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RESEARCH ARTICLE

Effect of peripheral vestibular pathologies on reading ability and auditory-verbal memory

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Abstract

Background and Aim: Auditory-verbal memory and reading problems are frequently observed in patients with vestibular disorders, but rarely considered as a cognitive consequence of vestibular disease. Many clinicians do not recognize or ignore the psychological symptoms of vestibular disease. This approach could underestimate the cognitive problems of the patients, or even led to misdiagnosis of a combined vestibular-cognitive condition. The current study aimed to assess the cognitive impact of acute vestibular disorders.

Methods: A total of 71 patients with unilateral vestibular neuritis, Meniere's disease, and benign paroxysmal positional vertigo underwent a through audiologic evaluation, including otoscopy, pure tone audiometry, tympanometry, vestibular evoked myogenic potentials, videonystagmography plus caloric testing, and video head impulse testing in the plane of horizontal semicircular canals. After determination of the disease, the Persian version of the dizziness handicap inventory, the Persian reading test, and Rey auditory-verbal learning test were administered.

Results: There were no significant difference between the patient groups with regard to their inabilities like reading and learning problems according to their auditory verbal memory score induced by acute vertigo. However, acute vertigo can reduce the reading ability and capacity of auditory-verbal memory of the patients compared with normal subjects.

Conclusion: Unilateral vestibular disorders in which patients suffer from acute rotatory vertigo could lead to reading difficulties and learning because of auditory-verbal memory impairment. The exact mechanism of vestibular impairment is not a determinant factor for these cognitive problems.

Keywords: Vertigo; reading; auditory-verbal memory

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Introduction

The main function of the mammals' vestibular system is providing information for the central nervous system about general body orientation in relation to gravity, balance in movement and body status, readjustment of autonomic functions after body orientation and gaze stability [1]. Several main systems, including vision, vestibular, proprioceptive; and some other accessory systems such as auditory system provide the brain with relevant information. It has been shown that the vestibular system not only affects body circadian rhythm but also has connections with cognitive performances [1,2]. During head movement, the vestibular system maintains body and gaze stability through detecting head movement and sending appropriate information to extra-ocular, cervical, and torso muscles. The most overt effects of acute unilateral vestibular impairment are acute true rotatory vertigo, nystagmus, body instability, and gate disturbance [3]. In addition, increasing evidence has supported that vestibular inputs have a key role in higher-order cognitive functions such as spatial memory and orientation, multisensory motion perception, and spatial orientation [4,5]. Several behavioral studies in rodents [6,7] and humans [8] have indicated that visual-spatial memory and cognition are related to vestibular function. They have shown that although two different ascending pathways contribute to the spatial cognition convey vestibular information from vestibular nuclei to the brain cortex via thalamus, they do this through different nuclei. The first pathway transmits information through anterior thalamic nuclei and contributes to place perception (in hippocampus cells) and orientation (in the limbic system). On the other hand, the second pathway contributes to the self-motion information which is used for motion planning and sensory representation of spatial relations of the objects in the outside world. Self-motion information integrates with other sensory inputs related to objects' movements to detect the origin of the movement. For example, head movement results in the movement of the objects' images on the retina even when the objects have no actual movements. Vestibular inputs enable us to discriminate the real movement of the objects from head movement [9]. Furthermore, some patients with the vestibular disorder complain of memory loss and attention deficit as well [10-12]. Some cognitive studies by using the Wechsler memory scale in patients with vestibular involvement reported that memory and attention, in general, are not affected [8], but some other studies show cognitive impairment such as math disorder, slower reaction time, or visual short-term memory loss in patients with vestibular involvement [13,14].

It should be noted that cognitive function disorder is not necessarily a secondary effect of attention allocation dysfunction in multi-tasks, but it can be related to the direct dependence of some cognitive performances on vestibular information [9]. One of the important cognitive functions in humans is auditory-verbal memory. It is short-term memory and refers to the ability to receive, process, store, and finally, recall the verbal stimuli. This type of memory is very important as it contributes to some skill developments such as word learning and recalling, language perception and usage, expressive and written language. So the disorder might have direct and indirect (through affecting speech perception ability) effects on individual and social quality of life [15-17]. In addition, reading as a complex task needs simultaneous side-to-side head and saccadic eye movements. For reading a text word by word, vestibule-ocular reflex (VOR) must fixate gaze on target words. Studies have shown that peripheral vestibular disorder can reduce VOR gain and therefore can lead to compensatory strategies, including cessation of head movement during reading. In these patients, saccadic eye movement is the only effective strategy during reading [10].

Cognition interactions with acute vertigo syndrome (combination of severe true vertigo with acute onset, nystagmus, imbalance, and nausea), especially the relation between acute vertigo and auditory-verbal memory deficit in reading comprehension are overlooked and to the best of our knowledge, there is no significant article in this field. Therefore, the present study aimed to investigate the effects of acute vertigo in patients with a unilateral vestibular deficit on reading comprehension, auditory-verbal memory, and learning.

Methods

After approval of (the Ethical Code: 1395.95-03-32-29387) the Deputy of Research, Iran University of Medical Sciences, 71 patients with chief complaint of acute vertigo referred to Audiology Clinic of Amir Alam Hospital (50 women and 21 men) (mean ± SD age: 48.28 ± 12.22 years; age range: 18–79 years) were selected and evaluated during 2016–2017. After explaining the participants the research procedure, aims, its benefits, entity, and duration of the tests, the written consent was taken from all the study patients in accordance with the instructions and ethical guidelines of Deputy of Research Review Board, Iran University of Medical Sciences. Then, the samples' personal/background information was collected to ensure the eligibility to enter the study according to the study inclusion criteria. All patients underwent otoscopy, pure tone audiometry, tympanometry, vestibular evoked myogenic potentials (VEMP), videonystagmography (VNG) with caloric testing, and video head impulse testing (vHIT) (All instruments made by Interacoustics Co., Denmark) at the plane of horizontal semicircular canals. The following criteria were used to identify acute vertigo syndrome:

Diagnosis of unilateral Meniere's disease (MD) was based on the guidelines published by the American Academy of Otolaryngology, Head, and Neck Surgery (AAO-HNS) [18]. Diagnostic criteria for unilateral vestibular neuritis (VN) were based on episodes of rotatory vertigo attack(s) lasting for several hours to several days, unilateral weakness of 25% or more at caloric testing, abnormal vHIT at the plane of horizontal canals, and no cochlear signs or other neurological signs. For detecting benign paroxysmal positional vertigo (BPPV), the occurrence of short living positional vertigo, with torsional geotropic nystagmus in Hallpike position were used.

For vHIT testing, 256 Hz video-oculography goggle with the inertial sensor was fitted on the patient's head and asked to fixate on a point at a 1.5-m distance. At first, eye movement calibration was done, and then, at least 10 unpredictable impulses at each side in the plane of the horizontal semicircular canals were applied to the patients. The degree of head rotation was about 15 to 20 degrees, and the maximum acceptable velocity was 150 degrees per second. Direction and timing of impulses were unpredictable to the patient. Possible compensatory saccades were averaged for 700 ms after starting the head impulses. Being within normative values ± 2SD and absence of compensatory saccades were taken as criteria for normal responses [19]. Then, VEMP testing with the traditional method by recording from neck muscles, and VNG using a video recording of Dix-Hallpike and Roll test to confirm the involvement of semicircular canals and occurrence of BPPV were used. After confirmation of acute vestibular disorder, the Persian version of the dizziness handicap inventory (DHI) questionnaire which its psychometric properties have been validated by Jafarzadeh et al. [20], was administered on all patients and total scores were calculated. This questionnaire has 25 items. "Yes" response scores 4 points, "sometimes" 2 points, and "no" 0 points. In the Iranian population, the mean ±SD total score of DHI is equal to 1.4 ± 6.3. Jafarzadeh et al. reported that the best cut-off point for detecting normal population from the pathologic one with 90% sensitivity and 98% specificity is 10 [20]. The test-retest consistency of this questionnaire ranges from 0.92 to 0.97, its internal consistency ranges from 0.72-0.89, and the Cronbach alpha coefficient is more than 0.78. Meanwhile, its construct validity is acceptable [20,21]. Then, the reading subtest of the Persian Aphasia test [22] was administered. The patients have to read a 2-paragraph passage and 10 questions were asked about the text. Scoring was based on the instruction of the original test. For scoring the test items, 0 is given to no answers, 1 to right answers, and -1 for wrong answers. With this scoring method, we can quantitatively calculate the reading ability of the subjects. The internal consistency of the reading subtest is equal to 0.90 [22,23]. After that, the Persian version of the Rey auditory verbal learning test (RAVLT) (which its psychometric properties have been validated by Jafari et al.) was administered. The

Table 1. Mean, standard deviation, min, and max values of dizziness handicap inventory score in all participants, and separately in each vestibular disorder

		DHI score		
Group	**N**	**Mean (SD)**	**Min**	**Max**
MD	**6**	49.66 (30.28)	4.00	96.00
VN	**25**	46.72 (24.69)	2.00	94.00
BPPV	**40**	37.25 (17.71)	6.00	76.00
ALL	**71**	41.63 (21.80)	2.00	96.00

MD; Meniere's disease, VN; vestibular neuritis, BPPV; benign paroxysmal positional vertigo, DHI; dizziness handicap inventory

normative age-specific values are reported in the original paper, and the currently acquired data are compared to those normative values [24]. The Persian version of RAVLT, like its English version, has 3 lists, a named list of Persian words (a), list of interruptive words (b), and recognition list. The examiner reads aloud (a) list words at the rate of one word per second. The participant is then asked to repeat all words from the list that he/she can remember. Whenever the patient announced that he/she could not remember any other word, the same list repeated again and the patient's response was recorded. For evaluating the effects of stimulus repetition and learning, the (a) list repeated 5 times (A1 to A5). Scores of these five repetitions were averaged and calculated as the final score. List (b) words were also presented like list (a) and responses were recorded (B). Again, the patients were asked to recall the (a) list, one time exactly after presenting the (b) list (A6), and one time after a 20-minute delay (A7) (recognition). In next step, the participant read a list of 50 words (30 words from [a] and [b] list, and 20 new words) and asked to indicate which word belonged to the first list (recognition). Whenever aged norms were available (such as RAVLT), the obtained data were compared with them, and if no aged norms were available, the data were compared with the average value of the final scores (such as DHI).

One-way ANOVA was used to compare the mean difference between DHI score, reading, and auditory verbal memory among 3 patient groups. The Pearson correlation coefficient was used to determine the correlation between variables. All statistical tests were considered significant at $p \leq 0.05$. Statistical analyses were performed in SPSS 16.0 (SPSS Inc., Chicago, USA).

Results

Seventy-one subjects with acute vertigo syndrome (50 women and 21 men) in the age range of 18-79 years (mean ± SD age: 48.28 ± 12.22 years) were evaluated. There were three groups of participants, including unilateral MD (6 subjects; one male and 5 females), unilateral VN (25 subjects; 8 males and 17 females) and BPPV (40 subjects; 12 males and 28 females). The participants' ages in each group were as follows: In the BPPV group, the age range was 25 to 79 years mean ± SD age: 48.25 ±12.14 years); in the MD group, the age range was 36 to 65 years (mean ± SD age: 49.33 ± 11.12 years); in the VN group, the age range was 18 to 75 years (mean ± SD age: 48.08 ± 13.02 years). Regardless of the study group, all patients had acute vertigo complaint. Therefore, the results were analyzed once regardless of the study group and once based on the group that they were assigned to. DHI score in each individual group is shown in Table 1. The DHI score was compared among the groups by one way ANOVA test and no significant difference was observed among three groups ($F(2,68) = 1.947$, $p = 0.151$). Fig. 1 shows a 95% confidence interval of the mean DHI score in the study groups.

Mean, standard deviation, minimum and maximum of the reading score in all participants regardless of the study group as well as in each group are presented in Table 2. Reading score was compared among three groups by one-way ANOVA and no significant difference was observed ($F(2,68) = 0.577$, $p = 0.565$). Fig. 2 shows a 95% confidence interval of the mean reading score in the study groups.

Rey auditory-verbal learning scores were

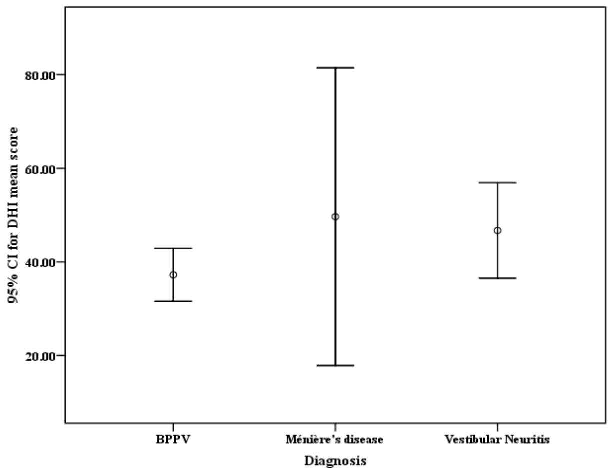

Fig. 1. 95% confidence intervals (CI) for dizziness handicap inventory mean scores in three patient groups with acute vertigo.

compared among three groups by using one-way ANOVA test and no significant difference was observed too ($p \geq 0.05$). Fig. 3 summarizes the comparison of the mean score of the list A1-5; the score for the repeating list A; mean score of the list B; immediate recall list; delay recall list; and Rey recognition list in three groups.

In order to investigate the relationship between the inability secondary to acute vertigo (DHI mean score) and the reading skill, the Pearson correlation test was used. This test showed no significant correlation between the handicap degree and the reading ability in these subjects ($r = -0.133$, $n = 71$, $p = 0.26$). In addition, in order to investigate the relationship between vertigo-related handicap (DHI mean score) and mean score of list A (1-5) and mean score of repeating list A (sum), list B score, immediate recall (A6), delayed recall list (A7), and recognition list, the Pearson correlation test was used that showed no significant correlation between vertigo-related handicap and Rey subtests.

Discussion

In the present study, three groups of patients with peripheral vestibular involvement and acute vertigo complaint, including subjects with MD, BPPV, and VN were investigated with regard to their handicap degree, reading skills,

Table 2. Mean, standard deviation, minimum, and maximum values of reading score in all participants, and separately in each vestibular disorder

		Reading score		
Group	**N**	**Mean**	**Min**	**Max**
MD	**6**	6.00 (1.09)	5.00	7.00
VN	**25**	6.40 (1.87)	3.00	10.00
BPPV	**40**	6.80 (2.20)	2.00	10.00
ALL	**71**	6.59 (2.01)	2.00	10.00

MD; Meniere's disease, VN; vestibular neuritis, BPPV; benign paroxysmal positional vertigo

and Rey auditory-verbal memory status. Comparing DHI scores with normative data showed a significant handicap in the study participants. Jafarzadeh et al. reported that 10 would be the best cut-off value for separating normal subjects from patients and this cut-off point has 90% sensitivity and 98% specificity [20]. Furthermore, the mean ± SD value of DHI in normal Iranian subjects is 6.3 ± 1.4 but this score in patients suffering from acute vertigo was 8.21 ± 6.41. Therefore, there is a significant difference between normal and the involved groups. On the other hand, there was not any significant difference among three groups regarding DHI score which is indicative of similar effects of acute peripheral vestibular involvements on individual physical, emotional, and functional aspects.

Performing reading subtest of the Persian Aphasia test battery showed a significant difference between the mean ± SD score of the participants (59.6 ± 1.2) and normal values. There was not any significant difference among the three study groups with regard to reading score. It shows that regardless of the underlying cause, acute vertigo affects reading skill.

Rey auditory verbal test showed that in general the scores of the participants were lower than normal Iranian adults but there was not any significant difference among three study groups. Thus, the type of vestibular disorder can be

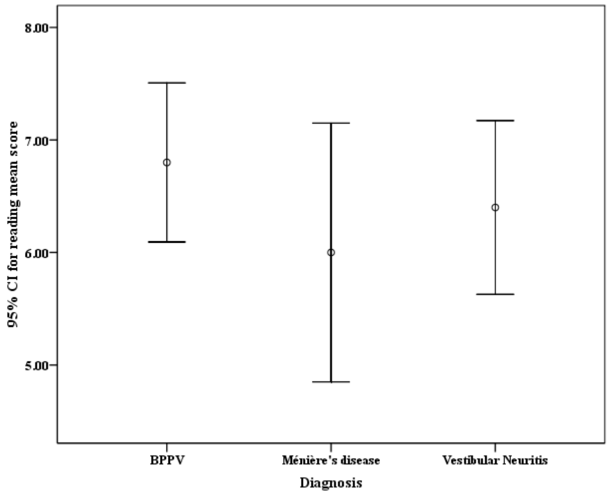

Fig. 2. 95% confidence intervals (CI) for reading mean scores in three patient groups with acute vertigo.

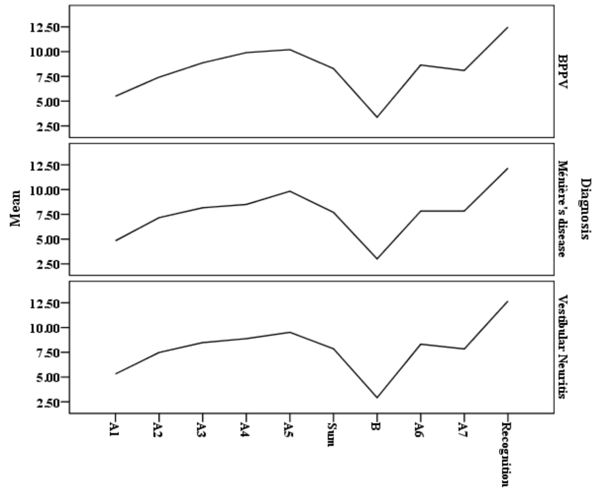

Fig. 3. Comparison of mean A1 to A5 scores, mean score of repeating a list (Sum), mean score of B list, immediate recall (A6), delayed recall (A7), and recognition list among three patient groups with acute vertigo

attributed to a random factor which has a generally negative effect on auditory verbal learning capacity and memory due to acute vertigo. The results of the study showed that one of the effects of acute vertigo on mental and cognitive functions is difficulty in learning verbal information and its faster forgetting. In the present study, similar to the past studies, it was shown that repeating the test in trial 1 through 5 made scores better which is known as “learning effect”. In addition, after presenting distractor list (b), the score of the list (a) reduced from trial 5 to 6 which in agreement with Sinnett and Holen [25] and also Jafari et al. [24] results. Recognition test can show the learning ability of the patients with acute vertigo regardless of immediate recall ability. The comparison of recognition and delayed recall trial scores is a kind of immediate recall measurement. This method can help us determine information recall problem. In the three groups, the recognition score was higher than trial 7 which is indicative of good learning but weak retaining of the new information.

In summary, the patients with acute unilateral vestibular disorder who suffers from acute true rotatory vertigo have more difficulty in reading comprehension and learning through auditory-verbal memory. The type of vestibular involvement is not an effective factor on cognitive involvements and acute vertigo per se, as a disturbing physical status, can lead to reading and auditory verbal memory disorder.

Conclusion

In general, although the degree of acute vertigo-related handicap in the three involved groups had no significant difference, acute vertigo reduces reading score and auditory verbal capacity compared to the normal subjects.

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Conflict of interest

The authors declared no conflicts of interest.

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