

Unattended Hospital and Home Sleep Apnea Testing Following Cerebrovascular Events

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Background: Home sleep apnea testing (HSAT) is an alternative to polysomnography for the detection of obstructive sleep apnea (OSA). We assessed the feasibility of HSAT as an unattended screening tool for patients with a stroke or transient ischemic attack (TIA). *Aims:* The primary outcome was the feasibility of unattended HSAT, as defined by analyzability of the data. Secondary outcomes included determining (1) predictors of obtaining nonanalyzable sleep data and (2) time to OSA detection and continuous positive airway pressure (CPAP) initiation. *Methods:* In this single-center prospective observational study, inpatients or outpatients who had sustained a stroke or TIA were screened for OSA using the ApneaLink Plus ambulatory sleep monitor in their home or hospital room. *Results:* There were 102 patients who completed unattended sleep monitoring. Mean age was 68.7 ± 13.7 years, 55.9% were male, 57.8% were outpatients, and 77.5% had a stroke (22.5% with TIA). Eighty-two (80.4%) patients obtained four or more hours of analyzable sleep data. Functional dependence (defined as a modified Rankin Scale of >2) and elevated body mass index were independently associated with obtaining nonanalyzable data. OSA was detected in 63.4% (52 of 82) of patients and, of those, 34 of 52 (65.4%) initiated CPAP therapy. The mean time from study recruitment to HSAT was 1.7 days (median: 1, interquartile range [IQR]: 2) and CPAP was initiated on average within 62.7 days of recruitment (median: 53, IQR: 30). *Conclusions:* Unattended HSAT can be feasibly implemented after stroke or TIA. This method facilitates rapid diagnosis and management of OSA in both the outpatient and inpatient settings. **Key Words:** Home sleep apnea testing—portable sleep monitoring—obstructive sleep apnea—stroke—transient ischemic attack—feasibility. © 2016 National Stroke Association. Published by Elsevier Inc. All rights reserved.

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Conflict of interest: Dr. Boulos' research program received from ResMed the ApneaLink Plus sleep monitors that were used in this study. ResMed was not involved in the study design or preparation of the manuscript. All the other authors have no conflicts of interest to declare.

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Background

Obstructive sleep apnea (OSA) is an independent risk factor for stroke and death.^{1,2} OSA can also develop after cerebrovascular events, and is detected in up to 72% of patients who have suffered a stroke or transient ischemic attack (TIA).³ Untreated OSA negatively impacts poststroke functional recovery⁴ and increases the risk of recurrent vascular events⁵ and mortality.⁶ Treatment of OSA with continuous positive airway pressure (CPAP) has been shown to improve poststroke functional and motor recovery.⁷ Outside of the stroke or TIA setting, randomized trials have demonstrated beneficial effects of CPAP for blood pressure management,⁸ lipid control,⁹ and improved daytime sleepiness and quality of life.¹⁰ CPAP has also been demonstrated to be cost-effective.¹¹ Accordingly, recent guidelines for secondary stroke prevention recommend considering sleep studies and CPAP for patients with stroke and TIA.¹² Given the high prevalence of OSA after cerebrovascular events and its unfavorable impact, a feasible method of screening for poststroke or TIA OSA is essential.

Although in-laboratory polysomnography (PSG) is the gold standard for diagnosing OSA,¹³ its utility as a broadly used diagnostic tool is hampered by limited access, lengthy wait times¹⁴ and, at times, patient unwillingness to sleep in a laboratory setting. Due to the atypical clinical presentation of OSA after stroke,¹⁵ paper-based screening tools are only moderately predictive for identifying OSA in stroke survivors, and objective testing is recommended to diagnose OSA in this population.¹⁶

Over the past few years, studies in the stroke or TIA population have moved toward the use of home sleep apnea testing (HSAT), which has been validated against in-laboratory PSG in adults with a high pretest probability of moderate to severe OSA (e.g., the poststroke or TIA population).¹⁷ Most studies in the poststroke or TIA setting have used HSAT to characterize OSA prevalence and its clinical features. However, only 2 studies to date have evaluated whether this approach is feasible: 1 studied hospitalized acute stroke patients¹⁸ and the other examined inpatients in a stroke rehabilitation unit.¹⁹ In both of these feasibility studies, patients had the sleep equipment attached by health-care professionals and were monitored by hospital or research staff. However, trained personnel are not always available to attach the components of the ambulatory sleep equipment or monitor patients. It remains to be determined whether unattended, unmonitored HSAT is feasible after stroke or TIA. Furthermore, no studies have assessed the feasibility of HSAT as a screening tool in the home setting for stroke or TIA outpatients. Prior studies using HSAT in stroke or TIA patients are summarized in [Table 1](#).¹⁸⁻³³

Aims

The aims of this study were to (1) assess the feasibility of an unattended HSAT screening strategy for detecting

OSA in stroke or TIA inpatients and outpatients, (2) determine predictors of obtaining nonanalyzable sleep data, and (3) determine whether this strategy expedites the time to diagnosis of OSA and initiation of CPAP therapy (as compared with previously published data in the province of Ontario, Canada¹⁴).

Methods

Research Ethics

This study was approved by the Sunnybrook Research Ethics Board (study ID #189-2014) and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All study participants gave their written informed consent before their inclusion in the study.

Study Population

From July 2014 to June 2015, we prospectively enrolled patients with stroke (ischemic or hemorrhagic) or TIA admitted to the Sunnybrook Stroke Unit or outpatients of the Sunnybrook Regional Stroke Prevention Clinic. Patients were excluded if they had (1) moderate or severe pulmonary disease or congestive heart failure that could compromise the validity of the HSAT results³⁴; (2) any medical device that would interfere with the placement of the HSAT; (3) significant physical or cognitive impairment or language barrier that would restrict their ability to use the HSAT or complete study questionnaires.

Hospital and Home Sleep Apnea Testing

OSA screening was performed either in the patient's hospital room for inpatients or at home for outpatients. Screening was done using the ApneaLink Plus (ResMed Corp, San Diego, CA), which has been shown to be sensitive and specific in detecting OSA compared with in-laboratory PSG in prior studies.^{35,36} The ApneaLink Plus is a multichannel device that records airflow via a nasal pressure cannula, oxygen saturation via a digital pulse oximeter, and respiratory movements via an effort sensor attached to a chest belt. Research assistants trained patients on how to assemble and use the device. The overnight recordings were unsupervised.

Overnight sleep data were analyzed manually by a registered sleep technologist who was blinded to the other study data, using apnea and hypopnea criteria outlined by the American Academy of Sleep Medicine criteria and also in accordance with previous validation studies of the ApneaLink device.³⁵⁻³⁷ Apneas were defined as a reduction in the peak signal excursion by 90% or greater of the pre-event baseline that lasted for 10 seconds or more. Hypopneas were defined as a reduction in the peak signal excursion of 30% or greater for 10 seconds or more with a corresponding oxygen desaturation event of 4% or greater. The apnea-hypopnea index (AHI) was calculated from

Table 1. *Observational studies using hospital/home sleep apnea testing in the stroke/TIA population*

Study (y)	N	Device	Setting	Recording condition	Purpose
Ahn (2013) ²⁰	293	ApneaLink	Inpatient	Not stated	Influence of SDB on acute stroke
Broadley (2007) ²¹	55	Embletta PDS	Inpatient	Monitored	Prevalence and associations of OSA in stroke
Brown (2014) ²²	52	ApneaLink	Inpatient	Not stated	Association between hypoglossal nerve conduction and SDB in acute stroke
Brown (2014) ²³	355	ApneaLink Plus	Outpatient	Not stated	Association between brainstem infarct with SDB
Chan (2010) ²⁴	66	Remmers Sleep recorder	Inpatient, outpatient	Not stated	Prevalence of OSA in minor stroke/TIA
Disler (2002) ¹⁹	38	AutoSet Portable II Plus	Inpatient	Monitored	Feasibility of HSAT in acute stroke
Harbison (2002) ²⁵	68	AutoSet II Plus	Inpatient	Not stated	Prevalence of SDB in acute stroke
Joo (2011) ²⁶	138	ApneaLink	Inpatient	Not stated	Prevalence of SDB in acute stroke
Kepplinger (2013) ¹⁸	61	SOMNOcheck effort	Inpatient	Monitored	Feasibility of early SA screening in stroke
Kotzian (2012) ²⁷	68	Embletta PDS	Inpatient	Assisted	Validity of BQ to detect SA in stroke
Lefèvre-Dognin (2014) ²⁸	45	ApneaLink	Inpatient	Not stated	Impact of SA on stroke recovery
Martínez-García (2004) ²⁹	139	AutoSet Portable Plus II	Inpatient	Assisted	Prevalence of SDB in acute stroke
Martínez-García (2006) ³⁰	59	AutoSet Portable Plus II	Inpatient	Assisted	Role of dysphagia in SDB in ischemic stroke
Parra (2000) ³¹	161	Edentec monitor 3711	Inpatient	Unattended	Prevalence of SRBD associated with stroke/TIA
Rola (2007) ³²	70	Embletta	Inpatient	Not stated	Incidence of SRBD in stroke/TIA
Wierzbicka (2006) ³³	43	Embletta	Inpatient	Not stated	Incidence of SA in stroke/TIA

Abbreviations: BQ, Berlin Questionnaire; OSA, obstructive sleep apnea; SA, sleep apnea; SDB, sleep disordered breathing; SRBD, sleep-related breathing disorders; TIA, transient ischemic attack.

the total number of apneic and hypopneic events detected per hour of recorded night data.¹⁶ Sleep studies with an evaluating time of 4 hours or higher were considered analyzable. A cutoff of 4 hours or greater was chosen as has been used in previous validation studies of the ApneaLink.^{35,36}

Outcomes

The primary outcome was the feasibility of the use of HSAT after stroke or TIA. The screening strategy was considered feasible if at least 80% of the HSAT recordings obtained 4 hours or more of analyzable data. Secondary outcomes were to (1) determine predictors of obtaining nonanalyzable data; (2) compute the time from recruitment to HSAT; and (3) calculate the time from recruitment to CPAP initiation.

As discussed previously,¹⁶ OSA was defined as moderate to severe OSA (AHI ≥ 15) or mild OSA with significant oxygen desaturation (AHI ≥ 5 with a documented lowest nocturnal oxygen desaturation $\leq 88\%$). This definition was used to account for the fact that level III sleep monitors are known to underestimate the frequency of respiratory events because the number of events detected is divided by the total amount of time that the device is on, rather than by the hours of actual sleep.³⁸ Treating stroke patients

with lower AHIs may be prudent and, consistent with this, in 2008 the U.S. Centers for Medicare and Medicaid Services announced they would reimburse CPAP for patients with an AHI of ≥ 5 and a history of stroke.³⁸ The choice of an 88% cutoff was guided by the oxygen-hemoglobin dissociation curve: The steep portion of the S-shaped curve lies between a partial pressure of oxygen (PO₂) of 40 and 60 mmHg. The hemoglobin saturation is approximately 89% at 60 mmHg PO₂ but at lower hemoglobin saturations, the PO₂ drops considerably,³⁹ and patients are exposed to potentially significant hypoxemia. In fact, the American Thoracic Society recommends long-term oxygen therapy in COPD patients with an arterial oxygen saturation of $\leq 88\%$.⁴⁰

Patients who fulfilled these criteria for OSA were seen by the primary investigator (M.I.B.), and the harmful effects of OSA on vascular disease were discussed in detail. Patients were then offered an ambulatory self-adjusting positive airway pressure device (auto-PAP) for 2 weeks to determine the appropriate CPAP pressure, followed by initiation of standard CPAP.

Statistical Analysis

Frequency counts were computed for categorical variables and compared with chi-square tests. Means and

standard deviations (SDs) were calculated for normally distributed continuous variables and compared with unpaired *t*-tests. For non-normal and ordinal data we calculated the median and range and compared values using the Wilcoxon rank-sum test. Multivariate logistic regression was used to determine if the following variables were independently associated with nonanalyzability of data: age, gender, body mass index (BMI), functional dependence (defined as modified Rankin Scale [mRS >2]), smoking history, and presentation with stroke (rather than TIA). Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each potential predictor. Statistical significance was defined as a *P* value of <.05. We calculated a minimum sample size of 62 patients was required, assuming analyzability of 80% of the study population's data with a confidence level of 95% and a lower confidence limit of 70%. All statistical analyses were performed with the Statistical Package for the Social Sciences, version 22.0 (IBM Corp., Armonk, NY).

Results

Of the 156 patients we approached who met criteria for inclusion in the study, 102 patients consented and used the ApneaLink Plus (Fig 1). No significant differences in age or gender were observed in patients who declined to participate compared with those who underwent HSAT. The mean (\pm SD) age of the cohort was 68.7 ± 13.7 years (range: 34-96 years), 55.9% were male, and 42.2% were inpatients (Table 2). The mean (\pm SD) AHI was 13.7 ± 15.4 . The median time from stroke or TIA to HSAT was 21 days (interquartile range [IQR]: 80).

Of the 102 patients who underwent HSAT, twenty recordings were nonanalyzable. Four recordings were inadequate (i.e., recording time <2 hours despite multiple attempts [$n = 3$] or the patient declined retrieval after

a single attempt with no data [$n = 1$]). An additional 16 recordings were nonanalyzable due to an insufficient evaluating time of less than 4 hours (Fig 1). Twelve patients attempted the device more than once. In total, 82 patients obtained an adequate recording with an evaluating time of 4 hours or higher. No significant baseline differences were observed between patients with analyzable recordings and those that did not have analyzable recordings (Table 2), although BMI ($P = .054$) and functional dependence (defined as mRS >2; $P = .058$) approached statistical significance. Of the variables we entered into the logistic regression model, both elevated BMI (OR: .91, $P = .033$, 95% CI: .83-.99) and functional dependence (OR: .22, $P = .018$, 95% CI: .065-.77) emerged as significant independent predictors of having a nonanalyzable study.

Fifty-two patients (63.4%) patients were diagnosed with OSA (Fig 1). Of these, only 11 of 52 (21.1%) had a history of OSA previously diagnosed by PSG. The mean time from study recruitment to use of HSAT was 1.7 days (median: 1, IQR: 2). Thirty-four (65.4%) of the 52 patients diagnosed with OSA initiated CPAP therapy. Four patients were already using CPAP and 14 declined use of CPAP. The mean (\pm SD) time from recruitment to initiation of CPAP was 62.7 ± 43.3 days (median: 53, IQR: 30).

Discussion

Our study demonstrated that unattended HSAT in the poststroke or TIA population is feasible and may expedite the diagnosis and treatment of OSA in both the in-patient and out-patient setting. Although studies in stroke are now using HSAT,⁴¹ few have specifically addressed feasibility, and they have generally focused on the inpatient setting (Table 1). To our knowledge, none have examined the feasibility of unattended HSAT in the poststroke out-patient setting, as in our present study.

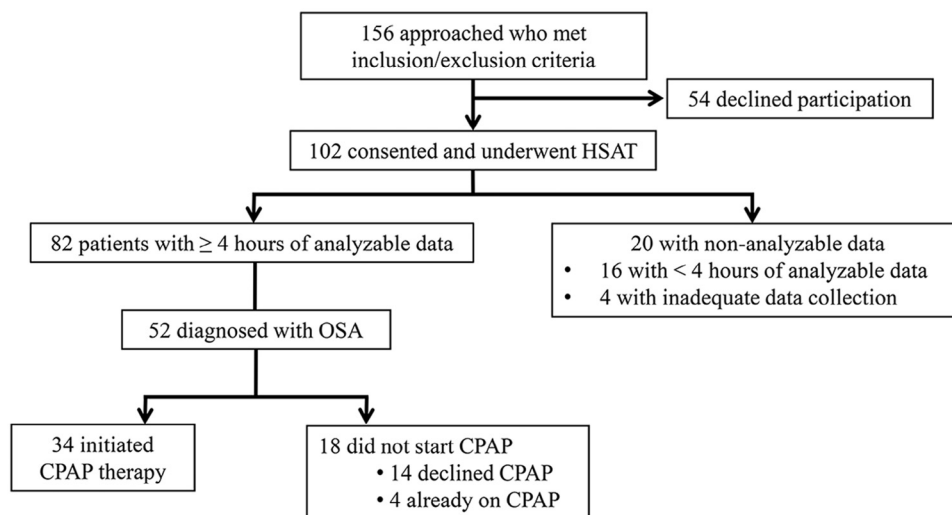


Figure 1. Patient flow through the study. Abbreviations: CPAP, continuous positive airway pressure; HSAT, home sleep apnea testing; OSA, obstructive sleep apnea.

Table 2. Study population demographics and clinical characteristics

	Total (N = 102*)	Analyzable (N = 82)	Nonanalyzable (N = 20)	P
Age (y), mean \pm SD	68.7 \pm 13.7	69.2 \pm 13.7	66.3 \pm 13.9	.384
Male, N (%)	57 (55.9)	45 (54.9)	12 (60)	.679
BMI, mean \pm SD	27.7 \pm 5.5	27.1 \pm 5.2	29.8 \pm 6.4	.054
Inpatient (as opposed to outpatient), N (%)	43 (42.2)	31 (37.8)	12 (60)	.072
Stroke (as opposed to TIA), N (%)	79 (77.5)	63 (76.8)	16 (80)	.761
Days from stroke/TIA to recruitment, median (IQR); N = 98	25 (119)	33.5 (125)	8 (79)	.329
Hypertension, N (%)	74 (72.5)	58 (70.7)	16 (80)	.405
Diabetes, N (%)	28 (27.5)	25 (30.5)	3 (15)	.164
Smoking history, N (%)	52 (51)	41 (50)	11 (55)	.688
Atrial fibrillation, N (%); N = 100	23 (22.5)	21 (25.6)	2 (10)	.151
Prior stroke, N (%); N = 101	21 (20.6)	18 (22)	3 (15)	.551
NIHSS, median (IQR); N = 99	1 (3)	1 (3)	2 (3)	.134
Functional dependence (mRS > 2), N (%)	25 (24.5)	17 (20.7)	8 (40)	.072
ESS, median (IQR); N = 93	7 (5)	7 (5)	7 (6)	.923
Stroke location				
Cortical stroke, N (%); N = 79	41 (40.2)	33 (40.2)	8 (40)	.865
Subcortical stroke, N (%); N = 79	60 (58.8)	48 (58.5)	12 (60)	.921
Cerebellar stroke, N (%); N = 79	13 (12.7)	12 (14.6)	1 (5)	.218
Brainstem stroke, N (%); N = 79	10 (9.8)	8 (9.8)	2 (10)	.983

Abbreviations: BMI, body mass index; ESS, Epworth Sleepiness Scale; IQR, interquartile range; mRS, modified Rankin Scale; NIHSS, National Institute of Health Stroke Scale; OSA, obstructive sleep apnea; SD, standard deviation; TIA, transient ischemic attack.

*Unless otherwise stated.

Disler et al reported that implementing monitored portable sleep monitors in a stroke rehabilitation ward was feasible and well-tolerated.¹⁹ Kepplinger et al reported that 91.8% of recordings obtained were analyzable in acute stroke inpatients.¹⁸ These inpatients were monitored and health-care staff attached and removed devices for each patient, in contrast to our study where patients were not monitored by research staff nor were nurses involved in the data collection. Given that the availability of trained personnel is often limited after-hours, especially in the home-based outpatient setting, our screening strategy has the potential for more widespread applicability and accessibility.

The ApneaLink device has also been validated for 2 hours of recording time.³⁵ If we had used a 2-hour cutoff, 88.2% of the recordings would have been analyzable. In our outpatients, the feasibility of HSAT was excellent as 51 of 59 (86.4%) of their recordings were analyzable, as compared with 31 of 43 (72.1%) of the inpatients, although this difference was not statistically significant. This may be due to inpatients having more severe cerebrovascular events compared with outpatients or suboptimal sleeping conditions in a hospital ward. Functional dependence after the cerebrovascular event (mRS > 2) was an independent predictor of having a nonanalyzable study, suggesting that functionally impaired patients had more difficulty using the device. Supervised sleep studies for this subset of stroke or TIA patients may be more feasible.

In-laboratory studies often have the disadvantage of lengthy wait times at many centers, which is a barrier to the timely diagnosis and treatment of OSA. A study of sleep apnea care in Ontario, Canada revealed that patients referred for PSG wait an average 149.5 and 390.4 days for a diagnostic sleep study and CPAP initiation, respectively.¹⁴ In comparison, the present screening strategy was able to reduce the average time from recruitment to sleep testing to 1.7 days and CPAP initiation to 62.7 days. Although not a direct comparison, our study demonstrates that unattended HSAT may substantially reduce wait times for a sleep study.

There are limitations to our study. We excluded patients with severe physical impairments or aphasia that would interfere with use of the device. This introduces a sampling bias toward less severe stroke patients and limits the generalizability of our results. However, our unattended HSAT screening strategy is likely most appropriate for outpatients or those with short stays in inpatient settings. More severely impaired populations with longer inpatient admissions may benefit from supervised HSAT and were never the intended targets of our study. Secondly, it is possible that some patients wore the portable sleep monitor incorrectly because they were not supervised. In most cases, this would result in nonanalyzable data, but on 1 occasion, a patient reported wearing the chest belt on the abdomen and yet still produced analyzable data. This patient had his HSAT

repeated. Because study patients were under the direct care of a sleep neurologist (M.I.B.) and were seen in consultation after HSAT, such circumstances should have been mitigated but cannot be entirely ruled out.

Conclusions

In conclusion, unattended HSAT appears feasible for patients with mild stroke or TIA, identifies a substantial prevalence of OSA in this population, and facilitates more rapid management of OSA as compared with traditional PSG that has long wait times in our region. Implementation of HSAT poststroke or TIA is a promising strategy to help address current problems of underdiagnosis and undertreatment of OSA. It remains to be determined if implementing such a broad screening strategy can improve clinical outcomes. Randomized controlled trials comparing unattended HSAT with the current standard of care, in-laboratory PSG, in the stroke or TIA population are warranted.

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