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Research paper

Changes in cochlear function related to acoustic stimulation of cervical vestibular evoked myogenic potential stimulation

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A B S T R A C T

Evaluation of cervical evoked myogenic potentials (c-VEMP) is commonly applied in clinical investigations of patients with suspected neurotological symptoms. Short intense acoustic stimulation of peak levels close to 130 dB SPL is required to elicit the responses. A recent publication on bilateral significant sensorineural hearing loss related to extensive VEMP stimulation motivates evaluations of immediate effects on hearing acuity related to the intense acoustic stimulation required to elicit c-VEMP responses. The aim of the current study was to investigate changes in DPOAE-levels and hearing thresholds in relation to c-VEMP testing in humans. More specifically, the current focus is on immediate changes in hearing thresholds and changes in DPOAE-levels at frequencies 0.5 octaves above the acoustic stimulation when applying shorter tone bursts than previously used. Hearing acuity before and immediately after exposure to c-VEMP stimulation was examined in 24 patients with normal hearing referred for neurotologic testing. The stimulation consisted of 192 tonebursts of 6 ms and was presented at 500 Hz and 130 dB peSPL. Békésy thresholds at 0.125–8 kHz and DPOAE I/O growth functions with stimulation at 0.75 and 3 kHz were used to assess c-VEMP related changes in hearing status. No significant deterioration in Békésy thresholds was detected. Significant reduction in DPOAE levels at 0.75 (0.5–1.35 dB) and 3 kHz (1.6–2.1 dB) was observed after c-VEMP stimulation without concomitant changes in cochlear compression. The results indicated that there was no immediate audiometric loss related to c-VEMP stimulation in the current group of patients. The significant reduction of DPOAE levels at a wider frequency range than previously described after the c-VEMP test could be related to the stimulation with shorter tone bursts. The results show that c-VEMP stimulation causes reduction in DPOAE-levels at several frequencies that corresponds to half the reductions in DPOAE levels reported after exposure to the maximally allowed occupational noise for an 8 h working day. Consequently, extended stimuli intensity or stimulation repetition with c-VEMP testing should be avoided to reduce the risk for noise-induced cochlear injury.

1. Introduction

Cervical vestibular evoked myogenic potentials (c-VEMP), are inhibitory surface potentials of the sternocleidomastoid (SCM) muscle elicited when sacculus is stimulated by intense air conducted clicks (Colebatch et al., 1994) or tonebursts (Young, 2006). The use of the c-VEMP test has become a standard procedure in detection of semicircular canal dehiscence syndrome (SCDS) and is useful in evaluation of saccular and inferior vestibular nerve function (Murofushi et al., 1999; Ochi et al., 2003). An assymetric large response or a low threshold for eliciting the response is suggestive of SCDS that may present with autophonia, sound induced vertigo

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and pulse-synchronous tinnitus with or without the typical audiometrical hallmarks of a third window lesion (Brantberg et al., 2001). The c-VEMP test allows convenient bedside detection of SCDS with better accuracy than high resolution CT scans that tends to overestimate the occurrence of SCDS (Re et al., 2013). A problematic aspect of c-VEMP testing is the intense sound stimulation required to elicit reproducible responses (Young, 2006). Short tone bursts share similarities with impulse noise that is known to be hazardous to hearing (Kryter et al., 1966; Hamernik et al., 1991; Mäntysalo and Vuori, 1984). Moreover, even if there are no reports of adverse hearing advents, the risk of negative effects in patients susceptible to noise induced hearing loss cannot be excluded hence the motivation for systematic evaluations of the effects of c-VEMP stimulation on hearing.

During calibrations that preceded this work the equivalent A-weighted sound pressure during standardised c-VEMP testing at our clinic using tone bursts of 6 ms at 500 Hz and 133 dB SPL as recommended in the literature (Isaradisaikul et al., 2012) was found to be 105.7 dB (A) with silent rests included. Despite routinely daily use of c-VEMP test we have had no reports of adverse hearing advents. However, recently, a case of significant bilateral noise induced hearing loss related to extended c-VEMP exposure was reported (Mattingly et al., 2015).

One study has evaluated the effect of the intense sound levels during c-VEMP stimulation (Krause et al., 2013). This study demonstrated significant immediate reduction of 0.5–3 dB in DPOAE levels at 6 kHz after the c-VEMP test, but did not find any significant reduction in DPOAE levels at other frequencies or threshold shift in the post exposure audiometry performed 24 h after the c-VEMP test. Noteworthy is that 27% of the test subjects reported transient muffled hearing immediately after exposure and that these individuals exhibited the largest reduction in DPOAEs.

In the light of recent animal studies indicating that completely reversible noise induced temporary audiometric shifts can be accompanied by progressive synaptic loss between inner hair cells and the auditory nerve (Kujawa and Liberman, 2009) the issue of the effect of c-VEMP stimulation merits further attention. The current study focuses on immediate audiometric effect of c-VEMP stimulation to enable relevant comparisons to known immediate effects of other borderline hazardous noise exposures. C-VEMP tone bursts of 2–10 ms have been reported to evoke stable responses (Welgampola and Colebatch, 2005; Murofushi et al., 1999). The effect of tone bursts with duration of 10 ms was investigated by Krause et al. (2013) but it remains to elucidate if tone bursts of shorter duration and rise time affect the hearing acuity differently.

The largest temporary threshold shifts after acoustic overstimulation with narrow band or tonal signals with center frequency over 250 Hz appears at 0.5 octaves above the stimulation frequency (Mills et al., 1979). A similar 0.5 octave shift is described for OAEs after temporary acoustic overstimulation at 1.4 kHz (Marshall and Heller, 1998) and 2 kHz in humans (Engdahl and Kemp, 1996) and 4 kHz in chinchillas (Harding and Bohne, 2004). Therefore, the current study aimed to evaluate unforeseen effects in DPOAE amplitudes at 750 Hz corresponding to 0.5 octave above the c-VEMP test stimulus tone bursts of 500 Hz. DPOAE measurements were also made at 3 kHz to validate the absence of DPOAE reductions in this region after the c-VEMP test as reported by Krause et al. (2013).

2. Aim of the study

The aim of the study is to investigate if repeated low frequency toneburst of c-VEMP stimulation with duration of 6 ms induce measurable changes in the inner ear as measured by behavioral hearing thresholds and DPOAEs. The behavioral hearing thresholds are obtained at 0.125–8 kHz while DPOAEs are measured at 750 Hz, which is ½ octave above the exposure frequency, and at 3 kHz. The focus is on the region ½ octave above the exposure frequency of 500 Hz and at 3 kHz as well as potential immediate post exposure shifts in hearing thresholds. A secondary aim is to investigate the slope of the DPOAE I/O function before and after c-VEMP test to detect post-exposure related changes in cochlear compression.

3. Materials and methods

The study was approved by the local ethical committee approved the study.

3.1. Participants

Patients that were referred to c-VEMP evaluation at our tertiary referral center by their otoneurologist were consecutively invited to participate in the study. All recruitment of participants and testing occurred at the Department for hearing and equilibrium disorders at Karolinska University Hospital.

Inclusion criteria were:

- Age between 18 and 50 years,
- Hearing thresholds equal or better than 20 dB HL at all tested frequencies between 0.125 and 8 kHz in the test ear.

Exclusion criteria were:

- Conductive hearing loss defined as more than 10 dB air-bone gap at 2 consecutive frequencies.
- Abnormal otoscopy or a middle ear pressure outside 100 daPa on the test day.

The right ear was chosen for the testing. If the threshold at any frequency was worse than 20 dB HL on the right ear, the left ear was tested if it met the inclusion criteria.

Twenty-six patients consented to participate in the study. Two were excluded due to problems related to fitting of the probe. In total, 17 women and 7 men with a mean age of 37 years participated in the study, with 21 right ears and 3 left ears.

3.2. Test setup

The hearing acuity was assessed before and after the c-VEMP test using two methods:

1. Hearing thresholds at frequencies between 0.125 and 8 kHz were measured according to the Békésy procedure.
2. DPOAE I/O functions at 0.75 kHz (half an octave above the sound exposure frequency) and at 3 kHz.

A Tucker–Davis System 3 and a MATLAB script on a PC controlled signal generation and recordings. The signal from the ER 10B + microphone was pre-amplified and then passed through an anti-aliasing low-pass filter before being digitized and stored on disk. DPOAE recordings were made for primary frequencies with geometrical means of 0.75 kHz and 3 kHz and with a stimulus frequency ratio of $f_2/f_1 = 1.25$. The intensity of L1 was 50–80 dB SPL in steps of 5 dB and L2 was 10 dB below L1. The DPOAE-values were averaged for 3.3 s for each stimuli level and frequency. The noise estimate was based on the average of three frequency bins on both sides of the f_{dp} frequency bin.

Behavioral thresholds were determined by a fixed-frequency Bekesy procedure at 0.125, 0.25, 0.5, 0.75, 1, 1.5, 2, 3, 4, 6 and 8 kHz. Each frequency threshold was determined from five lower