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A New Application of Cervical Vestibular Evoked Myogenic Potential

Seyede Faranak Emami, Farhad Farahani, Mohammad Reza Nikoo

Hamadan University of Medical Sciences Iran

ABSTRACT

INTRODUCTION: Acoustic sensitivity of the human vestibular system has long been established and can be demonstrated by means of the cervical vestibular evoked myogenic potential or cVEMPs. The objective of this cross-sectional study is to investigate the possibility that the acoustic sensitivity of the saccule improves stapedial muscle reflex threshold.

MATERIAL&METHODS: Twenty healthy persons and twenty-five patients as having unilateral benign paroxysmal positional vertigo (BPPV) investigated in our audiology department (Hamadan, Iran). The assessments consisted of pure-tone audiometry, tympanometry, stapedial muscle reflex testing, video-nystagmography, cVEMPs.

RESULTS: We compare findings among the three groups (the healthy, the affected and the unaffected ears of the patients with unilateral BPPV). The affected ears had delayed latencies of first waveform of the cVEMPs with normal ipsilateral stapedial muscle reflex threshold to 1000, 2000 and 4000 Hz, but delayed to 500HZ. The healthy and the unaffected ears had normal findings. Multiple comparisons of mean p13 and mean n23 latencies between three groups were significant (P_{p13} = 0.037, P_{n23} = 0.041, ANOVA).

CONCLUSION: Acoustic sensitivity of the saccule improves stapedial muscle reflex threshold to low frequency. The new application of cVEMPs test is the prediction of the possibility of ipsilateral stapedial muscle reflex to 500 HZ.

Introduction:

When an power sound is presented to the ear, it triggers a series of sound-evoked muscle reflexes or sonomotor responses (e.g. auropalpebral, stapedial, acoustic jaw reflexes and inion potential) (1). These responses can be detected the cranial musculature and are believed to be the basis of the so-called cortical responses to auditoty stimulation (2). The sonomotor responses simply constitute a component of the auditory muscle or startle reflex (1). An example of a sonomotor response generated by stimulation of the vestibular system is the cVEMPs, which is clearly ipsilateral dominant (2). The saccule is the peripheral generator of the first waveform of the cVEMPs. The saccule lies beneath the stapes and is the vestibular end organ most sensitive to sound (1-3). Neurons from the saccule that respond to tilts also respond to acoustical stimulation. The best frequency of saccular afferents to air-conducted sound are around 500 Hz (3).

Since both vestibular (saccule) and auditory (cochlea) transducers lie close to the stapes, it is reasonable to assume that sonomotor responses may be driven by acoustical stimuli that stimulate either the auditory or vestibular end organs (1), and another result is that the saccular projections may retain the ability to trigger stapedial muscle reflex to 500 Hz (low frequency). Accordingly, the objective is to investigate the possibility that the acoustic sensitivity of the saccule improves stapedial muscle reflex threshold.

Materials and Methods:

2.1. Ethical Considerations. This study was on human subjects, so to minimize harms and risks and maximize benefits and respect human dignity, privacy, autonomy, immunity, safety, respectability, and satisfaction, we took human precautions with our groups and strived to distribute the benefits and burdens of research fairly.

In addition, our research did not present the work of others as their own or did not fail to give appropriate credit for the work of others through citations.

2.2. Participants. This cross-sectional study involved twenty healthy controls (11 females, 9 males), and twenty-five selected patients (14 females, 11 males) as having unilateral benign paroxysmal positional vertigo (BPPV). They evaluated in audiology department of Hamadan university of medical sciences, from march through july 2013 (Hamadan, Iran). The diagnose of patients with BPPV found on results of typical nystagmus (torsional up beating nystagmus with latency and fatigue lasting less than 1 min and subjective vertigo in the Dix-Hallpike) (4). They were treated with canalith repositioning maneuver (CRM) on the side determined by Dix-Hallpike test (the mean of repetition of CRM was 2.1 with intervals of 3 days).

The inclusion criteria involved normal hearing and normal function of middle ear pressure with abnormal cVEMPs findings in unilateral BPPV patients. The exclusion criteria were conductive hearing loss (which can interfere with cVEMPs measurement) and conditions that can cause vertigo. This list included neurotologic problems (vestibular neurinitis, vestibular ototoxicity, and labyrinthitis); cardiac and/or metabolic diseases (orthostatic hypotension, heart failure, anemia, hypothyroidism, hyperthyroidism, diabetes mellitus, hypertension); and various neurological diseases (vertebrobasillar insufficiency, temporal lobe epilepsy, multiple sclerosis, central nervous system tumors, and cerebellar infarction).

2.3. Assessment. For evaluation of agreement between observers and equipment, the calibration of our instruments (LABAT evoked potential recorder, MADSEN diagnostic audiometer, HOMOTH impedance meter) had been keep under control. All of the tests performed on same day and performed bilaterally and consisted of pure tone audiometry (normal hearing thresholds in 250 , 500, 1000, 2000, 4000 and 8000 Hz = 0 to 15 dB HL) (5), tympanometry (normal middle ear pressure = ± 50 dapa) (6), ipsilateral stapedial muscle reflex testing (normal threshold in 500 to 4000 Hz = 85 to 100 dB Spl) (7), video-nystagmography (to eliminate any additional vestibular pathology) (8) , and cVEMPs (500 Hz air-conducted bursts, 120 dB SPL, rise/fall time = 1 ms, plateau = 2 ms, grand-averaged = 200, filtering = 20 - 20000 Hz, Which presented to the ear ipsilateral to the contracted sterno-cleido-mastoid muscle) (2).

Results:

All analysis was done by means of the statistics software SPSS17. Data expressed as mean ± standard deviation and as percentages. Kolmogorov-Smirnov test used for evaluation of normal test distribution. One-way ANOVA was to compare findings among the three groups (the healthy, the affected and the unaffected ears of the patients with unilateral BPPV). Tukey's least significant difference (Tukey HSD) test was chosen as the post hoc test. P-value of < 0.05 considered to indicate statistical significance.

We investigated forty-five volunteers (90 ears total) consisted of twenty healthy persons (mean age 31 years and range 18 to 40 years) compared to twenty-five selected patients (mean age 35 years and range 29 to 45 years) as having unilateral BPPV on the right side (25 out of 86 screened BPPV cases).

The latencies (p13, n23) and amplitude of the cVEMPs (p13-n23) were detectable in all healthy persons (table-1). They had normal values of ipsilateral stapedial muscle reflex threshold to 500, 1000, 2000 and 4000 Hz (table-2).

The affected ears of the patients with BPPV (n = 25) had delayed latencies of the cVEMPs (table-1). They also presented normal ipsilateral stapedial muscle reflex threshold to 1000, 2000 and 4000 Hz, but delayed to 500 HZ (mean = 115 dB Spl, 105 to 120 dB Spl) (table-2). The unaffected ears of the patients with BPPV (n= 25) presented normal findings of the cVEMPs (table-1), with normal ipsilateral stapedial muscle reflex to 500, 1000, 2000 and 4000 Hz.

Multiple comparisons of mean p13 and mean n23 latencies between three groups were significant (P_{p13} = 0.037, P_{n23} = 0.041, One-way ANOVA test). Comparisons of mean p13 and mean n23 latencies in the affected ears vs the healthy ears were significant (P_{p13} = 0.044, P_{n23} = 0.046, Tukey HSD), and neither differences of p13-n23 amplitude were significant (P > 0.05 for both). Since, the affected and the unaffected ears belong to the same individuals (matched ears). So, there would be no differences between these two regarding sex or age. Also, there were no significant differences in age and sex between the affected and the healthy ears (P > 0.05 for all, one-way ANOVA test).

Discussion:

We found the mean p13 and n23 latencies in the affected ears were slightly longer than the respective means in the healthy ears. A noticeable outcome of our findings was higher threshold of ipsilateral stapedial muscle reflex to 500 HZ. Therefore, we must defined why a person with abnormal saccular function might obtained an increased acoustic reflex threshold to 500 Hz (low frequency)? The inference is that there is an association between the saculue and the stapedius muscle and the saccular tuning curve partially but not completely overlaps stapedius tuning curves.

It is important to note the afferent part of the acoustic reflex also goes from the stimulated cochlea via the auditory nerve to the ipsilateral ventral cochlear nucleus (7). The afferent limb of the cVEMPs (the saccular projections) which are mainly in the inferior vestibular nerve run to the vestibular nuclear complex (3) and also into the ventral cochlear nucleus (9). The efferent limb influence on muscles by way of the medial and lateral vestibulospinal tracts (1) which are thought to mediate sonomotor responses (e.g. stapedial reflex) (1,2). Then, resembling to cochlear nuclei, vestibular nucleus neurons are sound sensitive (3,10).

Also, there is similar functions between two organs, for example like to saccular excitation by sound (3), the stapedius muscle is elicited by relatively high stimulus levels and its magnitude grows with increasing stimulus level (11). The phonetic role of saccule is in the regulation of the human voice and phonemic self-regulation (12). Saccular responses may be obtained to an individual's own vocalizations, particularly for singing (13). Also, the contraction of the stapedial muscle is elicited by eating, talking, yelling, and other vocalizations and reduces the noises produced by these activities which would have otherwise compromised the alertness and the sensitivity to salient aspects of the acoustical environment (7).

Saccule is an ancestor reinforcer for cochlea, which responds best to low frequency high-intensity sound and may contribute to the hearing of this frequency band (14). The stapedial muscle reflex actually acts to extend dynamic range. This feedback system can be expected to exert a greater effect on the representation of speech to loud sounds in human (7,11). The acoustic activation of the saccule can potentially contribute to auditory processing. The specific sensitivity of the saccule in the low frequency range, and its representation in cortical areas suggests the integration of the saccular information in neuronal networks (15,16). It may be effective to frequency discrimination of loud tones (17). Also, stapedial muscle reflex may serve an anti-masking function of low frequency on high frequency tones (e.g., reducing the masking produced by one's own speech). The latter constitutes an improvement in signal-to-noise ratio, and speech perception (11).

It has been mentioned that stapedial muscle reflex can not be measurable in twenty eight percent of normal population (7). It is important to note what verily were their criteria to description of normal population? Indeed, if they had been used of the cVEMPs testing in their measurements, the percent of absent responses truly should be decreased. However, the acoustic sensitivity of the saccule retains an ability to trigger ipsilateral stapedial muscle reflex to low frequency and the saccular afferents may give rise to a response in excitation of the stapedius.

Conclusion:

The cVEMPs is one of the vestibular tests which can evaluate saccular function and we strongly believe that the new application of this valuable test is the prediction of the possibility of ipsilateral stapedial muscle reflex to 500 HZ.

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Frequency (HZ)	Stapedial Muscle Reflex Threshold (dB)			
	Affected ear	Unaffected ear	Healthy ear	
500	**115**	90	95	
1000	100	95	90	
2000	95	100	100	
4000	95	100	95	

Table-2- The mean of ipsilateral stapedial muscle reflex threshold among the three study groups.

Variable	Healthy ears	Unaffected ears	Affected ears
P13 (ms)	12.06 ±	12.20 ±	14.05 ±
N23 (ms)	2.3	1.6	1.4
Peak to Peak Am-	20.16 ±	19.45 ±	22.62 ±
plitude (µv)	1.8	2.5	1.5
	66.18 ±	65.50 ±	63.08 ±
	20.6	19.8	11.7

Table-1- The mean of the right and left latencies and amplitudes of cervical vestibular evoked myogenic potentials (cVEMPs) in the healthy ears and the patients with BPPV (affected and unaffected ears).

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