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Relative diagnostic value of ocular vestibular evoked potentials and the subjective visual vertical during tilt and eccentric rotation

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ABSTRACT

Objective: We compared vibration-induced ocular vestibular evoked myogenic potentials (OVEMPs) with the visual vertical during whole-body roll tilt and eccentric rotation in healthy subjects and patients with unilateral vestibular loss, to determine which test was most sensitive in discriminating impaired utricle function.

Methods: OVEMPs and the visual vertical were measured in 11 patients and 11 healthy subjects. Visual vertical was measured during roll tilts between −9.6° and 9.6°, and during rotation at 400°/s with the head upright and the vertical rotation axis located between ±3.5 cm from the head center.

Results: OVEMPs in patients were strikingly asymmetric, whereas they were approximately symmetric in healthy subjects. Patients showed impaired visual vertical gain during eccentric rotation and increased errors for both roll tilt and eccentric rotation tests. OVEMPs were superior at discriminating between patients and healthy subjects, although eccentric rotation performed nearly as well.

Conclusions: OVEMPs provide a powerful test for discriminating between healthy subjects and patients with chronic unilateral vestibular loss, and testing the visual vertical testing during eccentric rotation was superior to testing during whole-body roll tilt.

Significance: OVEMPs are easier to administer, less demanding on patients, and in general are more effective at identifying chronic unilateral vestibular loss than visual vertical measurements.

1. Introduction

Our sense of head orientation in space is heavily dependent upon gravity sensors in the inner ear, the otoliths. These are comprised of two sensors that are approximately planar structures most sensitive to changes in linear acceleration parallel to their plane. The utricle is positioned roughly in the transverse (horizontal) plane, whereas the saccule is oriented roughly in the sagittal (vertical) plane. A change in head roll will change the response of each otolith, and the combined output of these sensors is the primary determinate of perceived head roll.

A traditional test of otolith function is the subjective visual vertical (SVV), where patients adjust a visible line to perceived vertical. The SVV can reliably identify acute vestibular disorders (Dieterich and Brandt, 1993), because an asymmetric otolith response produces a perceived head tilt. The SVV reflects the processing of otolith information by cortex. More recently, the SVV has been used during eccentric rotation (Clarke et al., 2001; Hong et al., 2009), which has the benefit that the centrifugation can selectively stimulate the left or right otolith, whereas tilting stimulates both otoliths. The somatosensory vertical during eccentric rotation has also been suggested as a test to identify unilateral vestibular dysfunction (Clement and Deguine, 2010). These tests have several limitations, most notably the requirement of patient participation and cost (in the case of eccentric rotation), but also the possibility that the other healthy sensory systems could compensate for otolith dysfunction in chronic cases ("central compensation") (Cnyrim et al., 2007; Hong et al., 2009; Strupp et al., 1998).

New tests of otolith function have been recently discovered which could overcome some of these problems. Ocular vestibular evoked myogenic potentials (OVEMPs) are the electromyographic responses from the inferior oblique and inferior rectus extraocular muscles as a result of loud, short duration sound or vibration (Jombik and Bahyl, 2005; Rosengren et al., 2005; Todd et al., 2007). Vibration-induced OVEMPs are thought to predominately assess utricular function (Curthoys, 2010b; Iwasaki et al., 2009), and are promising because they allow the selective testing of the

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response of either the right- or left-sided utricle (healthy subjects produce symmetric responses (Iwasaki et al., 2007); patients with unilateral vestibular response loss show asymmetrical responses (Iwasaki et al., 2007, 2008), and patients with bilateral vestibular loss do not show OVEMPS (Iwasaki et al., 2008)), they require little active participation by the patient, and can be performed in most patients.

Our purpose was to evaluate the diagnostic value of vibration-induced OVEMPs compared to the visual vertical under various conditions by measuring patients with chronic unilateral vestibular loss, and comparing the results with healthy subjects.

2. Methods

2.1. Subjects

Eleven healthy subjects (mean age = 43, standard deviation = 10) with no reported history of vestibular, auditory, neurological, or visual problems were studied. Eleven patients (mean age = 51, standard deviation = 16), in whom medical history and ancillary tests indicated persistent peripheral vestibular hypofunction, and who experienced symptoms of unilateral vestibular loss for at least 3 months participated (Table 1). The age difference between the patient and control groups was not significantly different (t-test, $t = 1.4$, $p > 0.15$). In each patient, vestibular loss was diagnosed by means of caloric irrigation, search-coil head impulse test, and air conducted sound cervical VEMPs. Impaired hearing or deafness was found in the patients with vestibular schwannoma, Ménière's disease, Zoster oticus, and otitis media with involvement of the inner ear. Some of these patients were repeatedly examined in our vestibular outpatient clinic, particularly those with Ménière's disease; in this case, the results of the most recent examination was considered and included in Table 1. Overall, however, head impulse testing, cervical VEMPs, and caloric testing were not re-administered immediately prior to the OVEMP and SVV, because peripheral vestibular dysfunction was regarded as irreversible and persistent.

The experiments conformed to the principles of the Declaration of Helsinki and were approved by the Local Ethics Committee. Subjects gave written consent after the experimental procedure had been explained.

2.2. OVEMPs

2.2.1. Equipment

Subjects lay supine with their head supported on a small pillow. The skin beneath the eyes and on the chin was cleaned with Abrasive Skin Prepping Gel (Nuprep, USA), and five surface electrodes were applied. For each eye the active (−) electrode was placed with the center of the electrode approximately 1 cm below the lower eyelash line. Reference electrodes (+) were placed 2 cm below the active electrodes. The center of each electrode was placed in line with the pupils, while the subjects were fixing straight ahead at point on the ceiling. Grounding was done with an electrode on the chin, or in patients with beards, on the chest.

Vibration stimuli were produced with a hand-held 4810 mini-shaker (Bruel and Kjaer, Naerum, Denmark). A 15 mm long bolt was attached to the mini-shaker, and capped with 17 mm diameter Bakelite cap that was the contact point with the head. The vibration produced by the mini-shaker was three cycles of a 500 Hz stimulus, repeated 3.1 times per second for approximately 21 s. To estimate the intensity of the stimulus, an accelerometer was attached to the skin behind the ear in one subject, and we recorded peak accelerations of about 5 m/s^2 in the interaural direction, 3.7 m/s^2 in the naso-occipital direction, and 2.6 m/s^2 in the dorsal–ventral direction.

2.2.2. Recording

Proper placement of the electrodes was checked by having subjects make small vertical saccades; if the responses from the electrodes beneath the left and right eyes were markedly different, the electrodes were removed and re-applied, and the proper placement checked again. During OVEMP measurements, subjects were asked to remain relaxed and to look up to a target on the ceiling about 28° up from straight ahead. The mini-shaker was placed on the forehead, in the midline about at the level of the hairline. Stimulations were performed at least twice.

2.2.3. Analysis

Signals were bandpass-filtered (1–250 Hz), and voltages from each electrode were aligned with vibration onset and averaged. We measured the difference between baseline voltage, measured just after the delivery of the stimulus, to the negative potential peak 10 ms after stimulus onset (N10), and the positive trough about 5 ms later (P15) (see Fig. 1A). P15 was occasionally difficult to identify (Fig. 1B, for example), in which case we took the first trough no earlier than 15 ms after stimulus onset. The neural projections underlying vibration-induced OVEMPs are thought to be primarily crossed, (Iwasaki et al., 2009), so potentials from the left eye represent right utricular function and vice versa. We used a standard Jongkees-type formula for asymmetry calculations in vestibular testing by comparing the magnitude of the N10 response in the left and right eyes:

Table 1
Patient characteristics.

P #	Diagnose	Time since onset or surgery	Age/side	hHIT gain, left/right	Canal paresis factor, (calorics) %	CVEMP asymmetry,%
1	Vestibular schwannoma	3 months	45/R	**0.51**/**0.31**		**100**
2	Vestibular neuritis	6 months	63/R	**0.64**/**0.27**	**100**	12
3	Vestibular neuritis	6 months	25/L	**0.37**/**0.56**	**49**	28
4	Zoster oticus with inner ear infection	18 months	73/L		**100**	**100**
5	Menière/gentamicin	4 years	55/L	**0.36**/**0.65**	**100**	**100**
6	Vestibular schwannoma	9 months	31/R			**100**
7	Acute otitis media with inner ear infection	3 years	37/R	0.72/**0.33**		100
8	Vestibular neuritis	3 months	52/L	**0.41**/1.09	**75**	13
9	Menière disease	32 years	54/R	0.78/**0.64**	**48**	**49**
10	Vestibular neuritis	14 years	76/L	**0.25**/**0.67**	**87**	8
11	Vestibular schwannoma	18 years	52/R	**0.57**/**0.21**		**100**

P, patient; R, right; L, left. Abnormal values in **bold**. hHIT: horizontal head impulse test, normal ⩾0.7. CP: canal paresis factor; normal ⩽25%. Air conducted sound CVEMP, normal ⩽35%.