Otolaryngology online journal

ISSN: 2250-0359 Volume 4 Issue 4 2014

Normal values of vestibular evoked myogenic potentials in Chinese healthy male military pilots

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Abstract:

Background: Vestibular function is essential to pilots. But for now there are little method to evaluate otolith function in pilots.Quite recently vestibular evoked myogenic potential (VEMP) test has been introduced to evaluate the saccule and the inferior vestibular nerve function. The purpose of the present study is to investigate the parameters of VEMP in Chinese Air Force fighter pilots so as to establish its normative data for Chinese Air Force pilots.

Methods: One hundred and twenty-six healthy Chinese Air Force active-duty fighter pilots were recruited as study participants. VEMP of 126 subjects were recorded bilateral during short tone burst stimulation. The latencies of p13 and n23, p13/n23 amplitude, and asymmetry ratio of VEMP in healthy pilots were collected for calculating normative date.

Results: All tests showed reproducible VEMP waveforms. The latencies of p13 and n23，p13/n23 amplitude，and asymmetry ratio of VEMP in healthy pilots (13.50±1.20) ms， (21.35±1.60) ms， (169.70±38.50) μV， and 0.12±0.11 respectively.

Conclusions: The present study have established the normal values of VEMP in military pilots，which is crucial for the application of VEMP in military pilots.

[Key Words]: Military personnel；Vestibular-evoked myogenic potential （VEMP）；Saccule

Introduction:

Pilot disorientation is a leading factor contributing to many fatal flying accidents [1-2]. Spatial orientation is the product of integrative inputs from the proprioceptive, vestibular, and visual systems. The normal function of all organs involved in orientation is emphasized in the aviation medical literature as being a prerequisite for flying [1]. Normal and effective vestibular system function is especially an absolute precondition for high performance fighter pilots. Not only is it necessary to exclude inner ear diseases such as Meniere's disease, benign paroxysmal positional vertigo, vestibular neuritis , vestibular schwannoma , labyrinthitis, vestibular migraine etc., but it is also important for the pilot to be able to produce symmetrical and sufficiently balanced responses in order to successfully fight against spatial disorientation.

Vestibular end organs comprise three semicircular canals and two otolithic organs, i.e., the saccule and utricle. Clinically, semicircular canals are assessed by the caloric test with videonystagmography or the head impulse test, whereas safe simple tests of otolith function are not common (3). Recently, vestibular evoked myogenic potential (VEMP) testing has been suggested as a non-invasive diagnostic technique to assess the vestibular saccular function. It measures the vestibulo-cervical reflex that consists in an inhibitory potential recorded from sternocleidomastoid(SCM) muscle in response to loud sounds: a biphasic (positive-negative),high amplitude and low latency wave(p13-n23).It is a useful tool to asses saccule and inferior vestibular nerve function[4]. Now VEMP has been clinically applied in the diagnosis of many peripheral or central vertigo such as benign paroxysmal positional vertigo, vestibular neuritis, Meniere’s disease, acoustic tumor, multiple sclerosis and vestibular migraine [5].

However, so far as we know, VEMP has not been applied in the medical selection and physiological assessment of fighter pilots due to lack of reliable normative data. Hence, the aim of the present paper is to investigate the parameters of VEMP in Chinese Air Force fighter pilots so as to establish reference normal values of VEMP parameters in Chinese military fighter pilots

Methods

Subjects

There were one hundred and twenty-six healthy Chinese Air Force male active-duty jet fighter pilots (age:25–44 yr, mean 32.7±5.4 yr, mean flight time 1122.8±550.9 hr) who served as study participants. All participants had to be mentally and physically fit according to the standards of Medical Fitness for Chinese Air Force aircrew. None of them had any history of inner ear diseases or dizziness, hearing loss, or tinnitus. None of them also had any history of neck pain or cervical muscle diseases. The hearing level was normal in all participants according to ISO 7029(6). Horizontal head impulse, headshaking, vibration-induced nystagmus test with Frenzel goggles, subjective visual vertical tests, and caloric tests were also within normal limits in all participants. The study protocol was approved in advance by the Chinese Air Force Institute of Aviation Medicine Institutional Review Board. Each subject provided written informed consent before participation after all procedures had been fully explained.

VEMP recordings

VEMP recordings were performed using a Medelec Synergy EMG/EP machine (Oxford Instruments Medical, Surrey, UK).Subjects were tested in a sitting position. The EMG signals were amplified and bandpass filtered between 30 and 3000 Hz. Acoustic stimuli as 100 dB nHL short tone bursts (STB, 500 Hz, rise/fall time=1 ms, plateau time=2 ms)with rarefaction polarity were delivered through an insert earphone. The stimulation rate was 5/s,with the analysis time for each response of 50 ms, and 200 responses were averaged for each run. Active electrode was placed on the upper one-third of bilateral SCM with the reference electrode on the anterior margin of the clavicle and the ground electrode on the forehead. Subjects were asked to elevated their heads to activate the bilateral SCM muscle and to hold this position throughout the recording period(Fig.1).Muscle activation was monitored during the recording and maintained at a constant level(>50 μV). Peak latencies of p13 and n23 and peak to peak amplitudes (p13-n23)were measured. The interside differences of p13 and n23 amplitude asymmetry ratio (AR)were calculated.AR was calculated as follows:(larger response-smaller response)/(larger response+smaller response)×100 %(7).We preferred to use AR for the interpretation of the VEMP amplitude, since VEMP response amplitude is significantly affected by the force of muscular contraction or stimulus intensity and exhibits wide variation.

Statistical Analysis

Statistical analysis was performed using SPSS for Windows version 15.Means and standard deviations (SD) of each VEMP parameter such as latencies, amplitudes, and asymmetry ratio were determined. Hypothesis tests were performed at the α:0.05 significance level (means $p<0.05$ were accepted as significant).The Shapiro–Wilk test was performed to check if the data were normally distributed. After evaluation of the assumption of the normal distribution, the reference normal values of VEMP parameters were calculated according to mean ±2 SD.

Results

Bilateral reproducible VEMP responses induced by air conducted sound were recorded in one hundred and twenty-six subjects (two hundred and fifty-two ears) and inducing rate achieved 100%. A typical example of the VEMP responses obtained in a jet fighter pilot is depicted in Fig.2. The latencies of p13 and n23, p13/n23 amplitude, and asymmetry ratio of VEMP in healthy pilots were (13.50±1.20) ms, (21.35±1.60)ms, (169.70±38.50)μV, and 0.12±0.11 respectively. According to test of normality, all VEMP parameters data were normally distributed. Therefore normative data for p13 latency,n23 latency, peak to peak amplitudes and AR in healthy male fighter pilots were established according to mean± 2SD,which were 11.10–15.90 ms,18.15–24.55 ms, 92.70-246.70 μV and ≤ 34% respectively.

Discussion

It had been observed in animal and human experiments that high loud sound could induce action potentials recorded over the cervical muscles. In 1964, Bickford et al [8]depicted in detail the characteristics of loud click-evoked union responses(responses obtained from the union as the place for active electrode) and drew a conclusion that the union responses were of vestibular origin. In 1994, Colebatch et al [4] established a reliable procedure to record myogenic potentials from the sternocleidomastoid (SCM) muscle evoked by clicks. A biphasic positive negativity (p13-n23) occurred in normal subjects but was abolished in patients who underwent selective vestibular nerve section. In 1995, Halmagyi et al reported the responses that were not of lateral canal origin and the term "Vestibular-evoked myogenic potentials"(VEMP)has been widely used since then[9]. VEMP assesses vestibular function through the vestibulocollic reflex (VCR).The VCR arc includes the receptor(the saccule),the afferent pathway(the inferior vestibular nerve), and the efferent pathway(the lateral vestibulospinal tract, the medial vestibulospinal tract, and the end muscle-SCM)[4-5]. Therefore VEMP can not only evalute the function of saccule and inferior vestibular nerve, but also can assess the integrity of descending brainstem vestibular-spinal pathway.

Electronystagmography (ENG) is a gold standard vestibular function test. The caloric test induces vertigo and assesses only the horizontal semicircular canal function[10].Compared to the ENG,VEMP testing is easier to perform, less complicated for interpretation, induces less dizziness or nausea, and is more tolerable to patients[5,11]. Hence VEMP to date has been applied clinically in the diagnosis of various peripheral and central vertigo [5， 11].

During VEMP test, subjects were asked to hold their heads raised when lying supine in order to activate bilateral SCMs because the magnitude of VEMP is influenced by SCM contraction level[12]. As for sound stimulation, it has been reported that both click and short tone burst (STB)can induce VEMP[12-13].The preferred repetition rate is 1-5 Hz and the optimal frequency is 500 Hz for STB[14].Wang et al [15] reported that binaural simultaneous stimulation shows similar responses to monaural stimulation in healthy subjects. So in order to reduce the testing time of VEMP and the physical efforts of subjects and to improve the reliability of AR, it is necessary to adopt the binaural simultaneous stimulation to bilaterally record VEMP.

The present study performed VEMP tests for 126 male healthy military pilots by the optimal stimulation mode above-mentioned and recorded reproducible VEMP waveforms in all subjects. The inducing rate achieved 100%. P13 latency normal values range from 11.10 to 15.90 ms and n23 latency normal values range from 18.15 to 24.55 ms. Shimizu et al [16] had reported the prolongation of p13 and n23 latencies in three patients with multiple sclerosis. They suggested that the prolongation of VEMP latencies has clinical significance in the assessment of the lesion in the vestibulo-spinal pathways. Murofushi et al [17] also investigated the clinical significance of VEMP latencies in the diagnosis of peripheral vestibulopathy. They found that few patients with Meniere's disease or vestibular neuritis showed the prolongation of p13 and n23 latencies and Four patients with large vestibular schwannoma and six patients with multiple sclerosis displayed the prolongation of p13 latencies. They suggested that brainstem compression or lesion contributes to the prolongation of VEMP latencies. Different laboratories have reported different normal values of p13 and n23 latencies in healthy people due to differences in sound stimulation magnitude and modes as well as recording devices. Murofushi et al [18] reported mean p13 and n23 latencies were 14.9±0.53 ms and 23.5±1.21 ms respectively. However according to Cheng et al [19], mean p13 and n23 latencies were 13.32 ms and 22.27 ms. Furthermore Zhou et al[20] showed that mean p13 and n23 latencies of click evoked VEMP in Chinese healthy people were 12.30 ms and 20.74 ms respectively. Mean p13 and n23 latencies of STB evoked VEMP recorded in the present study were similar to those results mentioned above.

As for VEMP interpeak amplitudes, in order to determine interaural amplitude asymmetry of VEMP responses, an asymmetry ratio (AR) was calculated by formula similar to canal palsy (CP) calculation formula in caloric test. According to the reports of Lim et al [21] and Akin et al [22], VEMP interpeak amplitudes were related to sound stimulation magnitude and the level of SCM contraction during recording. In the present study sound stimulation magnitude was 100 dB nHL, so it was especially important to control the level of SCM background activation. Lim et al [21] pointed out that the changes in the levels of SCM activation did not influence VEMP latencies but actually affected VEMP interpeak amplitudes. Due to individual variances and differences in the level of SCM activation during recording, there were large differences in VEMP peak to peak amplitudes reported in different laboratories. Wang et al [15] indicated that mean VEMP peak to peak amplitudes were 116.5 μV, whereas Zhou et al [20,23] showed that mean VEMP peak to peak amplitudes were 257.47 μV. Furthermore, the present study found that mean VEMP peak to peak amplitudes were 169.70±38.50 μV. Therefore the present study suggested that VEMP should be interpreted with the AR rather than raw amplitude in order to remove the effect of different raw amplitudes resulting from different levels of SCM activation. Up to now, the AR, instead of absolute peak-to-peak amplitude, has been used for determining side differences in cases of Meniere's disease and vestibular neuritis. According to the results of the present study, AR larger than 34% might mean the clinical significance of difference between bilateral saccule function. This was consistent with the results reported by Zhou et al [20,23], Young et al[24-25] and Murofushi et al[17-18].

VEMP testing is a diagnostic non-invasive, easy to perform and reproducible technique to assess about vestibular pathophysiology, which complements the classical studies for vestibular function. The combination of VEMP and caloric testing can provide comprehensive vestibular function for military pilots. The present study has established normal values of VEMP parameters and provided solid data support for the application of VEMP testing in the medical selection and physiological assessment of Chinese air force fighter pilots. In the future, VEMP testing in abnormal saccular function patients should be performed in order to obtain the optimal cut-off point for the reference value of VEMP parameters. The effect of gender and age on VEMP parameters and the sensitivity and specificity of the normal values of VEMP parameters established by the present study in the diagnosis of pilots with vertigo also should be investigated.

Fig 1 Vestibular evoked myogenic potentials (VEMP)recording sample in a jet fighter pilot. Active electrode was placed on the upper one-third of bilateral SCM with the reference electrode on the anterior margin of the clavicle and the ground electrode on the forehead.

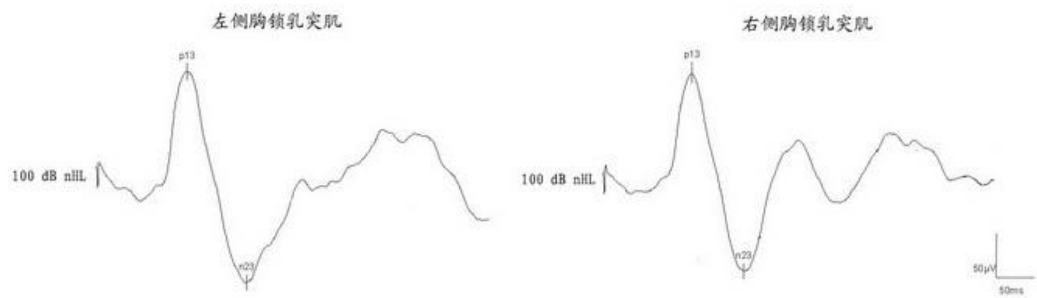

Fig 2 Typical example of VEMP responses obtained in bilateral SCM by air conducted tone-burst (500 Hz) stimulation

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