Characterization of age-related changes in vestibular evoked myogenic potentials

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Abstract. A tone-burst stimulation of 500 Hz seems to be clinically most appropriate to elicit vestibular evoked myogenic potentials (VEMPs) because those VEMPs can be recorded at the lowest stimulus intensity possible. However, little is known about gender and age-related changes of the amplitude in tone-burst (500 Hz) evoked VEMPs. The aim of the present paper was therefore to investigate the influence of gender and age on VEMP amplitude in relation to the tonic muscle activity.

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 with surface electrodes. Averages were taken for P1/N1 amplitudes of male and female volunteers within 3 different age groups.

Although the amplitude decreased with increasing age the tonic activity was not significant different between the age groups. Consequently the relation between VEMP amplitude and tonic muscle activity decreased with increasing age. The normative values of the age-dependent relation between VEMP amplitude and tonic muscle activity were described by the 90% confidence interval of the individual values. Normative thresholds were calculated. Normal saccular receptor function could be diagnosed if the VEMP amplitude is above (or equal to) the normative value at a given tonic muscle activity and age.

Keywords: VEMP, amplitude, tonic muscle activity, normative values

1. Introduction

The vestibulocollic reflex (VCR) can be elicited by high-level clicks or tone bursts [9,12,13,16,23], by mechanically tapping on the forehead [7,8] or by galvanic stimulation [11,14]. 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. Anatomical and physiological data suggest that the origin of the reflex arch is the saccular macula. Fibres of the inferior vestibular nerve, which originates in the saccule [9], increase their firing rate during the application of high-level auditory clicks [9,12]. Further the bipolar electrical stimulation of the human inferior vestibular nerve can induce VEMPs at the ipsilateral side [3].

However, it has been shown that the VEMP response characteristics (i.e. latencies, amplitudes) largely depend on the stimuli applied. Tone-burst evoked VEMPs have lower stimulus thresholds than click-evoked ones [20,22]. 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 [1,21]. Moreover, the latencies of the VEMP components (P1, N1) depend largely on the stimulus design (click or tone-burst) and the frequency applied [1,17,23]. In addition to this methodological bias, age-related changes of the vestibular system can possibly interfere with VEMP recordings. How-
ever, earlier studies, which investigated normative data, showed that P1/N1 latencies (tone-burst stimulation 500 Hz) are not age dependent [4]. But little is known about age-related changes of the amplitude in tone-burst (500 Hz) evoked VEMPs. The aim of the present paper was therefore to investigate the influence of gender and age on P1/N1-amplitude and to evaluate the diagnostic value of the VEMP amplitude for the saccular function.

2. Methods

Sixty-four subjects without any history either of ear, nose, and throat disease or of any vestibular disorder (20–76 years, 38 females (43.7 years ± 12.6) and 26 males (49.6 years ± 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: 60–76 years (n = 20).

All volunteers were examined by otoscopy before the examination. VEMPs were recorded ipsilaterally during acoustic air and bone conducted stimulation. The stimuli (tone burst, 500 Hz, 7 ms duration, 5/s) were delivered by a Viking IV system (Viasys Healthcare Corp., USA) monaurally either through insert tips (Type Tip 300, 115 dB SPL) or a bone conductor (Type B-70B, 140 dB FL) placed at the mastoid directly behind the pinna.

The EMG of the SCM was recorded ipsilaterally with 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 was 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 EMG signals were amplified (5000x), averaged (130x), filtered (bandpass 20–1500 Hz) and recorded with the Viking IV.

The EMG, which was recorded before the patient turned the head to the contralateral shoulder and within each pre-stimulus period, was analysed (normalized and averaged) and the difference between both mean values was used as the tonic EMG level.

Each individual recording from the subjects was repeated twice and the obtained data were averaged for P1/N1 amplitudes. Data are given as mean (± SD).

Statistical analysis of the P1/N1 amplitudes and EMG-levels was performed as group comparison by means of the Chi-square test or ANOVA (factors were gender, age and stimulation mode). Differences between VEMPs as generated by air- and bone conduction were analysed with the t- or U-test (depending on the data distribution). The tested significance level was p < 0.05 (SPSS 10.0).

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

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 amplitudes did not show any statistically significant differences between female and male subjects (Table 1). In addition, the differences between VEMP amplitudes as generated by air- and bone-conducted auditory stimulation were also not statistically significant (Table 1).

The P1/N1 amplitudes show statistically significant differences among the three age groups (Table 1). Although the amplitude decreased with increasing age the tonic activity was not significant different between the age groups (Table 2). There was also no significant difference between the tonic muscle activity of male and female volunteers (mean: female 127.3 ± 53.2 µV, male 136.8 ± 61.9 µV).

Consequently the relation between VEMP amplitude and tonic muscle activity decreased with increasing age (Table 2). The age-dependent relation between VEMP amplitude and tonic muscle activity within the investigated population is shown in Fig. 2. In addition to the linear regression line the 90% confidence interval of the individual values is indicated. The lower border of each confidence interval can be described by the following arithmetic functions:

- 20–40 years: \( y = 0.4527x – 42.318 \)
- 41–60 years: \( y = 0.3703x – 41.044 \)
- 60–76 years: \( y = 0.2213x – 23.183 \)

By means of these equations age-related normative values for VEMP amplitudes were calculated for a
Table 1
Average values of VEMP P1/N1 amplitudes calculated gender and stimulus related (air- or bone conduction) in 3 age groups

<table>
<thead>
<tr>
<th>age group</th>
<th>VEMP-amplitude in µV</th>
<th>air conduction</th>
<th>bone conduction</th>
<th>male</th>
<th>female</th>
</tr>
</thead>
<tbody>
<tr>
<td>20–40</td>
<td>73.8 ± 45.5*</td>
<td>60.2 ± 33.2*</td>
<td>69.8 ± 51.4*</td>
<td>65.8 ± 34.6*</td>
<td></td>
</tr>
<tr>
<td>41–60</td>
<td>45.0 ± 33.2*</td>
<td>34.6 ± 17.2</td>
<td>37.5 ± 22.9</td>
<td>42.1 ± 30.0*</td>
<td></td>
</tr>
<tr>
<td>60–76</td>
<td>35.8 ± 20.8</td>
<td>35.9 ± 22.9</td>
<td>37.2 ± 18.3</td>
<td>32.8 ± 28.5</td>
<td></td>
</tr>
</tbody>
</table>

*Indicates significant differences (p < 0.05).

Table 2
Relation between average values of VEMP P1/N1 amplitudes and EMG-tonic activity (sternocleidomastoid muscle) calculated in 3 age groups

<table>
<thead>
<tr>
<th>age group</th>
<th>tonic activity in µV</th>
<th>VEMP-amplitude in µV</th>
<th>ratio amplitude/tonic activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>20–40</td>
<td>139.8 ± 64.0</td>
<td>73.8 ± 45.5*</td>
<td>1:2</td>
</tr>
<tr>
<td>41–60</td>
<td>117.1 ± 41.3</td>
<td>45.0 ± 33.2*</td>
<td>1:3</td>
</tr>
<tr>
<td>60–76</td>
<td>138.0 ± 61.0</td>
<td>35.8 ± 20.8</td>
<td>1:4</td>
</tr>
</tbody>
</table>

*Indicates significant differences (p < 0.05).

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

number of tonic muscle activity values (Table 3). The minimum of tonic muscle activity for a VEMP generation is therefore 93.5 µV (20–40 y), 104.8 µV (41–60 y) and 110.8 µV (60–76 y).

4. Discussion

The present study used acoustic stimuli (500 Hz, tone bursts) delivered through air- or bone conduction to further characterize the resulting P1/N1 amplitudes in VEMP recordings of three different age groups. It could be shown that the stimuli (air- or bone conducted) as well as the gender do not affect the VEMP amplitude. This is in accordance to earlier studies with click-evoked VEMPs [15]. The fact that we could prove a clear effect of age on the P1/N1 amplitude is also in line with previous results. These studies showed that the amplitudes of click- [15,17] or tone- [23] elicited VEMPs significantly depend on the patients’ age (negative correlated).

It is well known that VEMP amplitudes are linearly dependent on the tonic activity of the SCM [2,5,22]. In the present study, the decrease of VEMP amplitude with increasing age could be confirmed. However, the tonic muscle activity was not significantly different between the investigated age groups. That why the quotient between VEMP amplitude and tonic activity decreased significantly with increasing age. This effect is possible caused by the decrease of vestibular hair cells [10], Scarpa’s ganglion cells [19] and cells of the vestibular brainstem [18] during the aging process.

In clinical practice, the pathophysiological state of the saccular macula should be analysed with VEMP testing [6]. The VEMP amplitude is probably more affected by a partial loss of saccular function than the latencies. That’s why the arithmetic function of the confidence interval (lower border) within the amplitude/tonic muscle activity relationship was used in the present study to calculate normative values of the VEMP amplitude. This values show on the one side that in healthy volunteers no VEMP response could be
Fig. 2. Age-dependent relation between VEMP amplitude and tonic muscle activity within the investigated population (A: 20–40 years; B: 41–60 years; C: 60–76 years). The linear regression line with the related R-square (coefficient of determination) and the 90% confidence interval of the individual values are indicated.
elicited if the age specific tonic muscle activity is below a minimal value. If this is not considered during testing, the danger of an underestimation of saccular function is given. On the other side the saccular receptor function is partial impaired if the VEMP amplitude is elicited if the age specific tonic muscle activity is below the normative value at a given tonic muscle activity and age.

The present paper describe that the VEMP-amplitude strongly depends on the age of the patient and the tonic muscle activity during the measurement. However, the evaluation of P1/N1 amplitudes by using normative values is only possible, if the VEMPs are elicited exactly with the same stimulus parameters.

Normative data as described above are required to detect isolated saccular defects, which are indicative of a vestibular disorder.

Acknowledgement

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References

