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SCIENTIFIC INVESTIGATIONS

Feasibility of unattended home sleep apnea testing in a cognitively impaired clinic population

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Study Objectives: Obstructive sleep apnea (OSA) increases the risk of developing dementia. Home sleep apnea testing (HSAT) is a convenient and validated method to screen for OSA among cognitively well individuals; however, it is unknown if it is a clinically feasible and practical approach in clinic patients with cognitive impairment. We evaluated if HSAT was a feasible and practical approach to screen for OSA in clinic patients with cognitive impairment.

Methods: Patients with cognitive impairment due to neurodegenerative and/or vascular etiologies completed OSA screening using HSAT. HSAT was considered a feasible technique if ≥ 80% of those who attempted HSAT obtained analyzable data (ie, ≥ 4 hours of flow, effort, and oxygen evaluation), and a practical technique if ≥ 50% of all patients approached for study inclusion obtained analyzable data.

Results: Of the 119 patients who were approached for participation, 83 were enrolled and offered HSAT; 5 did not complete HSAT screening, and the remaining 78 patients attempted HSAT; mean age (± standard deviation) of 72.86 (± 9.89) years and 46% were male. In those that attempted HSAT, 85.9% (67/78) obtained analyzable data and 56.3% (67/119) of eligible patients approached for study inclusion obtained analyzable data.

Conclusions: HSAT is a feasible and practical technique in a clinic population with cognitive impairment. As OSA is a modifiable risk factor for patients with dementia, HSAT has the potential to lead to expedited treatment for OSA, which may potentially improve health-related outcomes such as cognition.

Keywords: home sleep apnea test, feasibility, cognitive impairment, dementia, obstructive sleep apnea, ambulatory testing

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Obstructive sleep apnea (OSA) is an independent risk factor for the development of dementia, but diagnosis is often limited by in-laboratory polysomnography, which is inconvenient and poorly tolerated by patients with cognitive impairment. Home sleep apnea testing is a convenient and validated method to screen for OSA among cognitively well individuals; however, it is unknown if it is a clinically feasible and practical approach in patients with cognitive impairment.

Study Impact: This study demonstrates home sleep apnea testing is a feasible and practical approach to screen for OSA in clinic populations with cognitive impairment. As OSA is a modifiable risk factor for patients with dementia, home sleep apnea testing has the potential to lead to expedited treatment for OSA, which may potentially improve health-related outcomes, such as cognition.

INTRODUCTION

Cognitive impairment and dementia are associated with substantial health care expenditures and present a significant burden on healthcare providers and society.[1] In a report by Alzheimer's Disease International, it was estimated that in 2019 about 50 million people were living with some form of dementia worldwide, and it is believed that this number will rise to 152 million by 2050.[2] Dementia can result from a variety of neurodegenerative and vascular causes, however, other conditions also play a role. In particular, obstructive sleep apnea (OSA) is now appreciated to be closely linked to dementia.

OSA is a common sleep disorder where the upper airway collapses during sleep.[3] Repetitive closure of the upper airway can result in multiple awakenings, impacting the quality of sleep. OSA is prevalent in patients with cognitive impairment, with 60% of patients with mild cognitive impairment (MCI) and 70% with vascular cognitive impairment reporting symptoms suggestive of OSA.[4] Additionally, research has shown that the presence of OSA leads to an increased risk of developing dementia.[5,6] The presence of OSA is also associated with a decline in executive function,[7] attention,[8] and global cognition.[9] Fortunately, treatment with continuous positive airway pressure has been shown to improve cognition in patients both with dementia[10] and without dementia.[11] OSA may therefore be a modifiable risk factor for cognitive decline.

In-laboratory polysomnography (iPSG) remains the gold standard for diagnosing OSA;[12] however, due to the need to spend a night in a sleep laboratory, high costs, and lengthy wait times, limited numbers of patients are screened for OSA using iPSG.[13,14] Use of a home sleep apnea test (HSAT) may be a suitable alternative, as this technique is less

Table 1—Prior studies that have used HSAT in a cognitively impaired population.

Study	Population	n	Device	Recording Condition	Purpose
Gehrman et al. (2003)[16]	AD	38	Respitrace-Medilog portable system	Not stated	Relationship of sleep apnea and agitation in AD
Ancoli-Israel et al. (2008)[10]	AD with OSA	52	In-home PSG - Embla	Not stated	Relationship of CPAP therapy and cognition
Rose et al. (2011)[17]	Dementia	59	Grass Portable PSG	Attended	Examine sleep patterns in dementia
Maestri et al. (2015)[18]	MCI and AD	22	In-home PSG	Not stated	Evaluate sleep patterns in dementia
Vaughan et al. (2016)[20]	MCI	18	ApneaLink	Unattended	Feasibility of using HSAT
Carnicelli et al. (2019)[19]	Amnestic MCI	19	In-home PSG	Not stated	Relationship of sleep and conversion of MCI to dementia

AD = Alzheimer disease, CPAP = continuous positive airway pressure, HSAT = home sleep apnea test, MCI = mild cognitive impairment, OSA = obstructive sleep apnea, PSG = polysomnography.

expensive, more convenient and accessible, and has been validated against iPSG.[15]

A few earlier studies[10,16–19] used HSAT in patients with cognitive impairment for the purpose of assessing sleep and confirming a diagnosis of OSA (**Table 1**); this work examined the relationship between cognitive impairment, sleep patterns, and nocturnal behavior, as well as the benefits of using continuous positive airway pressure in patients with Alzheimer disease. Only 1 study[20] has assessed the feasibility of using HSAT in a research setting; in that study, 35 patients with mild cognitive impairment were offered to use HSAT, but only 8 consented to undergo the test (**Table 1**). The feasibility of broad screening in a clinic population of cognitive impairment has yet to be examined and is needed to determine if HSAT is a clinically meaningful screening test for patients with cognitive impairment.

Our primary objective was to evaluate the feasibility of obtaining analyzable data from HSAT in clinic outpatients with cognitive impairment. Our secondary objectives were to determine the practicality of the use of HSAT in clinic outpatients with cognitive impairment; to assess predictors of obtaining analyzable HSAT recordings; and to ascertain whether obtaining analyzable data from HSAT was correlated with severity of cognitive impairment, caregiver assistance, patient ease of use with HSAT, and actigraphy-derived total sleep duration.

METHODS

Ethics

The study was approved by the local Research Ethics Board and was conducted in accordance with the Declaration of Helsinki. Prior to being enrolled in this study, all participants, or their substitute decision maker, provided written informed consent.

Study population

This was an observational, single-center prospective study. Patients were consecutively recruited from academic cognitive neurology clinics at Sunnybrook Health Sciences Centre during a 20-month recruitment period (November 2017 to June 2019). Inclusion criteria included: 1) cognitive impairment primarily attributable to an underlying neurodegenerative and or/vascular etiology consistent with Alzheimer Disease, MCI,[21,22] vascular dementia, vascular MCI[23]; Parkinson disease-related dementia, dementia with Lewy bodies,[24,25] and/or mixed disease; 2) were outpatients being managed through an ambulatory care clinic at Sunnybrook Health Sciences Centre; 3) had the competency to provide informed consent or the availability of a substitute decision maker to provide consent; and 4) the availability of a caregiver to assist in study-related tasks, if needed. Patients who had any of the following were excluded: 1) the presence of a contraindication for the use of the HSAT used in the study (eg, moderate to severe pulmonary disease or congestive heart failure);[13] 2) any medical device that would interfere with the placement of the HSAT; 3) language barrier with no translator available; or 4) current use of continuous positive airway pressure for previously diagnosed OSA.

Eligible patients were identified by the patient's cognitive neurologist or by chart review performed by the graduate student (D.R.C) and/or cognitive neurologist following a patient's clinical visit. Patients were referred to the study regardless of whether they endorsed self-reported sleep complaints.

Study procedure and assessments

Eligible patients were educated on the importance of sleep disorders in the context of cognitive impairment and provided informed consent. Baseline questionnaires and assessments were completed and related to functional status, cognition, sleep, mood, and behavior. Assessments related to functional status included the Alzheimer's Disease Functional Assessment and Change Scale (ADFACS).[26] Cognitive assessments included the Psychomotor Vigilance Task (PVT),[27] Montreal Cognitive Assessment (MoCA),[28] Mini Mental State Examination (MMSE),[29] and the Toronto Cognitive Assessment (TorCA).[30] Sleep-related questionnaires included the Epworth Sleepiness Scale,[31] Berlin Questionnaire,[32] and STOP-Bang questionnaire.[33] For mood and behavior assessment, the Geriatric Depression Scale[34] and the full Neuropsychiatric Inventory Questionnaire (NPI)[35] were completed. Following completion of baseline assessments, patients were taught how to use and apply the HSAT and were provided HSAT instructional sheets and also a phone number to call if additional support was needed.

Home sleep apnea test

Patients underwent unattended OSA testing using the ApneaLink Air (ResMed, San Diego, CA). This level III HSAT is Health Canada and Food and Drug Administration–approved and records chest/respiratory effort by a chest effort sensor, nasal flow/pressure by a nasal cannula, and oxygen saturation by a pulse oximeter. This HSAT has been validated against iPSG for the detection of OSA.[36–38] Participants were educated by the graduate student (D.R.C) on how to apply and operate the device and were provided with an instructional sheet. The night recordings were completed at the participant's home and were unattended. Following completion of the night recording, a satisfaction survey was completed by the patient, which allowed them to provide feedback on their experiences with the HSAT. Actigraphy, which has been validated to assess sleep-wake disturbances such as sleep fragmentation,[39] was recorded on average for 6.5 days. Variables derived from actigraphy on the night the patient completed HSAT included wake after sleep onset (minutes), sleep efficiency (percentage), total sleep time (minutes), and onset latency (minutes).

HSAT recordings were automatically analyzed using the ApneaLink software as well as manually scored by a sleep physician according to the standards outlined in the American Academy of Sleep Medicine.[40] As previously described,[41] apneas were scored as a ≥ 90% reduction in airflow for ≥ 10 seconds and hypopneas were scored as ≥ 30% reduction in airflow for ≥ 10 seconds with ≥ 4% oxygen desaturation. The sum of apneas and hypopneas per hour were calculated to generate an apnea-hypopnea index.

Outcome measures

The primary objective of this study was to determine the feasibility of obtaining analyzable data from HSAT in clinic outpatients with cognitive impairment who completed HSAT. Use of HSAT was considered a feasible technique for the screening of OSA in a cognitively impaired clinic population if ≥ 80% of the patients who completed HSAT obtained analyzable data. The HSAT was considered analyzable if ≥ 4 hours of flow, effort, and oxygen evaluation were obtained. The cutoff of ≥ 4 hours was selected as it has been recommended by clinical practice guidelines[13] and previously used in a HSAT feasibility study.[42] Secondary objectives were 1) to determine the practicality of recruiting clinic patients with cognitive impairment to complete HSAT and 2) to assess predictors of obtaining ≥ 4 hours of analyzable data from the HSAT. For the practicality objective, HSAT was considered a practical technique for screening OSA if ≥ 50% of the patients approached obtained ≥ 4 hours of analyzable data. Moreover, we also 3) evaluated whether obtaining analyzable HSAT data was correlated with severity of cognitive impairment, caregiver assistance, and patient ease of use with HSAT, as well as whether HSAT evaluating time was correlated with actigraphy-derived total sleep duration in patients who obtained analyzable data.

Statistical analyses

Continuous measures were summarized by means and standard deviations, categorical measures by frequency counts and percentages, and ordinal variables by median and interquartile range. Comparison between groups that obtained analyzable data to those who obtained nonanalyzable data were made using *t* tests for normally distributed continuous variables, Mann–Whitney *U* test for nonnormally distributed continuous variables and ordinal variables and chi-square tests for categorical variables.

Multiple logistic regression was completed to determine factors that predicted analyzable HSAT recordings. Variables chosen a priori included age, sex, TorCA total score (assessment of global cognition), and ADFACS total score (assessment of functional ability). Variables from the univariate analysis that had a *P* value ≤ .01 were also included in the model to account for potential confounders. The beta coefficient ± standard error, odds ratio, 95% confidence interval, and *P* value were reported for each covariate. Multicollinearity of the model was assessed by variance inflating factor, where values greater than 10 suggested variables that were highly collinear and partial residual plots were assessed to determine if nonlinearity of continuous variables was a concern.

To ascertain whether obtaining analyzable data from HSAT was correlated with severity of cognitive impairment, we ran Spearman correlations between scores on the MMSE, MoCA, and TorCA with whether the HSAT recording was analyzable or not (coded as a dichotomous variable). Fisher's exact test was completed to assess if obtaining analyzable HSAT was correlated with caregiver assistance. Spearman correlations were also completed to assess whether obtaining analyzable HSAT data were correlated with patient ease of use of HSAT. Pearson correlations were computed to assess whether HSAT evaluating time was correlated with actigraphy-derived total sleep duration in patients who obtained analyzable data.

Sample size calculation

For the primary objective of our study, we determined that a sample size of 62 participants would be required, which was calculated assuming 80% of the study population obtained analyzable data, with a 95% confidence level and precision of 10%. A *P* value < .05 was considered to be statistically significant.

The statistics software "R", version 3.4.1 (R Foundation for Statistical Computing, Vienna, Austria) and the Statistical Package for the Social Science (version 24.0) was used to perform all analyses.

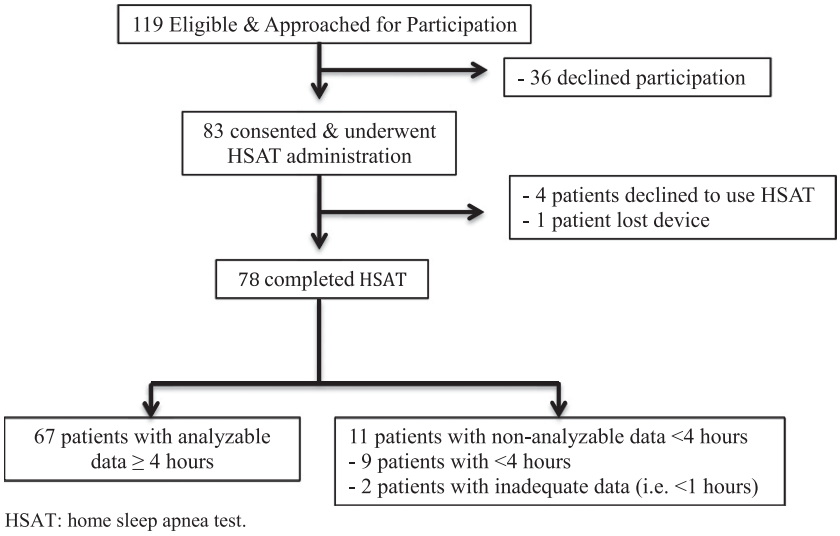
RESULTS

Patient demographics

One hundred and nineteen patients who were screened were eligible and approached for participation in the present feasibility study. Of these patients, 36 declined to participate and the remaining 83 attended baseline testing. Four patients returned the HSAT without using it and one lost the HSAT. The remaining analysis includes the 78 patients who attempted to complete the HSAT (**Figure 1**).

Patients who completed home sleep apnea testing had a mean (± standard deviation) age of 72.86 ± 9.89 years and 46.2% were male (**Table 2**). Actigraphy derived total sleep time identified

Figure 1—Participant flow through the feasibility study.



HSAT = home sleep apnea test.

that patients slept for a mean (± standard deviation) 457.14 ± 89.28 minutes (ie, 7 hours and 37 minutes). In our study population, MMSE scores ranged from 15 to 30 and MoCA scores ranged from 9 to 29. The study population included patients who were diagnosed with Alzheimer Disease (n = 20; 25.6%), MCI due to Alzheimer Disease (n = 28; 35.9%), vascular dementia (n = 4; 5.1%), vascular MCI (n = 11; 14.1%), mixed dementia (n = 6; 7.7%), and mixed MCI (n = 9; 11.5%).

Feasibility and practicality

For our primary objective (ie, to determine the feasibility of obtaining analyzable HSAT data in patients who completed HSAT), 85.9% (67 of 78) of patients who completed sleep apnea testing using the HSAT obtained analyzable data (defined as ≥ 4 hours of HSAT flow, effort, and oxygen evaluation data). For our secondary objective (ie, to determine the practicality of recruiting patients with cognitive impairment from neurology clinics to complete HSAT), 56.3% (67 of 119) of patients who were approached for participation in this study obtained analyzable data.

Factors determining analyzability of data

Univariate analyses compared patients who had analyzable data (≥4 hours) to those who had nonanalyzable data (< 4 hours). Variables that were significantly associated with having analyzable HSAT data included completing assessments in the morning (as opposed to the afternoon); higher ADFACS score for basic activities of daily living; lower NPI total score and NPI caregiver distress score; higher TorCA, MMSE, and MoCA scores; higher mean reciprocal reaction time; lower PVT derived lapses (reaction time > 500 ms); and having intermediate risk for OSA assessed by the STOP-Bang questionnaire (**Table 2**).

There was a range of diagnoses that were recruited, and, to investigate if the different etiologies for cognitive impairment had an impact on the ability to successfully obtain an analyzable HSAT, we assessed rates of obtaining analyzable data across the different diagnoses (**Table 3**). Using Fisher's exact test, there were no significant differences in the proportion of patients who obtained analyzable data to those who did not obtain analyzable data for the various diagnoses assessed.

Multiple logistic regression analysis was performed to assess for predictors of obtaining analyzable HSAT data (**Table 4**). As discussed above, the model included variables that were chosen a priori and the variables that were ultimately included were age, sex, TorCA total score, ADFACS total score, morning assessment, and PVT-derived lapses. Although the NPI total score had a P value ≤ .01 on the univariate analyses, it was not included due to missing data. The logistic regression model identified one variable that was significantly associated with obtaining an analyzable HSAT recording: having a morning assessment, compared to afternoon, was a significant independent predictor of obtaining analyzable HSAT data (odds ratio: 40.05, 95% confidence interval: 2.76, 580.90, P = .007).

Model diagnostics were completed for the multiple logistic regression model. Nonlinearity of continuous variables was not a concern after assessment of partial residual plots and multicollinearity was not a concern as no covariates had a variance inflating factor greater than 10.

Correlation analyses of analyzable HSAT data

There was a significant correlation between obtaining analyzable HSAT data and severity of cognitive impairment: attaining analyzable HSAT data was positively correlated with scores on the MMSE (ρ: 0.268, P = .018), MoCA (ρ: 0.253, P = .027), and TorCA (ρ: 0.306, P = .009) and significantly associated with not requiring assistance to assemble the HSAT (P = .009). Obtaining analyzable HSAT data was not significantly correlated with patient ease of use of HSAT (ρ: 0.188, P = .124). In patients with analyzable data, HSAT evaluating time was

Table 2—Patient clinical characteristics and demographics.

	Completed HSAT (n = 78)	Analyzable Data (n = 67)	Nonanalyzable Data (n = 11)	*P* Value
Age (y), mean ± SD	72.86 ± 9.89	72.82 ± 10.07	73.09 ± 9.10	.989
Male, n (%)	36 (46.2)	30 (44.8)	6 (54.5)	.782
BMI, mean ± SD	25.49 ± 5.31	25.64 ± 5.45	24.34 ± 4.11	.656
Years of education, mean ± SD	15.47 ± 3.75	15.69 ± 3.66	14.18 ± 4.17	.219
Dementia diagnosis (vs. MCI), n (%)	30 (38.5)	23 (34.3)	7 (63.6)	.094
Morning assessment, n (%)	61 (78.2)	57 (85.1)	4 (36.4)	.001*
Time between recruitment and HSAT test (days), mean ± SD	8.71 ± 14.63	7.77 ± 13.09	14.90 ± 22.29	.722
Actigraphy measures (n = 50), mean ± SD				
Wake after sleep onset (minutes)	45.10 ± 28.95	45.41 ± 28.81	42.30 ± 33.52	.925
Sleep efficiency (%)	84.41 ± 10.78	83.82 ± 10.99	89.78 ± 7.32	.227
Total sleep time (minutes)	457.14 ± 89.28	453.13 ± 91.87	493.20 ± 54.75	.346
Onset latency (minutes)	32.34 ± 49.80	34.74 ± 51.90	10.75 ± 10.51	.412
ADFACS (n = 74), mean ± SD				
Total score	89.35 ± 13.06	90.22 ± 12.50	83.80 ± 15.80	.202
IADL score	84.74 ± 18.05	85.77 ± 17.73	78.20 ± 19.67	.249
ADL score	95.46 ± 9.42	96.06 ± 8.95	91.82 ± 11.73	.024*
NPI total score (n = 55), mean ± SD	10.15 ± 10.45	8.13 ± 8.06	20.44 ± 15.13	.010*
NPI caregiver score (n = 55), mean ± SD	6.25 ± 6.34	5.28 ± 5.79	11.22 ± 7.05	.013*
TorCA overall score (n = 73), mean ± SD	244.75 ± 45.51	250.56 ± 40.87	203.44 ± 57.44	.010*
MMSE, median (IQR)	26 (4)	26.5 (4)	21 (8)	.019*
MoCA, median (IQR)	22 (6.75)	23 (6)	17 (6)	.028*
PVT measures, mean ± SD				
Mean RRT	3.08 ± 0.64	3.15 ± 0.58	2.67 ± 2.95	.021*
Mean FRRT	4.16 ± 0.68	4.20 ± 0.62	3.95 ± 0.94	.266
Lapses (reaction time > 500 ms)	12.65 ± 17.06	10.33 ± 14.04	26.82 ± 26.15	.008*
Geriatric Depression Scale, median (IQR)	6 (8.5)	6 (9)	7 (10)	.604
STOP-Bang, n (%)				
Low risk	25 (32.1)	20 (29.9)	5 (45.5)	.316
Intermediate risk	36 (46.2)	34 (50.7)	2 (18.2)	.045*
High risk	17 (21.8)	13 (19.4)	4 (36.4)	.242
Berlin Questionnaire - high risk (opposed to low risk), n (%)	27 (34.6)	24 (35.8)	3 (27.3)	.739
Epworth Sleepiness Scale ³ 10, n (%)	13 (16.7)	12 (17.9)	1 (9.1)	.679
Hypertension, n (%)	47 (60.3)	40 (59.7)	7 (63.6)	1.000
Hyperlipidemia, n (%)	44 (56.4)	41 (61.2)	4 (36.4)	.188
Diabetes, n (%)	9 (11.5)	9 (13.4)	0 (0)	.344
History of smoking, n (%)	35 (44.9)	29 (43.3)	6 (54.5)	0.529

*$P < 0.05$. ADFACS = Alzheimer's Disease Functional Assessment and Change Scale, ADL = basic activities of daily living, BMI = body mass index, FRRT = fast reciprocal reaction time, HSAT = home sleep apnea test, IADL = instrumental activities of daily living, MCI = mild cognitive impairment, MMSE = Mini Mental Status Examination, MoCA = Montreal Cognitive Assessment, NPI = Neuropsychiatric Inventory Questionnaire, OSA = obstructive sleep apnea, PVT = psychomotor vigilance task, RRT = reciprocal reaction time, SD = standard deviation, TorCA = Toronto Cognitive Assessment.

significantly correlated with actigraphy-derived total sleep duration (r=0.384, $P = .009$).

Patient satisfaction

After completion of the HSAT, patients had the opportunity to complete a satisfaction survey with regards to their experience with the HSAT (n = 68, **Figure 2**). Of the respondents, 54% stated they did not require assistance to assemble the device, 59% stated it was "easy" to "very easy" to attach the device on their body, 43% stated they were "relatively comfortable" to "completely comfortable" with using the device compared to a normal night's sleep, and 54% stated they were "somewhat aware" to "very aware" of the device during their sleep. For overall experience using the HSAT, 57% of the patients stated their experience was "good" to "excellent."

Table 3—Analyzable HSAT data by patient diagnosis.

Diagnosis	Analyzable Data	Nonanalyzable Data
Alzheimer disease (n = 20)	15 (75.0%)	5 (25.0%)
MCI due to AD (n = 28)	27 (96.4%)	1 (3.6%)
Vascular dementia (n = 4)	4 (100.0%)	0 (0.0%)
Vascular MCI (n = 11)	9 (81.8%)	2 (18.2%)
Mixed dementia (n = 6)	4 (66.7%)	2 (33.3%)
Mixed MCI (n = 9)	8 (88.9%)	1 (11.1%)

AD = Alzheimer disease, HSAT = home sleep apnea test, MCI = mild cognitive impairment.

DISCUSSION

Our results demonstrated that use of home sleep apnea testing was feasible in a clinic population of patients with cognitive impairment. We found that 86% of patients who underwent home sleep apnea testing were able to obtain ≥ 4 hours of analyzable data (ie, there were sufficient data to interpret). This was greater than a cutoff of 80%, which has been used in prior literature to assess the feasibility of home sleep apnea testing in other clinical populations.[42] Similarly, we demonstrated that use of home sleep apnea testing was a practical method, as we were able to demonstrate that 56% of patients approached for participation in our study obtained analyzable HSAT data. Moreover, we demonstrated that a morning assessment was associated with attaining analyzable data. We also found that obtaining analyzable data was correlated with degree of cognitive impairment and not requiring assistance to assemble the HSAT, but not with patient-reported ease of use with the HSAT. Finally, we found that in patients with analyzable data, HSAT evaluating time was correlated with actigraphy-derived sleep duration.

To our knowledge, only one study to date has assessed the feasibility of the use of HSAT in a research setting involving patients with cognitive impairment, specifically MCI[20]; they demonstrated poor feasibility of HSAT in individuals with and without cognitive impairment (25% and 54% completed ≥ 4 hours of HSAT, respectively). Our study demonstrated greater feasibility of HSAT (86%), which may be due to the method of HSAT instruction. In Vaughan et al (2016),[20] the HSAT and instructions were mailed to participants, and support via phone call was provided if necessary. In the present study, HSAT instructional sheets were provided on the day of the baseline assessments, and patients were given a demonstration of how to assemble and apply the HSAT in person; in addition, they were provided with a phone number to call if they required assistance.

Our study demonstrated that a morning assessment was independently associated with obtaining analyzable HSAT data. This association may be due to time of day effects, where older adults are typically at their optimal performance earlier in the day.[43] Participants were shown how to use and apply the HSAT after completion of baseline assessments; with demonstration of HSAT assembly being completed earlier in the day, participants may have been more alert and attentive when instructions were provided. Post hoc analyses demonstrated that after stratifying the study population by median age (ie, 74 years), time of day, and obtaining analyzable data for participants over the age of 74 years reached statistical significance, but not for participants under the age of 74 years. Additional post hoc analyses demonstrated that assessments of cognitive measures, such as the MoCA, MMSE, TorCA, and PVT, did not significantly differ with the time of day when they were completed. These findings suggest that training sessions earlier in the day may improve the chances of successful data collection using HSAT, particularly in patients greater than 74 years of age (regardless of cognitive status).

Additionally, obtaining analyzable HSAT data was positively correlated with severity of cognitive impairment (as assessed by the MMSE, MoCA, and TorCA). As HSAT may not be appropriate in patients with severe cognitive impairment, post hoc analyses were completed to assess a cut-off score on the MMSE and MoCA that primary care providers could use to guide them on whether patients should be referred for HSAT or iPSG. Receiver operating characteristic curves demonstrated cut-off scores of ≥ 22 on the MMSE (sensitivity: 0.89, specificity: 0.55, area under the curve: 0.72) and ≥ 19 on the MoCA (sensitivity: 0.83, specificity: 0.64, area under the curve: 0.71) as being associated with obtaining analyzable data. Future research should explore this further as ambulatory approaches to care may be an economically attractive method for diagnosing OSA as they can decrease usage of in-laboratory facilities.

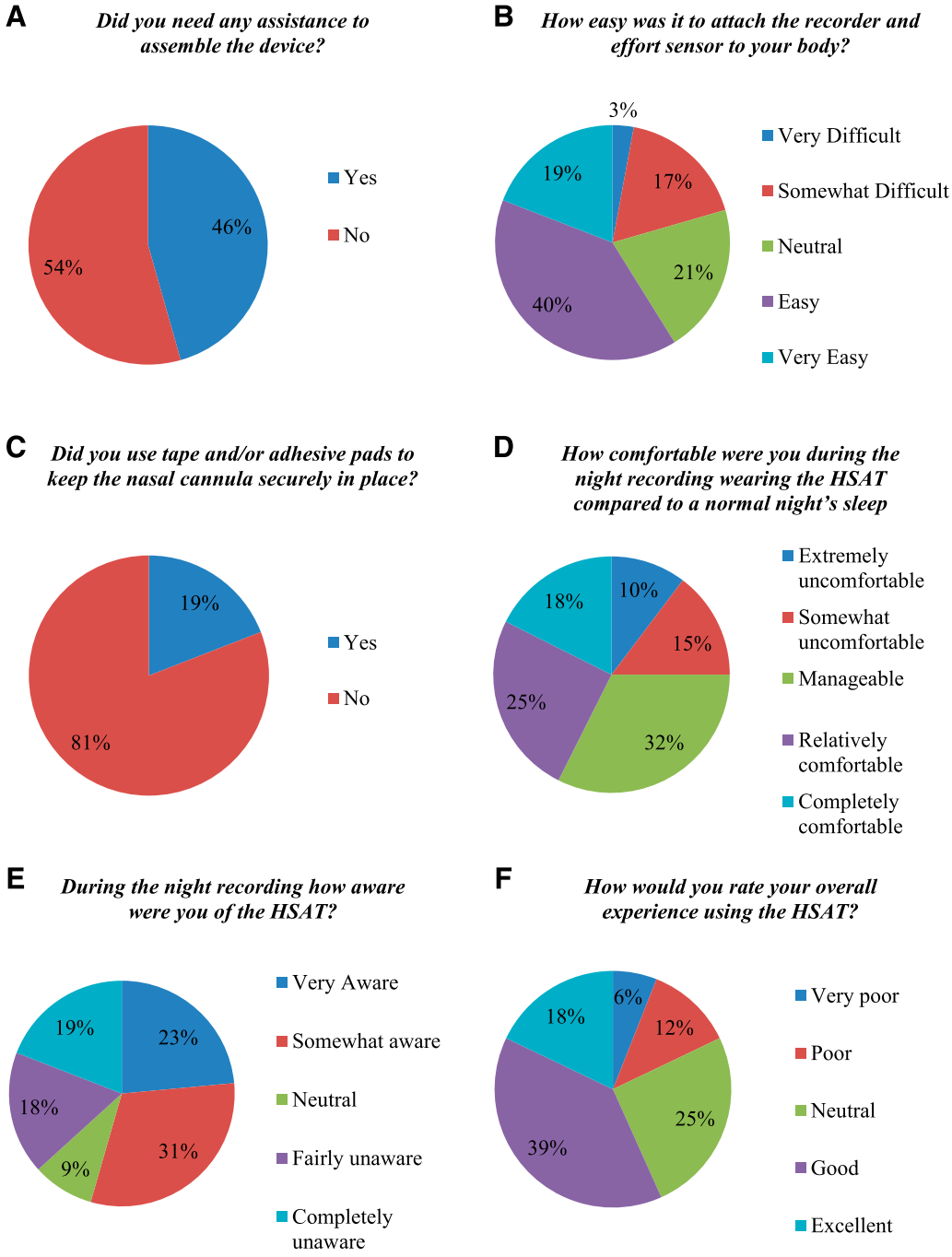
The HSAT also demonstrated high patient satisfaction, as most patients reported it to be easy to assemble and use and rated HSAT as being as comfortable as a normal night's sleep. Obtaining analyzable data was not correlated with patient ease of use; however, it was correlated with not requiring caregiver assistance to assemble

Table 4—Logistic regression for analyzable HSAT data.

	Coef ± SE	Odds Ratio	95% CI of the Odds Ratio	*P* Value
Age	0.06 ± 0.06	2.40	0.49, 11.68	.279
Male sex	-0.45 ± 1.05	0.64	0.08, 5.02	.667
TorCA total score	0.01 ± 0.01	1.62	0.55, 4.80	.385
ADFACS total score	0.05 ± 0.04	2.65	0.67, 10.49	.164
Morning assessment (opposed to afternoon)	3.69 ± 1.36	40.05	2.76, 580.90	.007*
PVT derived lapses	-0.05 ± 0.03	0.47	0.19, 1.16	.101

*$P < 0.05$.ADFACS = Alzheimer's Disease Functional Assessment and Change Scale, Coef = β-coefficient, CI = confidence interval, HSAT = home sleep apnea test, OSA = obstructive sleep apnea, PVT = psychomotor vigilance task, SE = standard error, TorCA = Toronto Cognitive Assessment.

Figure 2—HSAT patient satisfaction survey.



Each chart **(A–F)** demonstrates the proportion of answers patients provided on the HSAT patient satisfaction survey. HSAT = home sleep apnea test.

the device, suggesting the HSAT could be used for patients with cognitive impairment who live alone. Also, while many patients reported they were aware of the device during their sleep, the overall reported experience with the HSAT was positive.

Although the HSAT used in this study is not able to correctly assess total sleep time, our actigraphy-derived total sleep time demonstrated that, on average, patients slept for more than 7 hours per night. Notwithstanding the limitations of actigraphy, this suggests that patients may have been able to sleep for the recommended duration for adults (ie, 7 to 9 hours) and older adults (ie, 7 to 8 hours).[44] Moreover, in patients with analyzable data, HSAT evaluating time was correlated with actigraphy-derived total sleep time.

In this population with cognitive impairment, research has demonstrated sleep questionnaires, such as the STOP-Bang and Berlin Questionnaires, are not reliable tools to screen for OSA.[45] This may possibly be due to patients being cognitively unaware of their sleep issues or misunderstanding of the questions. Disagreement between objective and subjective assessments was seen in one study that included patients with Alzheimer Disease.[46] Alternatively, OSA may present differently in this population and it may

impact the operating characteristics of these questionnaires. Assistance by caregivers to complete these questionnaires may be beneficial for future studies. Of note, these sleep questionnaires have been reliable in other patient populations such as perioperative patients[33,47] and patients who have had a stroke.[48,49]

Lengthy wait times to complete iPSG often limit timely sleep assessment for patients. In a study that assessed wait times for sleep apnea care in the same province where the present study was completed (Ontario, Canada), they determined patients had to wait approximately 4.9 months to complete a sleep study after being referred.[50] In the present study, patients completed HSAT on average 9 days after the date of recruitment. While the 2 studies cannot be compared directly, this demonstrates the potential HSAT has in providing timely sleep assessments.

The present study has some limitations. In our study population, MMSE scores ranged from 15 to 30 and MoCA scores ranged from 9 to 29. Our study may be limited in the representation of patients with severe cognitive impairment (ie, scores < 10) and our results may not be generalizable to patients with severe cognitive impairment. However, given that the goal would be to intervene early in the disease trajectory of an individual with neurodegeneration, with OSA being a modifiable risk factor for decline, the target clinical population would be expected to have higher MMSE and MoCA scores, in line with our study cohort. Also, as this study was completed at tertiary care cognitive neurology clinics, it may limit the generalizability of the findings to primary care clinics. The HSAT used in this study was the ApneaLink Air, and our results regarding feasibility and practicality may only be applicable to this HSAT. However, given that approximately 80% of respondents to the HSAT satisfaction survey indicated that the ApneaLink was "neutral" to "very easy" to assemble and attach, our study suggests that ambulatory sleep tests requiring comparable or less effort to set up may be a viable tool in the future for both clinical and research purposes.

CONCLUSIONS

In conclusion, in a population of clinic patients with cognitive impairment, HSAT was a feasible and practical method to detect OSA, with patients' overall experience being positive. We also demonstrated that a morning assessment was associated with attaining analyzable data. Finally, we found that obtaining analyzable data was correlated with degree of cognitive impairment and not requiring assistance to assemble the HSAT, but not with patient-reported ease of use with the HSAT. Moreover, we found that HSAT evaluating time was correlated with actigraphy-derived sleep duration in patients with analyzable data.

With the impending rise in dementia prevalence, HSAT may play an invaluable role in addressing this challenge, given its potential to expedite assessment of OSA, an independent risk factor for dementia. That HSAT may be better tolerated than iPSG would be crucial, given the frail nature of this target population. Randomized controlled trials that compare iPSG (current standard of care) to HSAT in a population with cognitive impairment are needed to evaluate whether HSAT is comparable and/or superior to iPSG with respect to rates of sleep assessment completion, OSA diagnosis and treatment, clinical outcomes such as cognition, as well as cost-effectiveness.

ABBREVIATIONS

ADFACS, Alzheimer's Disease Functional Assessment and Change Scale
HSAT, home sleep apnea test
iPSG, in-laboratory polysomnography
MCI, mild cognitive impairment
MMSE, Mini Mental Status Examination
MoCA, Montreal Cognitive Assessment
NPI, Neuropsychiatric Inventory Questionnaire
OSA, obstructive sleep apnea
PVT, psychomotor vigilance task
TorCA, Toronto Cognitive Assessment

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