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Ocular vestibular evoked myogenic potentials to head tap and cervical vestibular evoked myogenic potentials to air-conducted sounds in isolated internuclear ophthalmoplegia

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HIGHLIGHTS

- Patients with isolated internuclear ophthalmoplegia (INO) frequently show abnormal ocular vestibular evoked myogenic potentials (VEMPs) in response to forehead tapping in the lesion side.
- The medial longitudinal fasciculus (MLF) appears to contain the fibers for the otolith-ocular reflex from the contralateral ear.
- The abnormal cervical VEMPs in some patients with isolated INO suggest a modulatory pathway for the inhibitory sacculocollic reflex descending in the MLF.

ABSTRACT

Objective: The central pathways responsible for ocular vestibular evoked myogenic potentials (VEMPs) to forehead tapping remain to be determined. This study aimed to determine whether the medial longitudinal fasciculus (MLF) carries the signals for ocular VEMPs (oVEMPs) in response to this mode of stimulation.

Methods: Twelve patients with isolated unilateral internuclear ophthalmoplegia (INO) due to brainstem infarction underwent evaluation of the ocular tilt reaction (ocular torsion and skew deviation), tilt of the subjective visual vertical (SVV), cervical VEMPs (cVEMPs) in response to tone burst sound, and oVEMPs induced by tapping the forehead.

Results: Eight (67%) patients showed abnormal oVEMPs that included no wave formation ($n = 4$) and decreased amplitude ($n = 3$) in the lesion side, and bilaterally absent responses in the remaining patient. Furthermore, the patients showed diminished oVEMPs responses in the lesion side compared with normal side (6.0 ± 5.6 vs. 11.7 ± 5.5 μV, paired *t*-test, $p = 0.001$) and increased IAD_{amp}(%) of the oVEMPs compared with normal controls (43.6 ± 41.2 vs. 9.1 ± 6.2, *t*-test, $p = 0.018$). In contrast, cVEMPs were abnormal in only three (25%) patients, decreased ($n = 2$) or no response in the lesion side. Eleven (92%) patients showed contraversive ocular tilt reaction or SVV tilt.

Conclusion: Patients with INO frequently show impaired formation of ipsilesional oVEMPs in response to forehead tapping. The occasional abnormality and decreased amplitude of ipsilesional cVEMPs also suggest a modulatory pathway for the inhibitory sacculocollic reflex descending in the MLF.

Significance: This study suggests that the MLF contains the fibers for the otolith-ocular reflex from the contralateral ear.

1. Introduction

Head tapping, along with both air-(AC) or bone-conducted sounds (BC) may elicit vestibular evoked myogenic potentials (VEMPs) in the contracting sternocleidomastoids (SCM, cVEMPs) or extraocular muscles (oVEMPs) (Colebatch et al., 1994; Halmagyi

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et al., 1995; Iwasaki et al., 2008; Rosengren et al., 2005, 2010; Rosengren and Kingma 2013; Todd et al., 2007, 2008a,b). Conventional cVEMPs are known to be mediated by the inhibitory vestibulocollic reflex that originates from the ipsilateral saccule. The central pathway for cVEMPs appears to be the medial vestibulospinal tract that descends within the medial longitudinal fasciculus (MLF) (Kim et al., 2010; Murofushi and Curthoys, 1997; Murofushi et al., 1995, 1996). However the central pathway responsible for oVEMPs elicited by forehead tapping remains to be determined. Given that oVEMPs are known to be mediated by the crossed otolith-ocular reflex pathway (Iwasaki et al., 2007), the MLF may contain the fibers associated with oVEMPs. Indeed, oVEMPs in response to AC were reported abnormal in up to 60% of the patients with internuclear ophthalmoplegia (INO) due to multiple sclerosis (MS) (Rosengren and Colebatch, 2011). However, the associated symptoms indicated that the lesions were not confined to the MLF in those patients (Rosengren and Colebatch, 2011). Furthermore, the potential dissemination of the lesions in MS limits the localization of the responsible lesion for abnormal oVEMPs in MS.

In this study, we determined whether the MLF carries the signals for oVEMPs elicited by forehead tapping by measuring this otolith-ocular reflex in patients with isolated INO due to restricted brainstem infarctions that were confirmed by MRI.

2. Methods

2.1. Subjects

From June 2011 to August 2012, we prospectively recruited 12 patients (8 men, mean age = 59.6 ± 13.3) with isolated INO due to brainstem infarctions that were confirmed by MRI (Fig. 1). The INO was diagnosed based on adduction paresis or the slowing of adducting saccades along with dissociated abducting nystagmus in the other eye during attempted horizontal gaze (Fig. 2). All patients underwent recording of eye movements, evaluation of the ocular tilt reaction (OTR; based on ocular torsion and skew deviation), audiometry, bithermal caloric tests, and measurements of the subjective visual vertical (SVV), cVEMPs elicited by AC and oVEMPs induced by forehead tapping within one week of symptom onset.

All experiments followed the tenets of the Declaration of Helsinki, and the study was approved by the Institutional Review Board of Seoul National University Bundang Hospital.

2.2. Recording of cVEMPs

cVEMPs were recorded with the subject supine on a bed with the head raised approximately 30° from the horizontal and rotated contralaterally in order to activate the sternocleidomastoid (SCM) muscles. The surface electromyographic (EMG) activity was measured from an active electrode placed over the belly of the contracted SCM and from a reference electrode located on the medial clavicle. A ground electrode was attached to the forehead. cVEMPs were recorded using a Nicolet Viking Select unit (Nicolet-Biomedical, Madison, WI, USA). A short burst of alternating tone (110 dB nHL, 123.5 dB SPL, 500 Hz, rise time = 2 ms, plateau = 3 ms, and fall time = 2 ms) was applied at 2.1 Hz monaurally via a headphone. The analysis time for each stimulus was 50 ms and responses elicited by up to 80 stimuli were averaged for each test. The signal was bandpass filtered at 30–1500 Hz, and the mean values of at least two trials were obtained from each ear for all

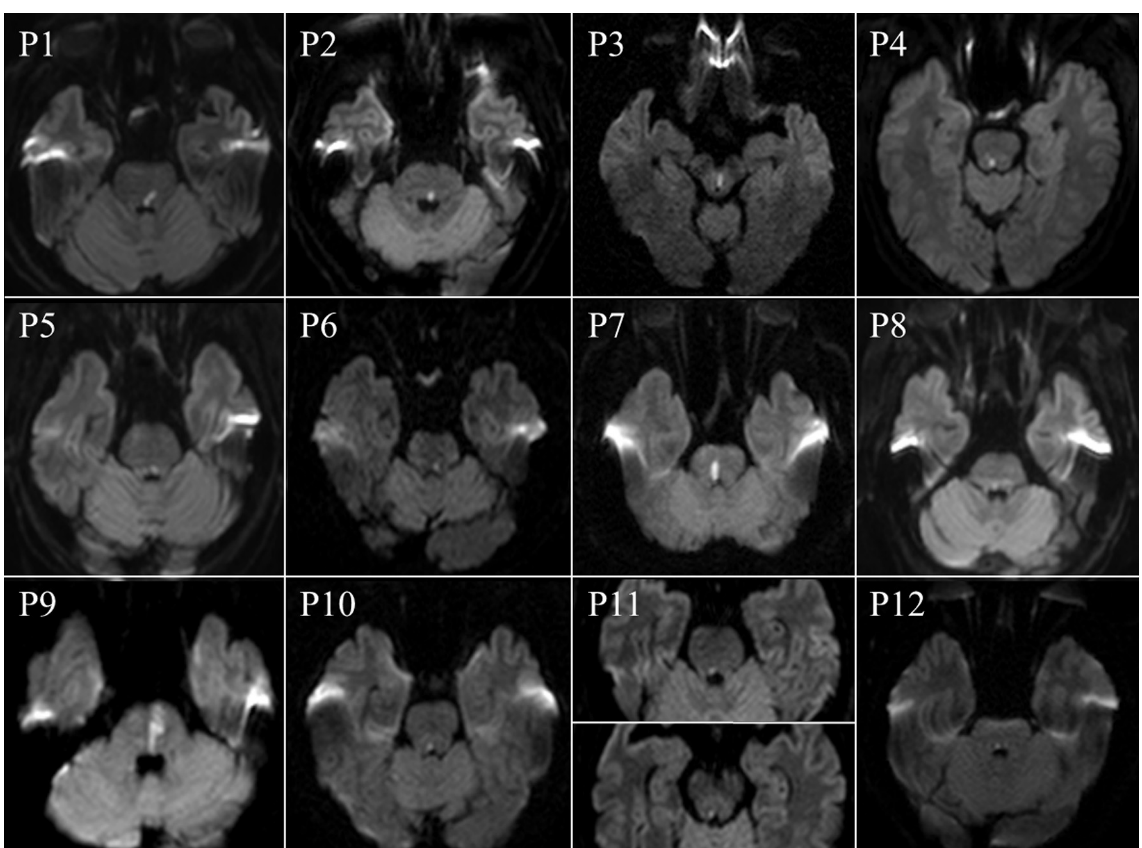

Fig. 1. MRIs of patients. All the patients show a discrete infarction involving the brainstem, the pons in 10, the midbrain in 1 (patient 3), and the pons and midbrain in another (patient 11). The number in each MRI indicates the patient number in Table 1.