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Electrode montage and gaze effects on ocular vestibular evoked myogenic potentials (oVEMPs)

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HIGHLIGHTS

- oVEMPS were recorded using 5 electrodes around the orbital rim.
- Bipolar montages had better selectivity than a chin reference.
- A mid-lateral electrode location showed the most consistent latency and gaze effects.

ABSTRACT

Objectives: To investigate the properties of lateral electrode locations compared to the conventional ones and to bipolar compared to chin-referenced montages for recording ocular vestibular evoked myogenic potentials (oVEMPs).
Methods: A total of 18 subjects were studied using 5 electrode locations around the eye, including the conventional location and more lateral ones (i.e. M, ML and L electrodes near the orbital margin, R_1 and R_2 electrodes below the two more medial ones). Unilateral air-conducted (AC) sound, bone-conducted (BC) impulses at the mastoid and BC vibration (500 Hz) at the forehead were used. These were applied while the subjects looked in neutral gaze and with 4 levels of increasing elevation. A subset of 10 subjects were also studied when looking downwards at 4 levels. Five bipolar montages were created offline by subtraction.
Results: The M and ML electrodes had the largest responses but responses were seen for all 5 electrodes. The chin reference was associated with substantial pickup from the contralateral side (as judged using unilateral AC stimulation). The M-R_1 (conventional) montage showed a significantly non-linear response to gaze angle, unlike the ML montages. The ML-R_1 montage gave the largest responses. There was a clear change in latency for the conventional montage with downgaze for the AC and BC impulsive stimuli.
Conclusions: The ML active electrode has a more stable n1 latency, a larger and a more linear response to gaze angle than the conventional recording site, probably due to contamination by pickup of inferior rectus activity when using the conventional site.
Significance: The ML location is a better site for the active pickup for recording oVEMPs if the main object of study is the inferior oblique muscle and particularly if subjects have difficulty with upgaze.

1. Introduction

Excitation of the inferior oblique (IO) muscle is chiefly responsible for the oVEMP response (Weber et al., 2012), and it has been demonstrated that oVEMP amplitudes increase with up-gaze, consistent with increasing tonic activation of the IO muscle which acts to extort and elevate the eye (Govender et al., 2009; Weber et al., 2012; Rosengren et al., 2013). Rosengren et al. (2005) initially showed that the largest amplitudes were elicited when active electrodes were placed inferiorly, closest to the eye, when compared to 15 other positions on the face, and using a reference of linked earlobes. Todd et al. (2007) and Iwasaki et al. (2007) used a more selective bipolar montage to eliminate contributions from muscle activity in nearby muscle groups. These two studies resulted in the currently widely used

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oVEMP montage which consists of an active electrode directly below the eye in the neutral position, located on the infraorbital margin with a reference electrode placed approximately 2 cm below (referred to here as the conventional montage).

Sandhu et al. (2013) recently investigated the effects of lateral and medial variations for the active electrode in the infra-orbital plane and the effects of repositioning the reference electrode to the inner canthus while having the active electrode lateral to the orbital midline (the 'belly-tendon' montage). While they found that this 'belly-tendon' montage produced significantly larger n10 amplitudes compared to the conventional montage, they cautioned that the larger amplitudes may simply reflect an increased sensitivity to signals from adjacent extraocular muscles, indicating a lack of selectivity for the IO muscle. They also showed that the active electrode in a slightly lateral position produced the largest averaged amplitude. Selectivity of recordings is important – wider electrode separation potentially allows pickup from both eyes, which will obscure laterality (Rosengren et al., 2005).

This study aimed to compare oVEMPs using bipolar electrode pairs over different sites. We sought to investigate the observations of Sandhu et al. (2013) by comparing the oVEMPs obtained using more lateral locations and by examining the changes with gaze elevation. This approach could potentially identify electrode pair montages that might produce larger oVEMP reflexes. We also assessed selectivity for detecting a single ocular source. These findings are particularly relevant for the air-conducted (AC) sound-evoked oVEMP which, while valuable in the detection of vestibular disease (Welgampola et al., 2008; Curthoys et al., 2011), is not always detectable, particularly in older subjects (Chihara et al., 2007; Iwasaki et al., 2008; Rosengren et al., 2011; Curthoys, 2012; Colebatch et al., 2013).

2. Methods

2.1. Subjects

Eighteen healthy subjects (42 ± 21 yrs; range: 22–79; 10 females and 8 males) were recruited and tested for the main experiment. These subjects had no history of inner ear pathology, neurological illness or conductive hearing loss. Consent was obtained from all participants prior to the start of the experiment and the study was approved by the local ethics committee.

2.2. Stimulation techniques

oVEMPs were elicited using air-conducted (AC) sound and two types of bone-conducted (BC) stimuli: BC 500 Hz at the forehead and BC impulses at the mastoid. AC stimuli comprised of 2 ms (0 ms rise/fall time), 500 Hz sinusoidal tone bursts of alternating polarity delivered to each ear using calibrated headphones (THD-49, Telephonics Corp., Farmingdale, NY, USA). Intensities used for AC sound were 105–110 dB L_{Aeq} (134–139 dB peak SPL at approx 5 Hz). BC stimulation utilised a minishaker (model 4810, Brüel and Kjaer P/L, Denmark) with an attached perspex rod (diameter 2.5 cm, length 9.5 cm). For both types of BC stimulation the polarity of the stimulus was initially in the "positive" direction (i.e. movement of the perspex rod away from the motor, towards the subject, accelerating the subject away from the minishaker). The minishaker was mounted on a customised stand which used a pulley system with a counterweight of 1–2 kg to deliver a constant force for the duration of the recording (Todd et al., 2008). The waveforms used for BC stimuli were 500 Hz sinusoids applied at the forehead and a third order gamma distribution for mastoid stimulation (Ross, 2007) as these appear to have different selectivities for the two otolith organs (Govender et al., 2015). The peak intensities used for BC were 136 dB pFL for BC (mastoid) impulses at the mastoid (10 V peak drive) and 143 dB pFL for 500 Hz forehead (AFz) stimulation (20 V peak drive). Stimuli were generated by customized software and amplifier using a micro1401 interface (Cambridge Electronic Design, Cambridge, UK) and presented at a rate of 5 Hz.

2.3. Electrode montages

Twelve self-adhesive electrodes (Cleartrace 1700-030, Conmed Corp., NY, USA) were used for the recordings; ten active electrodes (five beneath each eye), with a common reference electrode placed at the chin and an earth electrode positioned on the suprasternal notch (Fig. 1A). The M (medial) electrode was located below the centre of the eye, the L (lateral) electrode on the outer canthus and the ML (mediolateral) electrode halfway along the circumference of the orbit between the M and L electrodes, over the zygoma. All lay just outside the orbital rim. The M and ML electrodes each had another electrode 2 cm below them (R_1 and R_2 respectively). The M and R_1 electrode locations correspond to those commonly used to record oVEMPs ("conventional location"). Electrode pairs referenced to the chin were subtracted using custom MATLAB

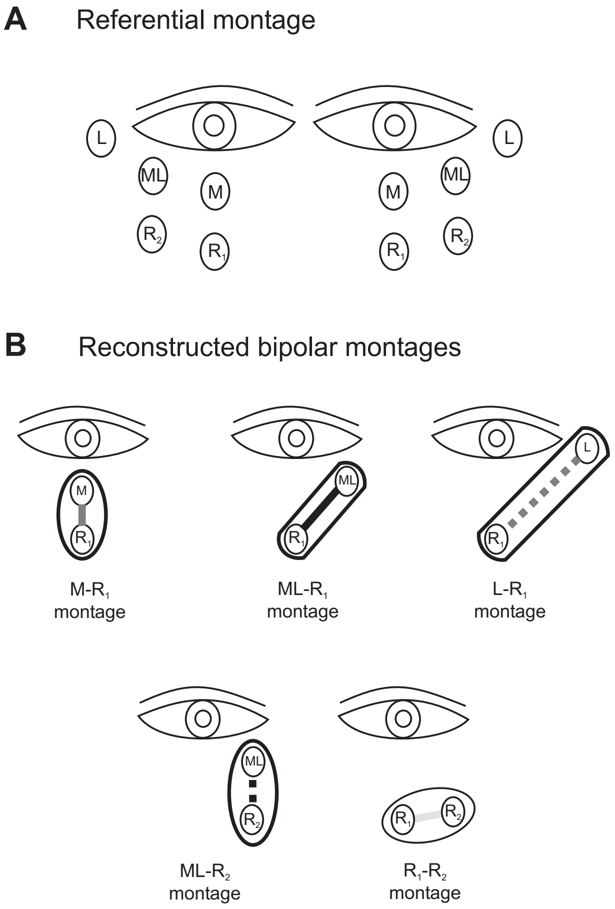

Fig. 1. (A) The locations of the ten electrodes positioned beneath both eyes. A common reference electrode (placed on the chin) and an earth electrode (positioned on the suprasternal notch) were also used (not shown). Three electrodes were positioned closest to the eyes along the inferior and lateral aspects of the orbital rim. The first electrode (M; medial) was positioned directly beneath the eye in the neutral position, on the orbital rim. The third electrode (L; lateral) was positioned just lateral to the outer canthus while the second electrode (ML; mediolateral) was placed midway along the orbital rim between the M electrode and the L electrode. Two electrodes were also placed approximately 2 cm directly below electrodes M and ML and were referred to as R_1 and R_2 respectively. (B) Illustrates the M-R_1, ML-R_1, L-R_1, ML-R_2 and R_1-R_2 montages that were constructed from the original recordings by subtraction.