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Normative data for P1/N1-latencies of vestibular evoked myogenic potentials induced by air- or bone-conducted tone bursts

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Abstract

Objective: The response characteristics of acoustically elicited vestibular evoked myogenic potentials (VEMPs) largely depend on the stimuli applied. A tone-burst stimulation of 500 Hz seems to be clinically most appropriate because those VEMPs can be elicited at the lowest stimulus intensity possible. The aim of the present paper was to describe normative data for tone-burst evoked VEMPs.

Methods: VEMPs of 64 healthy subjects were recorded ipsilaterally during air- or bone-conducted tone burst stimulation. The EMG of the tonically activated sternocleidomastoid muscle was recorded ipsilaterally by surface electrodes. Averages were taken for P1/N1-latencies and -amplitudes of male and female volunteers within 3 different age groups.

Results: The latencies did not show any significant differences between female and male volunteers or between air- and bone-conducted stimulation. The latencies did also not show any significant difference among the 3 age groups. The limits for normal latencies (mean + 2 SD) are, therefore, 20.3 ms for P1 and 28.0 ms for N1. Although the P1/N1-amplitudes were decreased with increasing age, the tonic muscle activity was not significantly different between the age groups.

Conclusions: The present findings strongly suggest the evaluation of VEMP latencies by using normative values obtained exactly with the same stimulus parameters.

Significance: Normative data as described in the present study are required to detect isolated saccular defects which are indicative of a vestibular disorder.

Keywords: VEMP; Air conduction; Bone conduction; Latency; Normative values

1. Introduction

Vestibular testing in humans includes the examination of the vestibulo-ocular, vestibulospinal and the vestibulocollic (VCR) reflexes (Akin and Murnane, 2001; Colebatch and Halmagyi, 1992; Ernst et al., 2005) in clinical practice. The VCR could be indicative of otolith (saccular) function and can be elicited by high-level clicks or tone bursts (McCue and Guinan, 1994; Murofushi et al., 1995; 1999; Sheykholeslami et al., 2000; Zapala and Brey, 2004), by mechanically tapping on the forehead (Halmagyi and Colebatch, 1995; Halmagyi and Curthoys, 1999) or by galvanic stimulation (Monobe and Murofushi, 2004; Murofushi et al., 2002).

The motor response of the VCR can be recorded as a short-latency vestibular evoked myogenic potential (VEMP) from different muscles of the neck (e.g. sternocleidomaostoid muscle (SCM), trapezoid muscle). Acoustically elicited VEMPs are meanwhile frequently used in clinical practice to evaluate the function of the VCR. However, it has been shown that the response characteristics (i.e. latencies, amplitudes) largely depend on the stimuli applied. Tone-burst evoked VEMPs have lower stimulus thresholds than click-evoked ones (Welgampola and Colebatch, 2001a; Welgampola et al., 2003). A tone-burst stimulation of 500 Hz seems to be clinically most appropriate because those VEMPs can be elicited at the lowest stimulus intensity possible (Akin and Murnane,

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2001; Welgampola and Colebatch, 2001b). Moreover, the latencies of the VEMP components (P1, N1) depend largely on the stimulus design (click or tone-burst) and the frequency applied (Akin and Murnane, 2001; Su et al., 2004; Zapala and Brey, 2004). Akin and Murnane (2001) demonstrated clearly that the P1/N1 latencies of the same subject were 10.9/17.7 ms for clicks and 18.3/25.5 ms for tone-bursts at 250 Hz, 14.3/20.3 ms for tone-bursts at 500 Hz and 12.5/17.3 ms for tone-burst stimulation at 1000 Hz. In addition to this methodological bias, age-related changes of the vestibular system can possibly interfere with VEMP recordings. Aging of the vestibular system is characterized by a decrease of vestibular hair cells (Merchant et al., 2000), Scarpa's ganglion cells (Velazquez-Villasenor et al., 2000) or cells of the vestibular brainstem (Tang et al., 2001). Click-evoked VEMPs, however, remained unchanged when comparing 4 different age groups (Su et al., 2004). Age-related changes of P1/N1 latencies have already been described providing a 250 Hz tone-burst stimulation was used (Zapala and Brey, 2004). Unfortunately no normative data for P1 and N1 latencies of tone-burst evoked VEMP's are available till now.

The aim of the present paper was to describe gender and age related normative data for P1/N1 latencies of tone-burst (500 Hz) evoked VEMPs. In patients with a conductive hearing loss (i.e. an air-bone gap), bone-conducted tone-bursts have to be applied to elicit VEMPs. Therefore, air and bone conducted stimuli (500 Hz) were applied in this study.

The study protocol was approved by our Institutional Review Board. The subjects gave their written, informed consent to participate in the study.

2. Methods

Sixty-four subjects without any history of ear, nose, throat disease nor of any vestibular disorder (20–76 years, 38 females (43.7 years $\pm$ 12.6) and 26 males (49.6 years $\pm$ 14.6)) participated in the study. The whole study sample was divided into the following age groups:

Group I: 20–40 years ($n=23$),
Group II: 41–60 years ($n=21$) and
Group III: >60 years ($n=20$).

All volunteers were examined by otoscopy before the examination. VEMPs were recorded ipsilaterally during acoustic stimulation. The stimuli (tone bursts, 500 Hz, 7 ms duration, 5/s) were delivered by a Viking IV system (Viasys Healthcare Corp., USA), monaurally, either via insert tips (Type Tip 300, 115 dB SPL) or a bone conductor (Type B-70B (Radioear Corporation), 140 dB FL, driving voltage 20 V (peak to peak)) placed at the mastoid directly behind the auricle. The stimulators were calibrated in accordance with the ISO 389 international standard. The EMG of the SCM was recorded ipsilaterally by surface electrodes. The active electrode was placed over the middle of the SCM and the reference electrode over the upper sternum. The ground electrode was placed at the forehead. The resulting impedance of the recording electrodes were maintained below 3 kΩ by cleaning the skin with a peeling gel.

The subjects had to turn the head to the contralateral shoulder before starting the measurement and hold this position exactly in place to achieve a constant tonic activation of the SCM (50–200 μV) during the whole recording period. The tonic EMG activity was recorded before the stimulation and the mean value of the activity range was calculated within a 100 ms time window. EMG signals were amplified (5000$\times$), averaged (130$\times$), filtered (bandpass 20–1500 Hz) and recorded with the Viking IV. Each individual recording from the subjects was repeated twice and the obtained data were averaged for P1/N1 latencies. Data are given as mean ($\pm$SD).

Statistical analysis was performed as group comparison by means of the Chi-square test or ANOVA in dependence of the data distribution and homogenicity of variances. Differences between VEMPs as generated by air- and bone conduction were analyzed with the *t*- or *U*-test (depending on the data distribution). The tested significance level was $P<0.05$ (SPSS 10.0).

3. Results

In all subjects, VEMPs could be successfully recorded bilaterally by the different stimulation methods (air- and bone conduction). A typical example of the VEMP responses obtained is depicted in Fig. 1. The P1/N1 latencies did not show any statistically significant differences between female (16.3 $\pm$ 2.3/23.9 $\pm$ 2.0 ms) and male (15.9 $\pm$ 1.9/23.6 $\pm$ 2.4 ms) subjects. In addition, the differences between VEMP latencies as generated by air- and bone-conducted auditory stimulation were also not statistically significant. The P1/N1 mean values were 16.0 ($\pm$2.0) /23.5 ($\pm$2.3) ms for air conduction and 16.3 ($\pm$2.2)/24.1 ($\pm$2.1) ms for bone conduction. Subsequently, the data could be pooled for further analysis. The P1/N1 latencies did not show any statistically significant differences among

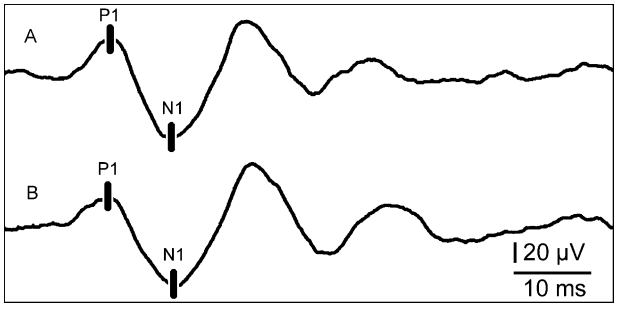

Fig. 1. Typical example of VEMP responses obtained by (A) air conducted or (B) bone-conducted tone-burst (500 Hz) stimulation.