Int. Adv. Otol. 2010; 6:(2) 245-251

ORIGINAL ARTICLE

Value of Head Shake Sensory Organization Test (HS-SOT) in Detecting Subclinical Vestibular Disorders in Type 2 Diabetic Patients

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Objective: Glucose metabolism has a significant impact on inner ear physiology, and both hypoglycemia and hyperglycemia may affect its normal function. Patients with glucose metabolism alteration, as it happens in diabetes, may present with auditory or vestibular symptoms, or both. Recent clinical studies have demonstrated that the Head Shake Sensory Organization Test (HS-SOT) of Computerized Dynamic Posturography (CDP) can be considered a good enhancement and supplement to the standard SOT test in detection of subclinical vestibular lesions or identifying compensated cases. The aim of this research is to study the value of HS-SOT in detection of sub clinical or compensated vestibular deficits in patients with type 2 diabetes mellitus.

Materials and Methods: Thirty patients with type 2 Diabetes Mellitus aged 40- 50 years constituted the study group. They were age and sex matched to 20 normal subjects. The following procedures were carried out: a medical history, otological examinations, detailed vertigo history, pure tone audiometry, acoustic impedance tests, videonystagmography, standard and head shake SOT Posturography.

Results: no subjective dizziness and no abnormalities regarding videonystagmography and standard SOT were noted in all tested patient apart from 3 patients (10%) of the cases, showed abnormalities in standard SOT. However, significant changes occurred after doing head shake SOT where 28 patients (93.3%) showed abnormal condition 5 in the three axes of HS-SOT under this study.

Conclusions: HS-SOT is more sensitive than standard SOT Posturography and VNG in detecting subclinical vestibular lesions in patients with type 2 diabetes mellitus.

Submitted : 08 October 2009 *Revised : 03 April 2010* *Accepted : 06 April 2010*

Introduction

According to data from the American Society of Diabetes, there are about 151 million diabetic persons in the world today, that is, 4.6% of the world population. Diabetes mellitus is a chronic systemic disease, related to an absolute or relative insulin deficiency or resistance, manifested by a deficient insulin secretion by the pancreas and/or a deficient insulin action on the target tissue[1]. According to Kuzuya et al. [2], insulin deficiency causes chronic hyperglycemia, leading to characteristic abnormalities in the metabolism of carbohydrates, lipids, proteins and others. Rybak [3], added that such condition may be associated with vestibular dysfunction. Glucose metabolism has great influence on the inner ear, and both hypoglycemia and hyperglycemia may affect its normal functioning. Patients with glucose metabolism alteration, as it happens in diabetes, may present with auditory or vestibular symptoms, or both[4].

Diabetic patients with peripheral neuropathy often have deep sense disorders. In diabetic patients with a long history of severe retinopathy and peripheral neuropathy, the degree of instability is expected to be greater than in non diabetic subjects [5].

Petrofsky et al [6], found gait impairments in diabetic patients with no sensory loss, they emphasized that whatever the mechanism; diabetic patients develop gait alterations before objective loss of sensation in the feet.

Human postural control is governed by vestibular, visual, and proprioceptive inputs and their central processing[7]. These three senses provide redundant information about the orientation of the body relative to gravity and the support surface. This is because under fixed surface and visual surround conditions, if any one sensory system is functioning normally, it can mask abnormalities in the other two sensory systems [8].

Computerized Dynamic Posturography (CDP) determines the cause, underlying functional limitation

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by measuring impairment to the sensory input and automatic motor response systems necessary for normal balance [9].

The protocol of Sensory Organization Test (SOT) is to quantify organization of vestibular, somatosensory, and visual inputs to balance, coordination of automatic motor and voluntary motor responses and strategies, and the center of gravity alignment. Thus, CDP analyses the subjects' ability to maintain or regain postural control under a variety of sensory conditions and challenges [10].

SOT involves three trials of six sensory conditions, lasting 20 seconds each, that examine postural control under various combinations of support surface and visual surround motion, as the condition became progressively more difficult, the subject is forced to rely more on visual, somatosensory or vestibular inputs individually [11].

The SOT is relatively insensitive in detection of subclinical vestibular lesions specially in patients who are well compensated [12]. Recent studies have demonstrated that the Head Shake-Sensory Organization Test (HS-SOT) technique is a good enhancement and supplement in detection of subtle vestibular disorders in individuals who are symptomatic, but perform within the normal range on the standard SOT[13, 14].

Head movements challenge the system by generating a vestibular stimulus in addition to that generated by the patient's sway. To maintain balance in the absence of alternative visual and somatosensory inputs while moving the head, the brain must differentiate the sway and head-shake stimuli. Degradations in the sensitivity and accuracy of the vestibular receptors, however, can interfere with the process of signal differentiation and reduce stability during head shaking. Because the vestibular system is composed of multiple, direction specific sense organs, these degradations may also be axis specific, creating instability only when head movements occur about the involved axis [14].

Although Mishra et al.(2009)[14], found that controlled horizontal head movement during the SOT led to highly significant reductions in the equilibrium score of the condition 5 in their unilateral peripheral vestibular patients, they had no significant effects on balance with normal somatosensory inputs (SOT condition 2).

With this study we tried find out the value of HS-SOT in detection of sub clinical or compensated vestibular disorder in patients with type 2 diabetes mellitus, who have normal somatosensory inputs.

Patients and Methods

Ethical Considerations:

We obtained approval from the committee for Ethics for researches, Sohag faculty of medicine (No: 59/2008). Also, all participants in our study were consented before starting our work.

Control group included 20 adults (12 males and 8 females), age ranged from 40-50 years, with no prior history of imbalance, free neuro otological history, free from any mobility problems that interfere with head movements, standing or walking.

The study group included 30 patients, with documented type 2 diabetes mellitus, (18 males and 12 females), age range was 40-50 years. All patients were referred from outpatient clinic of internal medicine department, Sohag University Hospitals.

Inclusion Criteria for normal subjects:

1. Willingness to undergo repeated CDP trials and Somatosensory evoked potential.
2. No evidence of cognitive dysfunction.
3. No evidence of musculo-skeletal abnormalities.
4. No motion intolerance.
5. No history of any disease required to give treatment that could affect results.

Inclusion Criteria of patients:

Included all of the previously stated for normal subjects, except number 5, with the addition of these written documents, of controlled type 2 diabetes mellitus, patient has normal somato sensory function from neurology department, and patient has normal visual acuity and free fundus examination.

All subjects were submitted to:

- Detailed medical history, full history of dizziness.
- E.N.T examination to rule out any otologic cause of vertigo.
- Neurological examination to rule out any sensory deficit, performed somato- sensory evoked potential, by NIHON Kohden Neuropack Four mini, at Neurology department.

- Office tests for vestibular evaluation:
  - a- Clinical Test of Sensory Interaction for Balance (CTSIB) [15]. The patients' ability to maintain quiet volitional stance was evaluated as they sequentially stood on: 1) a flat firm surface with eyes open, 2) a flat firm surface with eyes closed, 3) a compressible surface with eyes open, 4) a compressible surface with eyes closed.
  - b- Fukuda Stepping test: The patients were asked to march in place fifty steps with their eyes closed. The test was considered positive if the patient rotates 45 _or more indicating an asymmetrical labyrinthine function [16]. The test was repeated after active head shaking for 30 seconds (sharpened Fukuda Stepping test) and was considered positive if the patient rotates 60 _or more [15].
- Basic audiological evaluation which included pure tone and speech audiometry and acoustic impedance test.
- Videonystagmography (recording eye movements using digital video image technology). Connected to a water caloric irrigator model NCI-480. Following calibration, the testing protocol comprised random saccade, gaze, smooth pursuit at 0.1, 0.2 and 0.4 Hz, OPK, Positional, positioning, and bithermal caloric tests. Online analysis of results and measurement of nystagmus velocity was done through the ICS software program.
- Standard SOT and HS-SOT: This was done on the same day of VNG evaluation.

  The following steps were performed:

  1. Each session consisted of multiple balance trials using Computerized Dynamic Posturography (CDP), in a Neuro Com International platform, while the patient was wearing a safety harness.
  2. Measurement of patient height, which is a critical information for the computer to determine the relative position of Center of Gravity (COG), to set the sway angles for the movement of the surface and surrounding, and in calculating the equilibrium score.
  3. The standard SOT was performed first with three trials for conditions (2, 5), in these conditions, the subject stood with eyes closed on the dual force platform. This platform is stationary in condition 2, while in condition 5 the platform moved about an axis parallel to the ankle joint in response to sagittal (anterior/posterior) plane of subject movement.
  4. SOT conditions 2, 5 were repeated three times, each with the patient performing reciprocal head movements in 3 different planes (HS-SOT), at a rate of 1Hz with an excursion of 30 degrees peak to peak. The three axes of HS-SOT were, yaw (horizontal axis), pitch (vertical axis), and roll (side to side axis). The subject was cued for head movement by listening to metronom set at 1Hz recorded from the VORTEQ equipment on a cassette tap.

Head Shake results were analyzed with the standard SOT for each of the trials, and the three trials were averaged for each condition (SOT2, SOT5, HS-SOT2, and HS-SOT 5).

Four variables were used to characterize the performance on the head shake trials in each axis of movement, yaw, pitch and roll score (HS-SOT cond.2), (HS-SOT cond.5), accordingly, the values used in this study were

- SOT, 2 and SOT, 5.
- HS-SOT 2 (yaw) and HS-SOT 5 (yaw).
- HS-SOT, 2 (pitch) and HS-SOT, 5 (pitch).
- HS-SOT, 2 (roll) and HS-SOT, 5 (roll).

Analysis of data was done using the statistical analysis system (SAS) [17].

Equipment:

1. Sound treated room IAC model, 1602.
2. Computerized two channels pure tone audiometer, Madsen model, 922.
3. Immittancemeter, Amplaid model, 775.
4. Computerized video nystagmo-graphy VNG, ICS chartr with a light bar and an infrared camera, and connected to a water caloric irrigator model NCI-480.
5. Computerized Dynamic Posturography, system Neurocom (Smart Equi test).
6. NIHON Kohden neuropack four mini, somato-sensory evoked potential instrument.

Results

This study included 50 subjects. The study group consisted of 30 type 2 diabetic patients with a mean age of 48.2 years (SD= 7.9). The control group (n=20) was age and gender matched to the study group (mean age=49.1 years, SD= 8.3).

The audiological evaluation, As shown in (Table 1), revealed normal hearing sensitivity at all frequencies from 250 Hz to 8 KHz for the control group and bilateral, mild to moderate, symmetrical, high frequencies sensorineural hearing loss in six patients (20%) for the study group.

Hearing loss represent 20% of patients with type 2 diabetes mellitus and that reflects the effect of hyperglycemia on the auditory pathway.

All subjects under the study had bilateral type (A) tympanograms reflecting normal middle ear pressure.

Cranial nerves examination was symmetric, except for cranial nerve VIII as previously stated for the six patients in the study group.

Vestibular office test examination for the control and study group revealed no abnormal findings except in head shake testing in 3 patients (10%) where evidence of post- head shake nystagmus. These patients with further testing revealed abnormal standard SOT 6. On the other hand, no abnormalities found regarding videonystagmography test battery.

SOT- Posturography was done to all subjects under the study showing no significant differences in SOT 2, SOT 5 and HS- SOT 2 " yaw, pitch, and roll" {p> 0.05} between control and study group; while the difference were significant between the two groups in HS- SOT, 5 (yaw, pitch and roll) {p< 0.05}.

This histogram showed highly significant differences between standard and head shake Sensory Organization Test conditions on both groups.

Table 2 showed highly significant differences between the study and control groups in HS-SOT 5 in the three axes of the test (p < 0.001).

This histogram showed highly significant differences between standard and head shake Sensory Organization Test conditions on both groups.

Discussion

In this study, 20% of patients showed bilateral, symmetrical, high frequencies sensorineural hearing loss of mild to moderate degree.

Diabetes has been shown to affect hearing sensitivity in many studies [18-20].

Many authors have tried to identify the underlying cause of hearing loss in diabetic patients. In conclusion, the predominant mechanisms are microangiopathy of the inner ear [21], neuropathy of the auditory nerve, or combination of both, outer hair cell dysfunction and disruption of endolymphatic potential [22].

Table 1. Distribution of hearing evaluation of control and study group according to pure tone audiometry.

	NORMAL HEARING		HEARING LOSS	
	No	**%**	**No**	**%**
Control group	20	100%	0	%
Study group	24	80%	6	20%

Table 2. Mean X, Standard Deviation (SD), and T- test for comparison between the equilibrium scores for the standard and head shake sensory organization test conditions of the control and study groups.

TEST CONDITION	CONTROL GROUP		STUDY GROUP		P- VALUE
	X	**SD**	**X**	**SD**	
SOT 2	94	2.2	91.9	2.7	0.08
SOT 5	71.1	4.9	67.7	6.8	0.08
HS- SOT 2 (yaw)	92.6	2.3	90.1	2.5	0.07
HS-SOT 5 (yaw)	57.5	7.8	29.2	19.7	0.000***
HS-SOT 2 (pitch)	89.2	3.7	86.7	5.2	0.06
HS-SOT 5 (pitch)	57.2	5.3	28.1	15.7	0.000***
HS-SOT 2 (roll)	89.9	3.4	87.3	4.9	0.06
HS-SOT 5 (roll)	56.2	5.7	26.4	13.9	0.000***

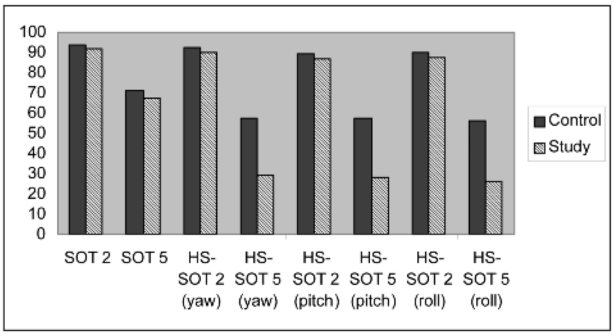

Figure 1. Comparison between the equilibrium scores for the standard and head shake Sensory Organization Test conditions on both groups.

Our results are in a good agreement with results of Bainbridge et al. (2008) (123), they studied a large number of diabetic patients (5140), after exclusion of noise exposure, smoking and medications that cause hearing loss, they found 54.1% of their patients, had high frequency hearing impairment, of mild or to greater severity.

Also, Panchu (2008) [24], found that hyperglycemic patients had sensorineural hearing loss when they were evaluated by a pure tone audiometer in all frequencies.

The principle purpose of balance function evaluation is to detect the site of vestibular lesion (Peripheral, Central or Mixed), also it helps to estimate extent, and functional disability experienced by the patient, finally the possible etiology could be reached [8].

The basic understanding of vestibular physiology and proper examination techniques, correct diagnosis can be made at office. So, bedside vestibular examination tests were done to both control and patient groups. Our work showed no abnormal findings on static or dynamic bedside vestibular function tests, except in

head shake testing in 10% of diabetic patients.

VNG (Videonystagmography) test battery, which is the gold standard in evaluation of the vestibular system, showed no abnormalities. This reflected normal oculo-motor system and vestibule-ocular reflex in our patients.

This result may be explained by either, vestibular system is more resistant to hyperglycemic effects compared to the auditory system, or the duration of hyperglycemia was not sufficient to do the effect, or our patients were well controlled diabetic ones.

On the other hand, out of 30 patients (10 %) showed post - head shake nystagmus and the same patients with further testing revealed abnormal standard SOT condition 6, inspite of all subjects under the study showed normal findings at all test battery of VNG. This could be attributed to the evaluation of the three pairs of semicircular canals and the use of active head rotation stimulus in HS-SOT in bedside head shaking test, and in moving surroundings in standard SOT condition [6].

These results highlight the value of HS-SOT in those patients denoting that it can be clinically applied to verify subclinical abnormalities not diagnosed by VNG testing.

Standardization of HS-SOT of CDP was based on the work of Moussa et al (2008) [13]

Similarly in this study, HS-SOT in the control group showed a tendency to increase sway with head shaking resulting in decreased equilibrium scores witch were more marked in SOT condition 5 than SOT condition 2 in the three axes of the test.

Decreased equilibrium scores, could be attributed to the increase challenge to maintain stance during condition 5. Shepard et al. (1998) (8) and Clark et al. (2003) [25], found that postural stability was significantly reduced in normal subjects attempting to execute controlled head movements while simultaneously maintaining balance in the absence of functionally useful information from vision and somato-sensory inputs (SOT condition 5).

Regarding the comparison between the control and study group, the results of the selected standard SOT conditions (2 and 5), were not significantly different between both groups. Table 2, p values > 0.5. Similar results were obtained by Moussa et al. [13] and Mishra et al. [14] who reported that patients with compensated vestibular disturbances showed no statistically significant differences from normal subjects in standard SOT condition 2 and 5.

These results of standard SOT could be explained by the relative insensitivity of SOT in detecting abnormalities of vestibular system in well compensated patients. This observation was detected by many authors as Di Fabio [26], Clendaniel [27], Moussa et al [13] and Mishra et al. [14].

Accordingly, some investigators suggested that the detection of imbalance is a function of the challenging nature of the investigation task. Based on this rationale, it was hypothesized that a dynamic task like head shaking may be used to disrupt central compensation resulting in a temporary disruption in balance, especially during challenging tasks as in SOT [13-14].

In the present study, the results of HS-SOT in the three axes (yaw, pitch and roll) showed significant reduction in the study group compared to the control group in condition 5 only while condition 2 HS-SOT showed insignificant reduction at any axis.

The impaired performance on the HS-SOT indicating a decreased use of vestibular inputs during head motion and suggested that the patients had residual deficits with respect to use of vestibular information.

Our results are in good agreement with Moussa et al [13] and Mishra et al.[14] Who found that controlled horizontal head movements had no significant effects on balance with normal somatosensory input (SOT condition 2), while their vestibular patients showed highly significant reduction in HS-SOT condition 5 performance relative to the normal baseline.

Conclusion

- Head shake sensory organization test (HS-SOT) can be considered as a good enhancement to the standard Sensory Organization Test in detecting subclinical vestibular lesion in type 2 diabetic patients.
- HS-SOT is beneficial in documenting the necessity of treatment, and counseling patients with type 2 diabetes mellitus.

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