Cervical and ocular vestibular evoked myogenic potentials test results in individuals with auditory neuropathy spectrum disorders

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Abstract

Auditory neuropathy spectrum disorder is a clinical disorder where the outer hair cell functioning is intact but the functioning of the auditory nerve is affected. Since, the 8th nerve is constituted by both the auditory and vestibular branch of nerve fibers, there are chances that the vestibular nerve might also be affected. Hence, the current study was carried out in order to determine the functioning of vestibular nerve in individuals with auditory neuropathy. A total of 11 participants were considered for the current study. Cervical vestibular evoked myogenic potentials (cVEMPs) and ocular vestibular evoked myogenic potentials (oVEMPs) were administered using the conventional protocol. In all the participants (100%) the oVEMPs were absent whereas in 20 ears out of 22 ears tested (90.90%) the cVEMPs were absent. The results of the present study indicate a high incidence of vestibular involvement in individuals with auditory neuropathy spectrum disorders. Also, it necessitates the inclusion of vestibular tests in the test battery used to assess individuals with auditory neuropathy spectrum disorder.

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Key words: auditory nerve, vestibular nerve, cervical vestibular evoked myogenic potentials, ocular vestibular evoked myogenic potentials, auditory neuropathy spectrum disorder.

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Introduction

The term *auditory neuropathy spectrum disorder* has been used to describe a form of hearing impairment in which outer hair cells function is normal, but afferent neural conduction in the auditory pathway is disordered.[1] The audiological findings that characterize the auditory neuropathy spectrum disorders are poor speech identification scores, presence of otoacoustic emissions/cochlear microphonics in the absence of auditory brainstem responses and acoustic reflexes.[1]

Eighth nerve consists of two components: the cochlear nerve and the vestibular nerve. In cases with auditory neuropathy spectrum disorder, the test findings have mostly been discussed in relation to the cochlear nerve and less attention has been paid to the evaluation of the vestibular branch of the 8th nerve. This may be due to the fact that most of the individuals with auditory neuropathy spectrum disorder do not report of any vestibular symptoms. There is sporadic information regarding vestibular abnormality in individuals with auditory neuropathy spectrum disorder either based on caloric test results or vestibular evoked myogenic potentials (VEMP) test results.[1-7] All these studies have indicated certain degree of vestibular abnormality with test findings obtained in caloric test results and cervical vestibular evoked myogenic potentials.

Vestibular evoked myogenic potentials are the commonly used test in the vestibular assessment which assesses the functioning of the otolith structures and its end organs.[8] There are two types of vestibular evoked myogenic potentials: cervical VEMPs (cVEMPs) and ocular VEMPs (oVEMPs). cVEMPs assess the functioning of the saccule and inferior vestibular nerve whereas oVEMPs assess the functioning of utricle and superior branch of the vestibular nerve.[8,9]

Since the vestibular branch of the eighth nerve is constituted by the superior vestibular nerve and inferior vestibular nerve, it is essential to know the pattern of neuropathic involvement of both superior and the inferior vestibular nerve components. cVEMPs primarily assess the inferior vestibular nerve and oVEMPs assess mainly the superior vestibular nerve, a combination of both the tests will provide a complete picture of the pattern of involvement in superior and the inferior vestibular nerve in individuals with auditory neuropathy spectrum disorder. The studies which have utilized a combination of cVEMPs and oVEMPs in various peripheral vestibular disorders such as Meniere's disease and Vestibular Neuritis have reported different sites of lesion in individuals with peripheral vestibular disorders.[10-12] Hence, a combination of cVEMP and oVEMP will give a holistic idea regarding the involvement of superior and inferior vestibular nerve in individuals with auditory neuropathy spectrum disorder. To the best of our knowledge this is the first study which has described the combination of cVEMP and oVEMP test findings in individuals with auditory neuropathy. However, there are few studies which have reported involvement of inferior vestibular nerve in individuals based on the results of cervical vestibular evoked myogenic potentials[4,5,13,14]

The aim of the study was to assess the functioning of the superior

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and inferior vestibular nerve fibers in individuals with auditory neuropathy spectrum disorders. The study also aimed at characterizing the different vestibular symptoms (if any) in individuals with auditory neuropathy spectrum disorders.

Materials and Methods

Participants

Control group

Total 11 participants (5 males and 6 females, n=22 ears) in the age range of 18 to 30 years were considered for the study. All the participants had bilateral normal hearing sensitivity as revealed by puretone audiometry. Additionally, these participants did not have any presence or history of any otological disorders. Also, these participants did not have any history/presence of any vestibular symptoms.

Experimental group

A total of 11 participants (4 males and 7 females, n=22 ears) in the age range of 15 to 28 years were considered for the study who had been diagnosed as having bilateral Auditory neuropathy spectrum disorder based on the criteria of normal outer hair cell function as evidenced by the preservation of otoacoustic emission (OAEs) and cochlear microphonics; abnormal auditory brainstem evoked potentials beginning with wave I of the auditory brainstem responses (ABR); poor speech identification; and absent acoustic reflexes to ipsilateral and contralateral tones. Prior to this, a detailed case history was taken regarding the signs and symptoms related to the vestibular disorders. Audiological test profiles of these clients have been given in Table 1.

Instrumentation

A calibrated two channel diagnostic audiometer, Madsen Orbiter 922 (G N Otometrics, Taastrum, Denmark) with TDH 39 headphones encased in MX 41AR (Telephonics, Farmingdale, NY, USA) ear cushion was used to obtain air-conduction thresholds and to perform speech audiometry. Bone conduction testing was done using Radio ear B-71 BC vibrator (Radioear, KIMMETRICS, Smithsburg, MD, USA). A Calibrated Grason Stadler Inc. - Tympstar middle ear analyzer (version 2.0) (GSI VIASYS Healthcare, WI, USA) was used to assess the middle

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Table 1. The details of the participants with auditory neuropathy spectrum disorder and the findings on the tests constituting the test battery.

Case no.	Ear	Age (years) /sex	Air conduction threshold*						Bone conduction threshold*					Immittance findings		OAE ++	ABR NR
			250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Tymp	Ref		
1	R	20/M	90	110	110 NR	110 NR	110 NR	100 NR	30	50	60 NR	60 NR	50 NR	A	NR	++	NR
	L		90	105	105	110	105	100 NR	30	50	60 NR	60 NR	50 NR	A	NR	++	NR
2	R	45/M	60	50	35	25	25	20	25	40	25	15	15	As	NR	++	NR
	L		65	45	30	30	30	30	25	45	15	25	20	A	NR	++	NR
3	R	19/F	30	20	20	35	40	25	15	10	10	20	30	As	NR	++	NR
	L		30	25	30	35	35	25	15	20	20	25	20	As	NR	++	NR
4	R	18/F	55	50	55	45	50	55	20	30	45	40	35	A	NR	++	NR
	L		50	50	50	40	40	40	15	35	35	30	25	As	NR	++	NR
5	R	23/F	60	60	65	55	60	70	25	45	50	45	50	As	NR	++	NR
	L		70	50	55	40	35	30	35	40	45	35	20	A	NR	++	NR
6	R	21/M	90	80	85	65	70	60	30	40	60	60	55	As	NR	++	NR
	L		90	75	75	60	30	30	30	35	60	50	20	As	NR	++	NR
7	R	16/M	85	70	75	70	65	50	25	50	55	60	60	A	NR	++	NR
	L		80	70	60	55	45	30	30	45	55	50	45	A	NR	++	NR
8	R	17/F	65	55	45	25	30	20	20	50	40	20	20	A	NR	++	NR
	L		60	40	25	30	40	20	25	25	20	20	30	As	NR	++	NR
9	R	18/F	55	50	60	50	30	20	30	30	45	40	20	As	NR	++	NR
	L		60	60	60	50	50	45	20	25	40	40	40	A	NR	++	NR
10	R	19/F	85	70	40	25	25	30	30	40	35	20	20	As	NR	++	NR
	L		70	65	25	20	25	25	30	25	15	15	20	A	NR	++	NR
11	R	19/F	55	35	30	25	15	10	20	20	25	25	10	As	NR	++	NR
	L		20	10	5	15	10	5	10	10	5	5	5	As	NR	++	NR

*Please note that all the air conduction and bone conduction thresholds are in dB HL. OAE, otoacoustic emission; ABR, auditory brainstem responses; Tymp, type of tympanogram; Ref, reflexes; ++, presence of otoacoustic emissions; NR: no response; R, right; L, left; A or As: type of tympanogram.

Table 2. Mean and standard deviations of latency and amplitude of cervical and ocular vestibular evoked myogenic potentials in control group.

	cVEMPs			oVEMPs		
	P1 latency (ms)	N1 Latency (ms)	P1-N1 amplitude (µv)	N1 latency (ms)	P1 latency (ms)	N1-P1 amplitude
Mean	13.48	20.31	47.40	9.15	13.60	6.47
SD	1.91	2.30	12.48	0.91	0.92	3.31

cVEMPs, cervical vestibular evoked myogenic potentials; oVEMPs, ocular vestibular evoked myogenic potentials; P1, positive peak; N1, negative peak; SD, standard deviation.

ear status and to rule out the middle ear pathology. ILO 292 V-6 (Otodynamics Ltd., Hatfield, Herts, UK) was used for recording of otoacoustic emissions. Intelligent Hearing System version 4.3.02 (Intelligent Hearing System, Florida, USA), with ER-3A Insert ear phone (Etymotic Research, Inc., Elk Grove Village, IL, USA) was utilized for recording of the auditory brainstem responses and cervical vestibular evoked myogenic potentials. oVEMPs were recorded using the Biologic Navigator (Natus Medical Incorporated, San Carlos, CA, USA) pro evoked potential system.

Test environment

All the tests were carried out in a well-illuminated air-conditioned rooms which was acoustically treated. The noise levels were within the permissible levels as recommended by the American Standard Institute (ANSI-S.3).[15]

Procedure

Audiological assessment

Pure tone audiometry was carried out for both the group using different pure tone frequencies from 250 Hz to 8000 Hz for air conduction and from 250 Hz to 4000 Hz for bone conduction to calculate the thresholds for air conduction and bone conduction respectively. Immittance audiometry was carried out in both ears using a probe tone frequency of 226 Hz and acoustic reflexes were measured for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz frequencies for ipsilateral and contralateral stimulations. Otoacoustic emissions were recorded using ILO 292 instrument (Otodynamics Ltd.). A non-linear method was utilized to record the OAE. The responses were recorded at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz and 4000 Hz frequency. Responses were accepted when the reproducibility was 80% or greater. Followed by this, ABR was recorded using clicks of 100 µs duration at 30.1/s repetition rate and with a filter setting of 100 to 3000 Hz. The electrodes were placed in the conventional method and responses were recorded in rarefaction polarity.

Cervical vestibular evoked myogenic potentials

During the cVEMP recordings, the participants were instructed to sit straight and turn their head to the opposite side of the ear in which stimulus was presented, so as to activate ipsilateral sternocleidomastoid muscle. A visual feedback was provided to the participant in order to maintain the tonicity of the sternocleidomastoid muscle for the cVEMPs. Non-inverting electrode (+) was placed in midpoint of the sternocleidomastoid muscle of the side being stimulated, inverting electrode (-) in sternoclavicular junction and ground electrode was placed on the lower forehead. Absolute electrode impedances and inter electrode impedances was maintained below 5000 ohms and 2000 ohms respectively. cVEMPs were recorded using 500 Hz tone burst (2 cycles rise, 0 cycles plateau, and 2 cycles fall, Blackman window) at a rate of 5.1/s using rarefaction polarity. A tone burst stimuli of 500 Hz was used as the 500 Hz tone burst stimulus gives better amplitude of the cVEMPs.[16] The stimuli were presented at 95 dBnHL intensity using ER-3A insert ear phones (Etymotic Research, Inc.). The responses were recorded for 50 ms post stimulus period along with the 10 ms pre-stimulus period and then amplified (X 5000) and band pass filtered between 30 to 1500 Hz. The responses were averaged totally for 200 stimuli.

Ocular vestibular evoked myogenic potentials

oVEMPs were recorded in the upper gaze direction. Participants were instructed to maintain the same upper gaze throughout the test run. Inverting electrode (-) was placed inferior to the lower eyelids of contra lateral eye to the side being stimulated, non-inverting electrode (+) was placed immediately inferior to the inverting electrode and ground electrode was placed on lower forehead. Absolute electrode impedances and inter electrode impedances was maintained below 5000 ohms and 2000 ohms respectively. 500 Hz tone burst (2 cycles rise, 0 cycles plateau, and 2 cycles fall, Blackman window) presented at a rate of 5.1/s using rarefaction polarity was used which was presented monaurally at a single intensity of 95 dBnHL using ER-3A insert ear

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Table 3. Vestibular signs and symptoms exhibited by clients and vestibular test results findings.

Case no.	Ear	cVEMPs	oVEMPs	Types of vestibular symptoms
1	R	AB	AB	No vestibular complaints
	L	AB	AB	
2	R	AB	AB	No vestibular complaints
	L	PR	AB	
3	R	AB	AB	c/o spinning sensation-objective type, for 2-3 min c/o weakness in lower limbs if mobile for long durations.
	L	AB	AB	
4	R	AB	AB	No vestibular complaints
	L	AB	AB	
5	R	AB	AB	No vestibular complaints
	L	AB	AB	
6	R	AB	AB	Complaint of imbalance while walking on uneven surfaces
	L	PR	AB	
7	R	AB	AB	c/o light headedness and blackouts, occasionally, 1-2 times/ month blurring of vision and burning sensation
	L	AB	AB	of eyes c/o weakness in lower limbs.
8	R	AB	AB	No vestibular complaints
	L	AB	AB	
9	R	AB	AB	c/o subjective spinning, swaying sensation, turning towards the left accompanied by nausea and vomiting, lasts for
	L	AB	AB	5 min 2-3 times/month, c/o blurring of vision, imbalance while walking, weakness in upper and lower limbs, difficulty breathing. o/E tremors of hand present
10	R	AB	AB	No vestibular complaints
	L	AB	AB	
11	R	AB	AB	c/o blurring of vision while gazing at objects for long accompanied by mild objective spinning
	L	AB	AB	

cVEMPs, cervical vestibular evoked myogenic potentials; oVEMPs, ocular vestibular evoked myogenic potentials; R, right; AB, absent; L, left; PR, present; c/o, complaint of; o/E, on examination.

phones (Etymotic Research, Inc.). A total of 200 stimuli were used for response averaging. The response was analyzed for 50 ms post stimulus period. A pre-stimulus period of 10 ms was utilized to record background electrical activity. The recorded electrical responses were amplified (X 5000) and band pass filtered between 1 Hz to 1000 Hz. oVEMPs responses were recorded twice in each ear to ensure the replicability of the responses.

Results

The results have been explained with reference to findings on audiological test results and vestibular evoked myogenic potentials in control as well as in participants with auditory neuropathy spectrum disorders.

Vestibular evoked myogenic potentials results in control group

For the participants in the control group, both cervical VEMP and ocular VEMP were present in all the ears (n=22). For cVEMPs latency of P1 and N1 and amplitude of P1-N1 complex were calculated whereas for oVEMPs, latency of N1 and P1 peaks and amplitude of N1-P1 complex were calculated. P1 is the positive peak which occurs at around 13 ms and N1 is the negative peak which occur around 23 ms in cVEMPs, whereas in oVEMPs N1 is the negative peak which occurs at around 10 ms and P1 is the positive peak which occurs around 14 ms. The mean and standard deviation for latency and amplitude of both cVEMP and oVEMP parameters are given in Table 2.

Vestibular evoked myogenic potentials results in experimental group

Both cVEMPs and oVEMPs were analysed for the participants with auditory neuropathy spectrum disorders. The results of cVEMPs and oVEMPs are discussed ahead. The audiological test details of all the participants with auditory neuropathy spectrum disorder are given in Table 1.

The results of the tests administered indicated the absence of responses for all the subjects on oVEMP where as the response was recordable in only two subjects (in only one of each of their ears) on cVEMP. Figures 1 and 2 show the patterns of recorded cVEMP and oVEMP waveforms respectively from individuals with auditory neuropathy.

Figure 3 shows a pie chart indicating the percentage of ears showing the percentage of presence and absence of cVEMPs and oVEMPs in the participants. Out of 22 ears tested for cVEMP and oVEMP, oVEMP was absent in all the participants, whereas, cVEMPs was present in one of the ears of two participants. It can be seen from Figure 1 that in 100 % of the subjects, the oVEMPs were absent whereas, cVEMPs were absent in 90.90% of the subjects. Additionally, we tried to characterize the types of vestibular symptoms in these individuals. The types of symptoms exhibited by the clients and the cVEMPs and oVEMPs test findings are given in Table 3. From Table 3 it can be seen that 6 (54.54%) out of 11 subjects did not report of any vestibular complaints whereas rest 5 (45.46%) of the subjects reported various types of vestibular symptoms. Thus, to summarize the results, in all the participants with auditory neuropathy, oVEMP is absent in both the ears and cVEMP is absent in 20 out of 22 ears tested. Also, around 55% of the participants showed no vestibular symptoms whereas the rest 45% of them showed at least one of the vestibular symptoms.

Discussion

In the present study, both the cVEMPs and oVEMPs were present for all the participants in the control group. The latency and amplitude values obtained for the cVEMPs and oVEMPs are almost similar to studies done on cVEMPs and oVEMPs earlier.[17] However, for individuals with auditory neuropathy spectrum disorders, in all the 22 ears (100%), the oVEMPs were absent, whereas, in 20 ears (90.90%) the cVEMPs were absent. The present results are suggestive of neuropathy of both the superior and the inferior vestibular nerve in addition to the involve-

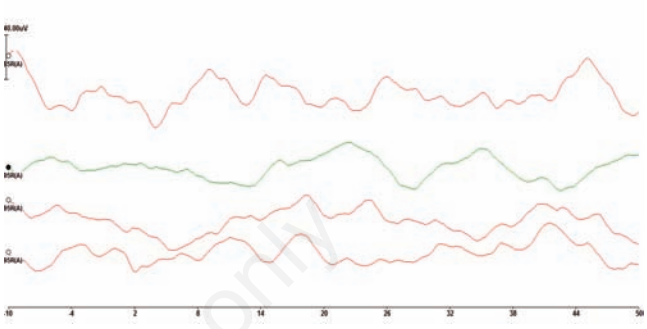


Figure 1. Absent cervical vestibular evoked myogenic potentials response in individuals with auditory neuropathy spectrum disorder.

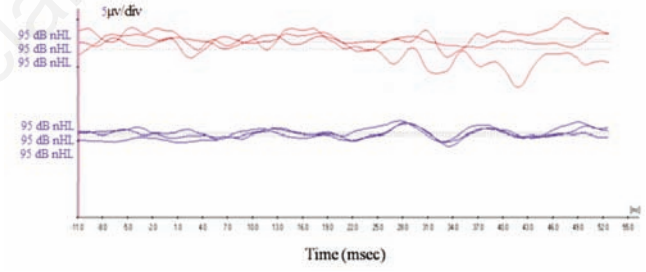


Figure 2. Absent ocular vestibular evoked myogenic potentials response in individuals with auditory neuropathy spectrum disorder.

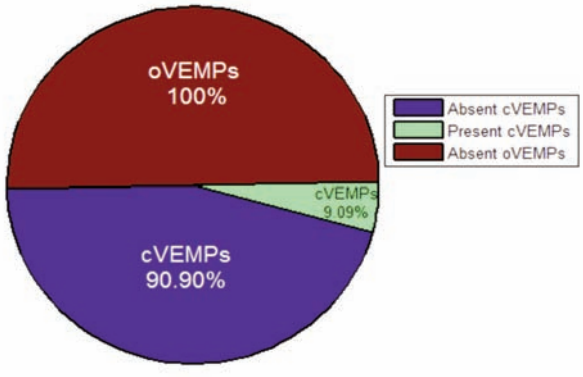


Figure 3. Pie chart indicating the percentage of ears showing presence and absence of responses on cervical vestibular evoked myogenic potentials (cVEMPs) and ocular vestibular evoked myogenic potentials (oVEMPs) in the individuals with auditory neuropathy spectrum disorder.

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ment of the cochlear branch of the auditory nerve. It has been reported that there are similarities in the vestibular hair cells and cochlear hair cells and the blood supply to both the systems.[18] As a result, the neuropathy of the cochlear branch of the auditory nerve may not occur in isolation.

These findings correlate with the anatomical changes found in the vestibular nerve in individuals with auditory neuropathy spectrum disorder.[18] It has been reported that the overall vestibular nerve population between the receptor organ and the ganglion within the internal auditory meatus is reduced in individuals with auditory neuropathy spectrum disorders.[18] In addition to this, the vestibular nerve shows an irregular beaded appearance in individuals with auditory neuropathy spectrum disorders.[18] Also, there is fragmentation of the myelin layer with gaps nearly equal to the diameter of the nerve fibers along with the distortion of the nerve structure in such individuals.[18] Such changes in the structure of the vestibular nerve probably existed in all the participants in the above study and could possibly explain the findings of absent caloric responses obtained in the current study.

The vestibular testing in individuals with auditory neuropathy is generally not carried out. This could be because of lack of information on vestibular symptoms exhibited by the individuals with auditory neuropathy spectrum disorders which may not prompt the clinician to administer the vestibular test battery. This is possibly due to the fact that the main complaint of such individuals may be poor comprehension rather than the vestibular symptoms. However, in the present study, 5 out of 11 subjects did report of the vestibular symptoms whereas, rest 6 of the subjects did not report of any vestibular symptoms.

Absence of vestibular symptoms in individuals with auditory neuropathy spectrum disorders also could be due to a bilateral distribution and slow progression of the neuropathy.[5,15] Also the central vestibular compensation which occurs via the propeoceptive and the visual systems might also account for subclinical nature of this disorder. Also, it is well known that the diameter of the vestibular nerve is slightly larger than the cochlear nerve fibers.[19] It is well reported that the conduction of the action potentials is faster in larger diameter neurons compared to the smaller diameter neurons.[19] Although, the demyelination would affect both cochlear and vestibular branches to an equal extent, the conduction of the action potentials would be affected more in cochlear branch compared to the vestibular branch. It can thus be hypothesized that the overt manifestation as well as progression of the auditory deficits would be earlier and greater than that of the vestibular symptoms; this is expected to therefore provide more opportunities for compensation to occur for the vestibular symptoms.

Conclusions

In the present study, the collective findings of the absence of both the cVEMPs and oVEMPs indicates a possible dysfunction of both the superior and inferior vestibular nerve fibers in individuals with auditory neuropathy spectrum disorders. In the present study we did not include any objective test to monitor the nystagmus in individuals with auditory neuropathy spectrum disorders, which would have excluded any other coexistent vestibular disorder. However, the main aim of the present study was to characterize the cVEMPs and oVEMPs finding in these participants. A group of studies (*e.g.* Sinha *et al.*[7]) have also not included any objective test and have characterized the vestibular abnormality based on either cVEMPs or caloric test. In all the participants with auditory neuropathy spectrum disorders along with the audiological testing, a vestibular testing should be carried out. This will help us better understand the pathophysiology in individuals with auditory neuropathy spectrum disorders.

References

1. Starr A, Picton TW, Sininger Y, Hood LJ, Berlin C. I. Auditory neuropathy. Brain 1996;119:741-53.
2. Fujikawa S, Starr A. Vestibular neuropathy accompanying auditory and peripheral neuropathies. Arch Otolaryngol Head Neck Surg 2000; 126:1463-56.
3. Sheykholeslami K, Kaga K, Murofushi T, Hughes DW. Vestibular function in auditory neuropathy. Acta Otolaryngol (Stockh) 2000; 120:849-54.
4. Sheykholeslami K, Schmerber S, Kermany MH, Kaga K. Sacculocollic pathway dysfunction accompanying auditory neuropathy: case report. Acta Otolaryngol (Stockh) 2005; 125:786-91.
5. Kumar K, Singh NK, Bharti AK, Sinha SK, Barman A. Vestibular evoked myogenic potential as a tool to identify vestibular involvement in auditory neuropathy. Asia P J Sp Lang Hear 2007; 10:181-7.
6. Sinha SK, Barman A, Singh NK, Rajeshwari G, Sharanya R. Involvement of peripheral vestibular nerve in individuals with auditory neuropathy. Eur Arch Otolaryngol 2012. [Epub ahead of print].
7. Sinha SK, Barman A, Singh NK, Rajeshwari G, Sharanya R. Vestibular test findings in Individuals with auditory neuropathy: review. J Laryngol Otol 2013; 127:448-51.
8. Halmagyi GM, Curthoys IS. Clinical testing of otolith functions. Ann N Y Acad Sci 1999; 871:195-204.
9. Rosengren SM, Todd NP, Colebatch JG. Vestibular-evoked extraocular potentials produced by stimulation with bone-conducted sound. Clin Neurophysiol 2005;116:1938-48.
10. Chiarovano E, Zamith F, Vidal PP, De Waele C. Ocular and cervical VEMPs: a study of 74 patients suffering from peripheral vestibular disorders. Clin Neurophysiol 2011;122:1650-59.
11. Jacobson GP, Mc Caslin DL, Piker EG, Gruenwald J, Grantham SL, Tegel L. Patterns of Abnormality in cVEMPs, oVEMPs, and caloric tests may provide topological information about vestibular impairment. J Am Acad Audiol 2011; 22:601-11.
12. Murofushi T, Nakahara H, Yoshimura E, Tsuda Y. Association of air-conducted sound oVEMPs findings with cVEMPs and caloric test findings in patient with unilateral peripheral vestibular disorders. Acta Otolaryngol 2011; 131:945-50.
13. Sazgar AA, Yazdani N, Rezazadeh N, Yazdi AK. Vestibular evoked myogenic potential (VEMP) in patients with auditory neuropathy: auditory neuropathy or audiovestibular neuropathy? Acta Otolaryngol 2010; 130:1130-4.
14. Akdogan O, Selcuk A, Ozcan I, Dere H. Vestibular nerve functions in children with auditory neuropathy. Int J Pediatr Otorhinolaryngol 2008; 72:415-19.
15. American Standards Institute. American National standards maximum permissible ambient noise levels for audiometric test rooms. ANSI S3.1. New York: American National Standards Institute; 1991.
16. Kumar K, Sinha SK, Bharti AK, Barman A. Comparison of vestibular evoked myogenic potentials elicited by click and short duration tone burst stimuli. J Laryngol Otol 2011; 125:343-7.
17. Bohra V, Sanju HK, Sinha SK. Comparison of cervical and ocular vestibular evoked myogenic potentials in dancers and non-dancers. Poster session presented at 44th Indian Speech and Hearing Association Conference; Jan 20-222012; Hyderabad, India.
18. Starr A, Michalewski HJ, Zeng FG, Fujikawa-Brooks S, Linthicum F, Kim CS, et al. Pathology and physiology of auditory neuropathy with a novel mutation in the MPZ gene (Tyr145-Ser). Brain 2003; 126:1604-19.
19. Brevern V, Lempert MT, Bronstein AM, Kocen R. Selective vestibular damage in neurosarcoidosis. Ann Neurol 1997; 42:117-20.

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