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Vestibular function testing in individuals with cognitive impairment: our experience with sixty participants

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Dear Editor

A growing body of literature suggests that vestibular loss is associated with cognitive impairment. Individuals with vestibular loss have reduced spatial cognitive skills such as spatial memory and spatial navigation.^{1–3} They have also been found to have hippocampal atrophy,² suggesting underlying loss of neural pathways. Several studies have explored vestibular function among individuals with cognitive impairment and reported reduced vestibular function in this population.^{1,3} However, the extent to which individuals with cognitive impairment are able to complete vestibular testing has not been rigorously evaluated.

The goal of this study was to investigate the level of cognitive function required to complete standard vestibular physiologic tests. We evaluated the ability of patients with progressive levels of cognitive impairment (ranging from mild to severe) to complete assessments of otolith function (cervical and ocular vestibular-evoked myogenic potentials) and semicircular canal function (the video head impulse test). Our findings will help guide clinicians in performing and interpreting vestibular tests among individuals with cognitive impairment.

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Author contributions

Aisha Harun contributed to the study design, data acquisition, data analysis and the interpretation, and drafting of the manuscript. Esther Oh contributed to the study design, data acquisition, data analysis, drafting of the manuscript and critical revision of the manuscript. Robin Bigelow contributed to data acquisition and critical revision of the manuscript. Yuri Agrawal contributed to study design, data analysis and critical revision of the manuscript. Yuri Agrawal had full access to all of the study data and takes responsibility for the integrity of the data and accuracy of the data analysis.

Conflicts of interest

The authors have no conflict of interests to declare.

Materials and methods

Ethical considerations

The study was approved by the Johns Hopkins Institutional Review Board. All participants or their legally authorised representatives gave informed consent.

Study participants

Participants were recruited from December 2014 until November 2015 from the Johns Hopkins Memory and Alzheimer's Treatment Centre, an interdisciplinary memory disorder clinic, and the Johns Hopkins Alzheimer's Disease Research Centre.

The inclusion criteria were as follows: (i) age 55 years or greater; (ii) diagnosis of mild cognitive impairment, Alzheimer's disease or other cognitive impairments or dementias; (iii) Mini-Mental State Examination score of 9 or greater (cut-off for severe cognitive impairment) using serial 7s for attention; (iv) fluency in English; and (v) ability to obtain informed consent from the participant or legally authorised representative. The National Institute on Aging/Alzheimer's Association diagnostic criteria were used for the diagnosis of mild cognitive impairment and Alzheimer's disease.^{4,5} The Cognitive Impairment No Dementia diagnosis was used for individuals whose cognitive testing was not normal, but did not meet the mild cognitive impairment criteria.⁶ Patients with a Mini-Mental State Examination score of 9 or greater were screened by a Memory Centre Physician who determined that the patient may be able to follow examination procedures, as they were able to follow commands while undergoing routine evaluation of attention, memory, and executive function by Memory Centre staff. Individuals were excluded if they were unable to participate in study procedures because of physical conditions, such as blindness, poor neck range of motion or cervical spine instability. Demographic information (age, gender and education) was extracted from the patients' chart.

Vestibular function tests

Vestibular-evoked myogenic potentials—For vestibular-evoked myogenic potential recording, a commercial electromyographic system (software version 14.1; Carefusion Synergy, Dublin, OH, USA), was used. Sound-evoked cervical vestibular-evoked myogenic potentials testing methods of measuring saccular function have been published in detail previously.⁷ Vibration-evoked ocular vestibular-evoked myogenic potentials assess utricular function, and testing methods have also been published previously.⁷ Individuals were considered able to complete vestibular-evoked myogenic potential testing if they could follow the instructions to calibrate the individual tests (generate sufficient background neck contraction for the cervical vestibular-evoked myogenic potential testing and generate vertical saccades for the ocular vestibular-evoked myogenic potential testing).

Video head impulse testing—The horizontal vestibular ocular reflex was assessed using the video head impulse test.⁸ The video head impulse test was performed in the plane of the right and left horizontal semicircular canals using the EyeSeeCam system (Interacoustics, Eden Prairie, MN, USA), and testing methods have been previously published.⁸ Individuals were judged able to complete testing if they could follow the instructions to calibrate the

EyeSeeCam (i.e. follow the calibration laser point for video head impulse test to calibrate eye movements).

Statistical analysis

The main outcome of interest was ability to complete each of the vestibular testing procedures (vestibular-evoked myogenic potentials and video head impulse test). Characteristics of the patient population are provided, including patient age, gender, educational level, and diagnosis including mild cognitive impairment, Alzheimer's disease, Cognitive Impairment No Dementia and other (all other dementia diagnoses). The ability to perform each vestibular test as a function of Mini-Mental State Examination score was described.

Results

The overall study population is presented in Table 1. The population includes a total of 60 patients: 28 (46.7%) with Alzheimer's disease, 14 (23.3%) with mild cognitive impairment, 6 (10.0%) with Cognitive Impairment No Dementia and 12 (20.0%) with other dementias (six with mixed vascular and Alzheimer's dementias, three with vascular dementia, one with Parkinson's disease, one with Lewy body dementia and one with traumatic brain injury). The mean age of the study population was 76.1 years (SD 8.2, range 60–94 years). Sixty-eight per cent of the population was female, and 40% was college educated. The mean Mini-Mental State Examination score of the study population was 21.9 (SD 5.5, range 9–30).

Ability to complete vestibular testing

The ability to complete vestibular testing by Mini-Mental State Examination score is presented in Table 2. With the exception of one individual (Mini-Mental State Examination score 23), all patients with a Mini-Mental State Examination score of 13 or above were able to complete the testing. One individual (Mini-Mental State Examination score 12) was unable to complete the cervical vestibular-evoked myogenic potential testing, as he was unable to maintain the sustained neck muscle contraction for the testing because he did not understand the directions. Five individuals (Mini-Mental State Examination score 9, 12, 12, 12 and 23) were unable to complete the ocular vestibular-evoked myogenic potential testing. These individuals were unable to perform the vertical saccades needed for the calibration, as they became confused as to which target to focus on. Two individuals (Mini-Mental State Examination score 12 and 12) were unable to complete the video head impulse test examination. These individuals became confused as to which target they needed to look at when calibrating their eye movements.

Discussion

In this study, we observed a cognitive impairment threshold below which individuals were too impaired to participate in the vestibular testing. Specifically, individuals who scored a Mini-Mental State Examination score of 12 – corresponding to moderate-to-severe dementia – or below were too impaired to complete the full battery of tests. This study extends prior work by demonstrating the degree of cognitive impairment that may restrict vestibular

testing. As studies increasingly demonstrate a link between vestibular and cognitive function, vestibular testing among patients with dementia will likely become more widespread. This study provides practical data about the minimal cognitive function required to successfully perform standard clinical vestibular tests.

Previous work has reported assessments of vestibular function in individuals with cognitive impairment. Nakamagoe *et al.*³ successfully administered the caloric nystagmus test to patients with Alzheimer's disease with a mean Mini-Mental State Examination score of 18 (i.e. moderate dementia). Birdane *et al.*¹ reported cervical vestibular-evoked myogenic potential results for individuals with severe Alzheimer's disease with a Mini-Mental State Examination score of 19 or below. Our work builds on these studies by specifically demonstrating a lower limit of cognitive impairment that may restrict the successful administration of vestibular assessment.

Both the vHIT and the oVEMP testing involved participants fixating on targets to calibrate the tests; however, more individuals were unable to complete the oVEMP calibration. The oVEMP testing required individuals to recline and look at targets on the ceiling, whereas the participants were seated upright looking straight ahead for the vHIT. Some participants needed prompting to remain recumbent. As a result, they became confused as to which target to look at, which may have contributed to their increased inability to complete the oVEMP testing. Although seated upright during the vHIT, a few participants persisted with difficulty with keeping their head still while focusing on the correct target. Lastly, one individual had difficulty in following the instruction to maintain sustained neck muscle contraction for the cVEMP testing.

We note several limitations of the current study. First, this is a cross-sectional study of patients seen at a tertiary care referral clinic, and therefore, the findings may not be representative of the broader population of individuals with mild cognitive impairment and dementia. In addition, given that we excluded patients with severe dementia who were determined by the Memory Centre clinician to be possibly too impaired to complete vestibular testing procedures, it is possible that individuals with an Mini-Mental State Examination score lower than nine could have successfully completed the testing. However, the severe global cognitive limitations in these individuals make this successful completion unlikely. Lastly, the Mini-Mental State Examination score is a measure of global cognitive function, but can be confounded by factors such as age and education,⁹ as well as intrarater and inter-rater variability.¹⁰ Therefore, the Mini-Mental State Examination score should only be used as a rough guide for assessment of cognitive function when considering whether to refer an individual for vestibular testing.

In summary, our work demonstrates that individuals with cognitive impairment with suspected vestibular loss can be referred for vestibular testing; however, this testing may be limited in individuals with advanced dementia. A discussion with these individuals' primary neuropsychiatry provider may help determine whether an individual is appropriate for testing.

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Keypoints

- With the ageing population, referrals for vestibular function testing may increase, including for individuals with cognitive impairment. However, testing may be limited in these individuals, as it requires participants to follow instructions.
- This study reports the feasibility of assessing vestibular function in individuals with cognitive impairment. Otolith function was assessed with cervical and ocular vestibular-evoked myogenic potentials and semicircular canal function with video head impulse testing.
- With the exception of one individual, all patients with a Mini-Mental State Examination score greater than 12, corresponding to moderate-to-severe dementia, were able to perform the complete battery of tests.
- Our work demonstrates that that individuals with cognitive impairment can be referred for vestibular testing, although testing may be limited in severely cognitively impaired individuals.
- A discussion with an individual's primary neuropsychiatry provider may help determine whether he or she is appropriate for vestibular testing.

Table 1

Study population characteristic

Total N = 60 (SD/%)	
Mean age (SD)	76.1 (8.2)
Gender	
Female	41 (68.3%)
Male	19 (31.7%)
Education	
Less than college	22 (36.7%)
College	24 (40.0%)
More than college	14 (23.3%)
Mean MMSE (SD)	21.9 (5.5)
Diagnosis	
AD	28 (46.7%)
MCI	14 (23.3%)
Other	12 (20.0%)
CIND	6 (10.0%)
Unable to complete testing	
cVEMP	1 (1.5%)
oVEMP	5 (7.7%)
vHIT	2 (3.3%)

MMSE, Mini-Mental State Examination; MCI, mild cognitive impairment; AD, Alzheimer's dementia; CIND, Cognitive Impairment No Dementia; cVEMP, cervical vestibular-evoked myogenic potential; oVEMP, ocular vestibular-evoked myogenic potential; vHIT, video head impulse testing.

Table 2

Ability to complete vestibular testing by participant

MMSE	Age	Gender	Diagnosis	Education	cVEMP	oVEMP	vHIT
9	69	F	AD	Less than college	X	●	X
12	73	M	AD	More than college	X	●	●
12	74	M	Other	Less than college	X	X	X
12	79	M	AD	Less than college	●	●	X
12	94	F	Other	More than college	X	●	●
13	84	F	AD	Less than college	X	X	X
13	87	F	AD	Less than college	X	X	X
14	79	F	AD	College	X	X	X
15	78	F	AD	Less than college	X	X	X
15	80	F	AD	College	X	X	X
15	88	F	Other	Less than college	X	X	X
16	89	M	Other	More than college	X	X	X
17	83	M	AD	College	X	X	X
18	71	F	AD	More than college	X	X	X
18	78	F	AD	College	X	X	X
18	79	F	AD	College	X	X	X
18	92	F	Other	College	X	X	X
19	80	F	Other	More than college	X	X	X
20	72	F	AD	Less than college	X	X	X
20	75	F	AD	College	X	X	X
20	78	F	AD	Less than college	X	X	X
21	72	F	Other	Less than college	X	X	X
21	74	M	AD	College	X	X	X
22	70	F	AD	Less than college	X	X	X
22	84	F	AD	College	X	X	X
22	86	F	Other	More than college	X	X	X
22	86	M	MCI	College	X	X	X
23	72	F	AD	College	X	X	X

MMSE	Age	Gender	Diagnosis	Education	cVEMP	oVEMP	vHIT
23	76	M	Other	College	X	●	X
23	78	F	AD	Less than college	X	X	X
23	79	M	CIND	College	X	X	X
24	66	F	AD	Less than college	X	X	X
24	69	F	MCI	College	X	X	X
24	72	F	MCI	College	X	X	X
24	82	F	MCI	College	X	X	X
24	85	F	AD	Less than college	X	X	X
24	87	F	AD	Less than college	X	X	X
25	62	F	AD	College	X	X	X
25	64	F	CIND	Less than college	X	X	X
25	66	M	Other	Less than college	X	X	X
25	74	F	MCI	College	X	X	X
25	81	F	MCI	Less than college	X	X	X
26	61	F	MCI	College	X	X	X
26	62	M	AD	College	X	X	X
26	68	F	AD	Less than college	X	X	X
26	78	M	MCI	College	X	X	X
26	82	F	Other	Less than college	X	X	X
27	72	F	MCI	Less than college	X	X	X
27	72	M	MCI	More than college	X	X	X
27	75	F	Other	College	X	X	X
27	77	M	AD	More than college	X	X	X
27	85	F	MCI	More than college	X	X	X
28	68	F	MCI	College	X	X	X
29	60	F	CIND	College	X	X	X
29	60	M	CIND	More than college	X	X	X
29	64	M	AD	More than college	X	X	X
29	75	M	CIND	More than college	X	X	X
29	77	M	MCI	More than college	X	X	X
29	83	M	CIND	College	X	X	X

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MMSE	Age	Gender	Diagnosis	Education	cVEMP	oVEMP	vHIT
30	83	F	MCI	Less than college	X	X	X

MMSE, Mini-Mental State Examination; MCI, mild cognitive impairment; AD, Alzheimer’s dementia; CIND, Cognitive Impairment No Dementia; M, Male; F, Female; cVEMP, cervical vestibular-evoked myogenic potential; oVEMP, ocular vestibular-evoked myogenic potential; vHIT, video head impulse testing; X, able to complete the testing; ●, unable to complete the testing.