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Nighttime Oxygen Desaturation and Symptoms of Sleep-Disordered Breathing in Long-Stay Nursing Home Residents

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Background. Sleep-disordered breathing (SDB) is common in older adults and has been implicated as a cause of decreased quality of life and even death. Sparse data exist on SDB in the nursing home setting. The authors evaluated SDB (using attended nocturnal pulse oximetry) in nursing home residents with daytime sleepiness and nighttime sleep disturbance.

Methods. Pulse oximetry was used to estimate the prevalence of nighttime oxygen desaturation in 109 long-stay nursing home residents (mean [standard deviation] age = 86.2 [9.2] years; 74% women). Pulse oximetry findings were compared to a structured observational measurement of symptoms of SDB, the Observational Sleep Assessment Instrument. Seventy-one participants had concurrent wrist actigraphy to estimate total sleep time during oximetry recording.

Results. Using the oxygen desaturation index (ODI; average number of oxygen desaturations 4% or more below the baseline level per hour), the authors found that 40% of the residents had abnormal ODI (ODI more than 5, which is suggestive of SDB). Of all observational variables assessed, only loud breathing during sleep was significantly correlated with ODI ($r = .284$; $p = .003$). When ODI was adjusted for estimated total sleep time, higher adjusted ODI was associated with higher body mass index (kg/m^2).

Conclusions. Abnormal ODI is common in nursing home residents. Observed loud breathing at night and high body mass index may suggest that further assessment of SDB is indicated. Future research should determine the importance of SDB and abnormal nocturnal oxygen desaturation on functioning and quality of life in nursing home residents.

AGE-RELATED changes in sleep patterns and sleep structure have been described in older adults. Increased daytime sleepiness, taking longer to fall asleep, and more episodes of nighttime awakening are accompanied by decreased sleep efficiency (i.e., time asleep/time in bed) and shorter periods of deep sleep in older adults (1). These changes are both common and more severe in nursing home residents than in community-dwelling older adults. Sleep disruption in nursing home residents likely results from multiple factors, including increased time spent in bed, reduced daytime bright light exposure, lack of structured daytime activities, and few regular social and environmental cues to regulate sleeping and waking patterns (2).

In addition to age-related changes and environmental factors, certain sleep disorders, such as sleep-disordered breathing (SDB), are more common in older persons (1). SDB is defined as repeated pauses in breathing during sleep lasting 10 seconds or more (3,4). These respiratory events often lead to decreased blood oxygen saturation levels, which can precipitate awakenings followed by resumption of breathing. In addition, SDB contributes to daytime sleepiness and nighttime sleep fragmentation, which can impair daytime functioning. Several adverse outcomes in older adults have been associated with SDB, including cardiovascular consequences (hypertension, cardiac arrhythmias, myocardial infarction, and stroke) and cognitive impairment (memory problems, attention difficulties, and difficulty concentrating) (1,5–8). Some studies have shown that older adults with severe SDB have higher mortality rates compared with those without SDB (9).

Associations between SDB and increased age, higher body mass index (BMI), male sex, and dementia have been reported (4,10,11). An association between SDB and increased risk for mortality has been reported in both community-dwelling older adults (9) and female nursing home residents (12).

Traditionally, SDB is studied with polysomnography in a sleep laboratory. To definitively diagnose SDB, polysomnography uses multiple channels including the electroencephalogram, electrooculogram, electromyogram, electrocardiogram, pulse oximetry, chest movement, and airflow (3). Persons undergoing polysomnography are then assigned a respiratory disturbance index (mean respiratory events per hour of sleep). A respiratory disturbance index less than 5 is typically considered normal, whereas a respiratory disturbance index of 15 or more suggests moderate to severe SDB worthy of treatment (4,13).

Some persons cannot be examined in the traditional sleep laboratory setting. Less intensive ambulatory methods can be useful in detecting sleep disorders in such persons. Pulse oximetry alone has been investigated as an alternative way to screen for SDB because it is simple, allows the patient to sleep in their usual environment, and is less expensive than traditional polysomnography. Pulse oximetry is particularly

attractive for use in nursing home residents with dementia because it is more easily tolerated than multichannel polysomnography.

Pulse oximetry alone yields an oxygen desaturation index (ODI) rather than a respiratory disturbance index. The ODI is the average number of oxygen desaturations at least 4% below baseline level per hour. Several studies have tried to determine the sensitivity and specificity of this method, with results ranging from sensitivity of 31% to 98% and specificity of 41% to 100%, depending on the specific devices and ODI cutoffs used (14,15). Using a cutoff of ODI of 5 or more appears to optimize the sensitivity of identification of patients with SDB compared with patients without SDB in sleep clinic samples (15); nonetheless, pulse oximetry has been shown to be more specific than sensitive in most studies. As a result, pulse oximetry is unlikely to falsely identify a person as having SDB, but it is more likely to fail to identify some persons who, in fact, have SDB (14,16). To date, no validation studies have been conducted in nursing home settings.

One caveat against using pulse oximetry alone is that the indices can be computed based only on the duration of the recording, whereas in the laboratory setting, the indices are computed based on the total amount of time the patient is asleep (i.e., time awake is excluded). This may lead to an underestimation of SDB severity when pulse oximetry is used alone. Estimation of total sleep time (e.g., with wrist actigraphy) may improve the accuracy of pulse oximetry-based estimation of SDB severity.

The cardinal symptoms of SDB are snoring and excessive daytime sleepiness. When both symptoms are observed together, SDB is often suspected and further evaluation is indicated. Structured observations of nighttime sleep and symptoms of SDB have been studied in the nursing home setting (17,18), but only limited objective data exist on nighttime oxygen desaturation among nursing home residents.

In this study, we assessed the frequency of nocturnal oxygen desaturation in nursing home residents with daytime sleepiness and nighttime sleep disruption. We hypothesized that observations of disturbed breathing during sleep would be related to ODI. We also hypothesized that persons with more cognitive impairment would have higher ODI and more observed breathing disturbances during sleep. We also expected to confirm findings of previous studies showing that male sex and BMI were correlated with SDB severity.

Methods

Participants

Participants were residents in four Los Angeles-area community nursing homes with daytime sleepiness and nighttime sleep disruption enrolled in a randomized controlled trial of nonpharmacologic interventions to improve sleep. Pulse oximetry data for the current study were collected under usual-care conditions. Daytime sleepiness was assessed using behavioral observations of sleep versus wakefulness performed by research staff every 15 minutes from 9:00 AM to 5:00 PM for 2 days for all residents at each nursing home. Only those who were bed-bound, in contact isolation, or who left the facility before screening were excluded. Daytime sleepiness was defined as being asleep on 15% or more of observations, where ''sleep'' was defined as ''eyes closed with no purposeful movement.'' Residents who met criteria for observed daytime sleepiness and who gave consent to participate then had 2 nights of wrist actigraphy. Those who were scored asleep 80% or less of the time between 10:00 PM and 6:00 AM were enrolled in the study.

Apparatus

Enrolled participants had 1 night (approximately 9:00 PM to 6:00 AM) of attended pulse oximetry monitoring with a fingertip sensor connected via cable to an Ohmeda Biox 3700 pulse oximeter (Louisville, CO), which recorded oxygen saturation, heart rate, and time continuously on a laptop computer. Observations during sleep were performed simultaneously by research staff using the Observational Sleep Assessment Instrument (OSAI). The OSAI was developed to assess symptoms of SDB in nursing home residents (18). This instrument involves hourly 3-minute observations during which snoring, breathing rate, loudness and continuity, and chest movements are recorded.

To estimate total sleep time during oximetry recordings, nighttime wrist actigraphy was also performed using a Minimotionlogger (Ambulatory Monitoring, Inc., Ardsley, NY). The actigraph was placed on the dominant wrist, and activity levels were recorded in 60-second epochs. Sleep/awake was scored using a validated algorithm within the ActionW software (Ambulatory Monitoring, Inc.). Wrist actigraphy has been shown to accurately reflect total sleep time in nursing home residents (19).

The Mini-Mental Status Examination (MMSE) was used to measure cognitive functioning (20). A measure of comorbidity, the Cumulative Illness Rating Scale–Geriatrics was completed by a study physician using data from a structured medical record review and a brief physical examination (21). In our previous work, the Cumulative Illness Rating Scale–Geriatrics predicted acute illness episodes and death in long-stay nursing home residents (22).

Procedures

Participants underwent comprehensive screening including the MMSE and Cumulative Illness Rating Scale–Geriatrics. Demographic and medical record information (i.e., diagnoses and medications received during the study) were noted. Pulse oximetry recordings, OSAI observations, and wrist actigraphy were collected or performed while residents slept in their own rooms receiving usual care.

Data Analysis

For each participant, baseline oxygen saturation was determined using the mean oxygen saturation rate during the first 30 minutes of recording or the first 30-minute period with sufficient data to assign a baseline. An oxygen desaturation event was defined as a decrease to 4% or more below the baseline level. Oxygen desaturation indices were computed for each participant with at least 3 hours of pulse oximetry (mean [*SD*] recording length = 7.4 [1.2] hours). The ODI was defined as the average number of oxygen desaturations per hour of recording.

Table 1. Descriptive Characteristics ($N = 109$) and Associations With Oxygen Desaturation Index (ODI)*

	Mean (*SD*) or %	*r*	*p* value
Age	86.2 (9.2)	−0.044	.65
Years in nursing home	2.9 (2.9)	−.042	.68
Body mass index, Kg/m^2	25.3 (5.6)	0.186	.053
MMSE score	11.3 (9.6)	−0.089	.36
No. of medical diagnoses	9.9 (3.9)	−0.088	.37
No. of routine medications	9.1 (5.2)	−0.042	.67
No. of PRN medications	1.9 (1.8)	−0.144	.14
CIRS-G score	24.6 (5.0)	0.063	.52
		t	*p* value
Gender, % female	74.3%	−0.62	.54
Ethnicity, % non-Hispanic white	92.7%	1.36	.18
Sedative medications, % taking*	17.4%	0.30	.76
Cardiac disease, % of patients with†	10.1%	0.67	.52
Pulmonary disease, % patients with†	56.9%	0.40	.69
Neurologic disease, % patients with†	62.4%	−0.35	.73

* *SD* = standard deviation; MMSE = Mini Mental Status Examination; PRN = as needed; CIRS-G = Cumulative Illness Rating Scale-Geriatrics.

† Includes sedating antipsychotics, benzodiazepines, and benzodiazepine-like agents.

‡ Based on CIRS-G ratings.

Table 2. Summary of Nighttime Variables From Simultaneous Pulse Oximetry, Observational Sleep Assessment Instrument (OSAI), and Wrist Actigraphy

	Mean (SD)	Range
Pulse oximetry ($N = 109$)		
Total recording time (minutes)	445.4 (71.87)	182.7–610.9
Baseline oxygen saturation (%)	93.7% (2.3%)	84.8%–97.8%
Mean heart rate (beats per minute)	67.8 (9.8)	31.2–96.2
Mean oxygen desaturation index (ODI)	7.0 (9.3)	0–52.9
OSAI ($N = 109$)		
Number of observations per night*	6.5 (1.7)	2–12
Discontinuity of breathing†	0.27 (0.47)	0–1.83
Discontinuity of chest movements†	0.27 (0.46)	0–2.4
Loudness of breathing‡	1.4 (0.51)	1.0–3.0
% of observations with snoring	13.3% (25.1%)	0%–100%
Breathing rate (per minute)	17.6 (3.5)	11.1–26.0
Wrist actigraphy ($N = 71$)		
Total sleep time (TST; in hours)	4.3 (2.1)	1.1–9.0
Percent sleep (TST/total monitoring time)	47.9% (25.4)	5%–100%
Number of awakenings during recording	18.2 (8.4)	0–43

* Observations completed only when patient was asleep.

† Total number of events during the 3-minute observation period, reported as mean number per hour.

‡ Scored as 1 (low) to 3 (high).

We used actigraphically estimated total sleep time to calculate the number of desaturations per hour of sleep for 71 participants with acceptable actigraphy recordings. Although there were no differences in ODI between patients with ($n = 71$) and without ($n = 38$) wrist actigraphy recordings ($t_{107} = -.319$, $p = .75$), patients with wrist actigraph recordings had lower MMSE scores (9.6 vs 14.5; $p = .003$), fewer medical diagnoses (9.3 vs 11.0; $p = .040$), and took fewer routine (8.3 vs 10.6, $p = .025$) and as-needed (1.5 vs 2.6, $p = .002$) medications compared with participants without actigraphic recordings. As a result of these differences, we report analyses based on calculations of ODI with and without adjustment for total sleep time.

We used Student's *t* tests and regression analyses to test for associations between ODI and descriptive and OSAI variables. We anticipated that higher ODI would be associated with older age, higher BMI, lower MMSE scores, more medical diagnoses, use of more medications, and higher (more severe) Cumulative Illness Rating Scale–Geriatrics scores. For variables that were highly skewed, descriptives are presented as raw values and we used a normal scores transformation for statistical analyses (23). Two-tailed probability values less than .05 were considered significant.

Results

Participant Screening

Of the 492 nursing home residents screened with daytime behavioral observations, 339 met criteria for daytime sleepiness. Of those, 194 gave informed consent to participate and 133 met criteria for nighttime sleep disturbance. One hundred twenty-one nursing home residents were randomized into the larger controlled trial of which 109 had 3 or more hours of pulse oximetry and were included in the current study. Table 1 shows descriptive characteristics. No participants had a documented diagnosis of SDB in medical records. Of those participants with complete oximetry data, 77 had concurrent wrist actigraphy recordings during oximetry testing. Actigraphy recordings were considered inadequate if the patient was not asleep for at least 1 hour during the recording ($n = 6$). Analyses were based on the 109 participants with pulse oximetry and were repeated for the 71 participants with adequate concurrent actigraphic recordings.

Table 2 shows the results of the simultaneous pulse oximetry, OSAI, and wrist actigraphy. The mean ODI for the group was 7.0 (*SD*, 9.3). Forty percent of patients had ODI $\geq$5, 23% had ODI $\geq$10, and 13% had ODI $\geq$15 (Figure 1). The ODI was not significantly correlated with age, sex, ethnicity, BMI, MMSE score, number of diagnoses, or number of medications taken.

Loudness of breathing was the only OSAI variable significantly correlated with ODI ($r = .28$, $p = .003$; Table 3). Louder breathing was also related to higher BMI ($r = .28$ $p = .004$). When BMI was included in the regression model, loudness of breathing remained a significant predictor of ODI ($F_{2,104} = 5.23$, $p = .007$).

Oxygen Desaturation Index Based on Actigraphically Estimated Total Sleep Time

The mean total sleep time during the oximetry recording period for patients with acceptable actigraphy recordings ($n = 71$) was 4.3 hours. Patients with higher ODI had shorter total sleep time ($r = -.52$, $p < .0005$). When the ODI was

Table 3. Relationship Between Observed Symptoms of Sleep Apnea (Observational Sleep Assessment Instrument) and Oxygen Desaturation Index (ODI)

	Correlation	*p* value
Number of observations per night*	0.036	.708
Discontinuity of breathing†	−0.007§	.939
Discontinuity of chest movement†	0.140§	.148
Loudness of breathing‡	0.284	.003
% of observations with snoring	0.126	.191
Breathing rate (per minute)	−0.011	.914

* Observations completed only when patient asleep.

† Total number of events during the 3-minute observation period, mean per hour.

‡ Scored as 1 (low) to 3 (high).

§ Non-parametric correlation coefficient (Spearman's rho).

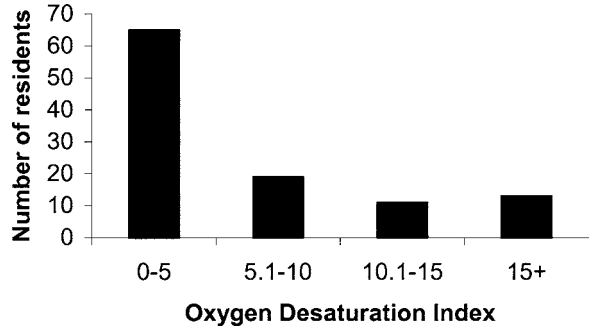

Figure 1. The distribution of oxygen desaturation index (ODI) scores (unadjusted for total sleep time) is shown for all participants. Sixty percent of participants fell within the normal range (ODI <5), whereas the remaining 40% had ODI of 5 or more, suggesting at least mild sleep-disordered breathing.

computed based on total sleep time, the severity of SDB appeared substantially worse (mean [*SD*] adjusted ODI = 20.6 [40.6]). Fifty-one percent of patients had adjusted ODI ≥5, 62% had adjusted ODI ≥10, and 25% had adjusted ODI ≥15. The association between the standard and adjusted ODI was strong ($r = .94$, $p < .0005$).

The relationship between adjusted ODI and BMI was significant such that patients with higher BMI had higher adjusted ODI ($r = .30$, $p = .012$). Adjusted ODI was not significantly associated with age, sex, ethnicity, MMSE, number of diagnoses, or number of medications, and adjusted ODI was not related to OSAI variables (i.e., snoring, breathing rate, continuity of breathing, loudness of breathing, or continuity of chest movements).

Discussion

We found that at least 40% of long-stay nursing home residents with evidence of daytime sleepiness and nighttime sleep disturbance had an abnormal ODI (≥5), and 13% had moderate-to-severe oxygen desaturation (ODI ≥15). When ODI was adjusted for actigraphically estimated total sleep time, the prevalence of severe oxygen desaturation appeared even higher (25% of participants had adjusted ODI ≥15). The ODI was not associated with age, sex, or comorbidity.

Although we found that observed loud breathing was significantly related to oxygen desaturation, we did not find a relationship between other observed symptoms of SDB such as snoring or discontinuous chest movement. It is possible that these events are simply more difficult to detect with nighttime observations than is loud breathing.

One previous study of SDB in a nursing home population using thoracic and abdominal effort sensors plus wrist actigraphy (12) found 43% of residents had at least five apneas per hour of sleep with no statistical difference between men and women. This is comparable to our results showing that 40% of nursing home residents with daytime sleepiness had ODI ≥5, with no statistical difference between men and women, although our methods of measurement were different.

Although BMI was not significantly associated with ODI (based on total recording time), it was related to the adjusted ODI (based on total sleep time). Given that patients with actigraphy recordings were medically healthier (i.e., took fewer medications and had fewer diagnoses), the relationship between ODI and BMI may be stronger in these persons. Nursing home residents with multiple medical comorbid conditions and who take more medications may have SDB as the result of these factors rather than because of high BMI.

When BMI and loudness of breathing were evaluated simultaneously, both were related to ODI. Although BMI is strongly predictive of SDB in community-based populations, obesity by itself may not be sufficient to predict SDB in the nursing home setting. Further study is needed to determine whether the combination of high BMI and loud breathing during sleep are predictive of SDB.

Although previous studies have shown a link between cognitive impairment and SDB, we did not find an association between MMSE score and ODI. Twenty-nine participants (27%) received a score of 0 out of 30 on the MMSE, suggesting that a floor effect may have influenced our findings. Nursing home residents with intact cognitive abilities but poor physical health may have more SDB than residents who are cognitively impaired but physically healthy.

The main limitation of this study is that pulse oximetry is an indirect method of estimating SDB because it only detects respiratory events sufficient to cause oxygen desaturation, and the true number of events occurring during sleep cannot be precisely determined. We tried to address this concern with concurrent wrist actigraphy; however, we could not obtain actigraph recordings on all 109 participants. The participants with actigraphic recordings tended to be more cognitively impaired but more medically healthy. Although full polysomnography would have been more accurate, many nursing home residents will not tolerate such cumbersome recording equipment, and sleep electroencephalography can be difficult to interpret in persons with dementia.

The strength of this study is that we were able to complete pulse oximetry recordings for 90% of enrolled participants with daytime sleepiness and nighttime sleep disturbance, which enhances the generalizability of our findings. In addition, based on validation studies conducted in sleep clinic samples, pulse oximetry has been shown to be more specific than sensitive in the identification of patients with

SDB (14), and we may have underestimated the true prevalence of SDB in our study sample as a result of using pulse oximetry rather than complete polysomnography.

Conclusion

We found a high prevalence of abnormal oxygen desaturation among nursing home residents with daytime sleepiness and nighttime sleep disruption. The clinical significance of this desaturation is unclear. Future research should focus on potential implications of oxygen desaturation and SDB in this setting.

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