standard deviation.
Results: In all healthy subjects mastoid-forehead galvanic vestibular stimulation produced a positive-negative biphasic EMG responses on SCM ipsilateral to the cathodal electrode. The latency of p13 was 11.7 ± 3.0 ms. The latency of n23 was 17.8 ± 3.4 ms. The amplitude of p13-n23 was 147.0 ± 69.0 μV. The interaural asymmetry ratio (AR) of p13, n23 latency and the amplitude was respectively 0.12 ± 0.09, 0.08 ± 0.08 and 0.16 ± 0.10.
Discussions: Galvanic vestibular stimulation could elicit biphasic EMG responses from SCM via the vestibular nerve but not from the otolith organs. Galvanic stimulation together with air conducted sound (ACS) or bone conducted vibration (BCV) can elicit VEMPs and may enable the differentiation of retrolabyrinthine lesions from labyrinthine lesions in vestibular system.

Keywords: Galvanic vestibular stimulation; Vestibular nerve; Vestibular-evoked myogenic potentials; Sternocleidomastoid muscle; Interaural asymmetry ratio (AR)

1. Introduction

Auditory stimulated vestibular-evoked myogenic potentials (VEMPs) recorded by using surface electrodes can be used clinically to assess vestibular function (Colebatch and Halmagyi, 1992; Welgampola and Colebatch, 2005). They can be classified into two types: cervical vestibular-evoked myogenic potential (cVEMP) and ocular vestibular-evoked myogenic potential (oVEMP). Both VEMPs are elicited by auditory stimuli such as clicks, short tone bursts or tapping. cVEMPs, which are recorded from the sternocleidomastoid muscle (SCM), have been used to evaluate the function of the saccule and the inferior vestibular nerve, since physiological and clinical studies have shown that cVEMPs to air conducted sounds (ACSs) reflect the function of saccular afferents (McCue and Guinan, 1994; Murofushi et al., 1995, 1996; Welgampola and Colebatch, 2005). Ocular vestibular-evoked myogenic potentials (oVEMPs), which are recorded from extraocular muscles beneath the eyes in response to ACS and bone conducted vibration (BCV) (Rosengren et al., 2005; Todd et al., 2007) have been used to evaluate the function of the utricle and superior vestibular nerve (Iwasaki et al., 2009a, 2009b; Curthoys et al., 2006).

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Three types of stimulation have been used to elicit VEMPs: ACS (clicks and tone bursts), BCV (tapping) and galvanic vestibular stimulation (GVS). GVS has been used as a non-mechanical means to activate the vestibular apparatus (Camis, 1930).

Murofushi et al., reported that patients who had no myogenic responses on the SCM evoked by clicks or galvanic stimulation are likely to have retro-labyrinthine lesions while patients who had no response to clicks but normal responses to galvanic stimulation. These results did not correlate with a caloric response. Therefore they speculated galvanic stimulation might have stimulated only the otolith organs system (Murofushi et al., 2002, 2003).

Vestibular nerve response through galvanic VEMPs evoked by electrical stimulation in humans has rarely been described with respect to pathophysiology of auditory neuropathy and vestibular neuropathy.

In this study we designed to investigate vestibular nerve response through galvanic VEMPs induced by electrical vestibular nerve stimulation in normal people for later study of auditory neuropathy, vestibular neuropathy and vestibular synaptopathy.

2. Subjects and methods

2.1. Subjects

Sixteen normal volunteers (31 healthy ears; 9 female, 7 male.) aged from 20 to 60 years old were enrolled in this study. They were healthy without hearing loss or vertigo. The neck of all the subjects was not fixed and could rotate freely. All the subjects were obtained their informed consent.

2.2. Test methods

2.2.1. Recording

The active recording electrodes were placed in the middle of SCM meanwhile the indifferent electrodes were placed on the lateral end of the upper sternum. The ground electrodes were placed in the middle of the forehead.

2.2.2. Galvanic stimulation

Electrodes for GVS were placed on the mastoid. These were cathode, while the other electrodes for GVS were placed on the forehead. These were anode. We used 3 mA (duration: 1 ms) galvanic stimulation. The thresholds of responses by galvanic stimulation were measured in electromyographic (EMG) activities amplified and bandpass-filtered (20–2000 Hz). The analysis time was 50 ms, and the stimulation rate was 5 Hz. The responses to 50 stimuli were averaged twice with and without contraction of SCM by the rotation of the neck. When these galvanic stimuli were presented, the subjects felt a slight tapping sensation but no pain (Murofushi et al., 2002; Watson and Colebatch, 1998; Watson et al., 1998).

In order to remove the electrical stimulation artifacts, the average responses obtained without contraction of SCM would be subtracted from the average responses obtained with contraction of SCM (Watson and Colebatch, 1998; Watson et al., 1998). We monitored an electromyogram wave forms during recordings. Then, muscular tonus of SCM in both sides was maintained the same level. Furthermore, in order to remove artifacts from VEMP using the electrical stimulation in this study, we subtracted the average obtained without contraction of the SCM from the average obtained with contraction of the SCM. This method was the same as that reported by Watson and Colebatch (1998), Watson et al. (1998).

The interaural asymmetry ratio (AR) is another important parameter for evaluating both ears' vestibular function. The calculation method for AR (for example, a latency of p13) was as follow: $|Lr - Ll|/(Lr + Ll) \times 100\%$. Lr is the p13 latency of the right ear, Ll is the p13 latency of the left ear and $|Lr - Ll|$ is the absolute value of $(Lr - Ll)$ (Oh et al., 2013; Murofushi et al., 2001). Then, the mean + standard deviation (SD) of AR about the latency of p13 was calculated. The latency of n23 and the amplitude of p13-n23 were calculated by the same method. In electrophysiological measurements such as that of VEMP, the symmetry of results between both ears is important; a lack of the symmetry between both ears may be a sign of a unilateral deficit in the vestibular function or system. The value of AR is between 0 and 1. AR is close to zero, the better the symmetry between the right and left ears. However AR is close to 1, the worse the symmetry between the right and left ears.

2.3. Statistical methods

SPSS18.0 software was used to analyze the data for mean and standard deviation.

3. Results

All of the normal subjects showed biphasic responses. In this study we call the first positive peak due to galvanic stimulation 'p13' and the first negative peak due to galvanic stimulation 'n23'. The latency of p13 was 11.7 ± 3.0 ms. The latency of n23 was 17.8 ± 3.4 ms. The amplitude of p13-n23 was 147.0 ± 69.0 μV. The statistical data are shown in Table 1. Our records of the responses of SCM with and without contraction and the waves after subtraction are shown in Fig. 1. The AR of p13 and n23 latency, and the amplitude are respectively 0.12 ± 0.09, 0.08 ± 0.08 and 0.16 ± 0.10. The statistical data are shown in Table 2.

Table 1
Mean and standard deviation (SD) of latencies of p13 and n23, and amplitude of p13-n23 in all ears.

N = 31 (ears)	p13 Latency (ms)	n23 Latency (ms)	Amplitude (μV)
Mean	11.7	17.8	147.0
SD	3.0	3.4	69.0

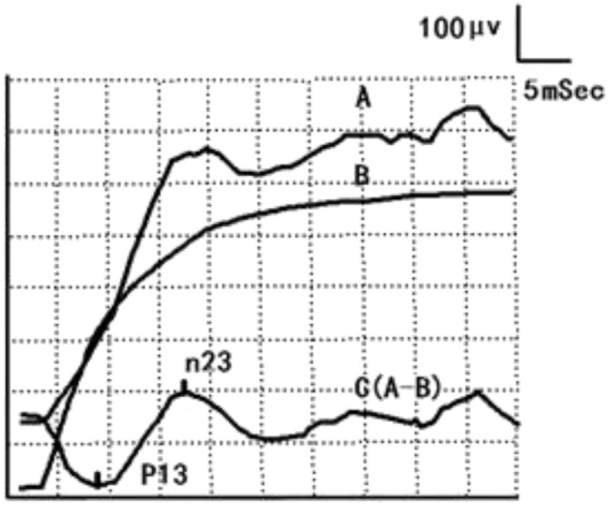

Fig. 1. One of subjects was tested for gVEMP. A is the reflex response that occurred with SCM contraction. B is the reflex response that occurred without SCM contraction. C is obtained by subtracting B from A in order to remove artifacts, thus obtaining the real trace of gVEMP.

Table 2
Asymmetry ratio, AR of p13 and n23 latencies and amplitude in 15 subjects.

AR (N = 15 subjects)	Mean	SD
Latency p13	0.12	0.09
n23	0.08	0.08
Amplitude (−)	0.16	0.10

4. Discussion

VEMPs elicited by ACS and BCV are used to evaluate the function of the utricle, saccule, and vestibular nerve. Watson and Colebatch reported that galvanic stimulation of the forehead and mastoid region could evoke myogenic responses in SCM (Watson and Colebatch, 1997, 1998; Watson et al., 1998). The myogenic responses were disappeared when the selective vestibular nerve section was performed (Oh et al., 2013). Watson and Colebatch's results indicated that these myogenic responses were the vestibular nerve in origin. They supposed that GVS activated the most distal portion of the vestibular nerve. ACS and BCV could activate the receptor level of vestibule, utricle and saccule (Figs. 2 and 3) (Kaga, 2012). Murofushi et al. (2002) reported that the combined use of click- and galvanic-cVEMP was useful for the differential diagnosis of labyrinthine lesions from retrolabyrinthine lesions of vestibular system in patients with vestibular deficits. In their study, all the 10 patients who were diagnosed as having delayed endolymphatic hydrops or Meniere's disease showed normal galvanic-cVEMP on the affected side, although they did not show click-evoked myogenic responses on this side. In contrast, 16 patients diagnosed as having acoustic neuroma or other cerebellopontine angle tumors did not show any responses on the affected side even to click and galvanic stimulation. In most of the patients diagnosed as the vestibular neuritis, the myogenic responses elicited by click-

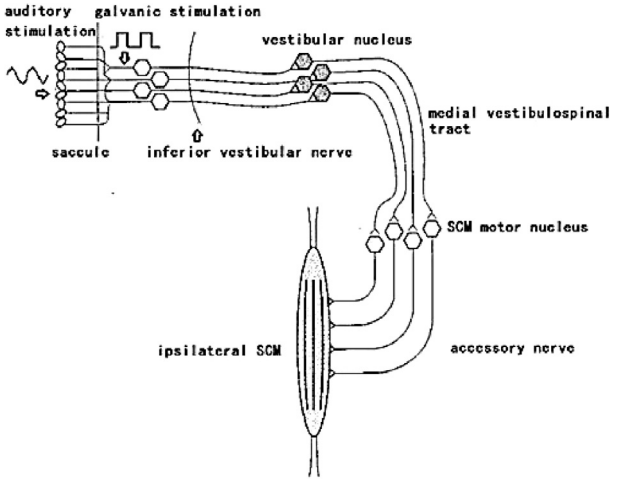

Fig. 2. Auditory stimulation (ACS and BCV) activated the receptor level of vestibule, utricle and saccule. Galvanic stimulation activated the most distal portion of the vestibular nerve (Kaga, 2012).

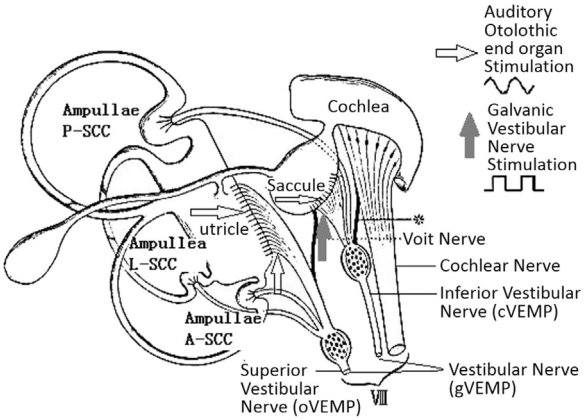

Fig. 3. Auditory stimulation (sine wave) activated the receptor level of vestibule, utricle and saccule. Galvanic stimulation (square wave) activated the most distal portion of the vestibular nerve. (L-SCC: lateral semicircular canal; P-SCC: posterior semicircular canal; A-SCC: anterior semicircular canal).

stimulation and galvanic stimulation were absent on the affected side. These results suggested that the site of lesions in vestibular neuritis was primarily in the vestibular nerve (Murofushi et al., 2003). Therefore, the use of galvanic stimulation together with ACS or BCV stimulation may enable the differentiation of labyrinthine lesions from retrolabyrinthine lesions. The accurate determination of the location of lesions is useful for studying the pathophysiology of vestibular diseases. From the data of our normal subjects, we can establish GVS elicited VEMPs criteria for their clinical applications of vestibular neuropathy complicated with auditory neuropathy as a next step research. Then, the vestibular diseases could be diagnosed and treated by the use of galvanic VEMPs with ACS- or BCV-VEMPs, such as auditory neuropathy, vestibular neuropathy and vestibular synaptopathy.

Finally, the interaural asymmetry ratio (AR) of galvanic VEMP is an important parameter for evaluating right and left vestibular nerve function in both ears.

In the reports of VEMP of the McCaslin group, the amplitude of the cervical VEMP is related to both the integrity of the sacculo-coolic pathway and the magnitude of electromyographic (ENG) activity at the time of recording. McCaslin pointed out that one cannot determine whether cVEMP asymmetries are occurring due to unilateral and organ disease of asymmetric tonic EMG activity, if EMG amplitude is uncontrolled. They showed two methods to control EMG amplitude (McCaslin et al., 2013, 2014). (1) patient self-monitoring of EMG activity with biofeedback and (2) mathematical correction (i.e., amplitude normalization) of the left and right cVEMP waveforms. We did not have these methods, however, we monitored electromyogram waves from during recording. Then, muscular tonus of SCM in both ears was maintained the same level. Furthermore, in order to remove artifacts from VMEP using the electrical stimulation in this study we subtracted the average obtained without contraction of the SCM from the average obtained with contraction of the SCM. This method was the same as that reported by Watson and Colebatch (1998), Watson et al. (1998). Consequently, the AR of our galvanic VEMP was very low and is useful to compare the right and left difference of the galvanic VEMP in both sides.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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