

Utility of Actigraphy in the Diagnosis of Obstructive Sleep Apnea

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Study objectives: To determine whether adding actimetry to simplified polygraphy (respiratory-parameter monitoring without neurophysiologic variable recording) improves apnea-hypopnea index (AHI) evaluation as compared to simplified polygraphy alone.

Design: Comparison of AHI values obtained by all-night polysomnography and by simplified polygraphy with and without actimetry.

Setting: A teaching-hospital sleep laboratory in Garches, France.

Patients: 20 adults with suspected obstructive sleep apnea syndrome (OSAS).

Measurements and results: Data were analyzed by two scorers working independently. AHI was calculated as the number of apneas and hypopneas per hour of sleep time (polysomnography: AHI-pg), per hour of time

in bed (simplified polygraphy: AHI-tib), and per hour of actimetry-estimated total sleep time (AHI-act). AHI-pg showed that 12 patients had OSAS (AHI>10), which was severe (AHI ≥30) in eight. AHI-act was more closely correlated to AHI-pg ($r=0.976$) than was AHI-tib ($r=0.940$). According to the Bland and Altman method, AHI-tib underestimated the AHI in two patients and AHI-act overestimated the AHI in one patient. For the diagnosis of severe OSAS, sensitivity and negative predictive value were 50% and 75% with AHI-tib as compared to 88% and 92.5% with AHI-act.

Conclusions: Actimetry, when added to simplified polygraphy, may assist in the diagnosis of OSAS.

Key words: Actimetry; sleep apnea; polygraphy; actigraphy

INTRODUCTION

OBSTRUCTIVE SLEEP APNEA SYNDROME (OSAS) IS EXTREMELY COMMON¹ BUT CAN RARELY, IF EVER, BE DIAGNOSED BASED ON HISTORY AND PHYSICAL EXAMINATION ALONE.² Laboratories that perform diagnostic sleep recordings have long waiting lists. Polysomnography, the reference standard for diagnosing sleep apnea syndrome, is both expensive and timeconsuming. Simplified recording techniques have been developed recently. Most include pulse oximetry and one or more of the following: oronasal airflow, respiratory inductance plethysmography, snoring, heart rate from the electrocardiograph (ECG), and body position.²⁻⁸ These simplified recordings may be appropriate for patients whose history and physical findings are highly suggestive of sleep apnea syndrome but may underestimate the apnea-hypopnea index because they cannot determine total sleep time. Recent work has shown that body or eye-movement recording can provide a rough estimate of total sleep time.^{9,14} Wrist-movement recording by a piezoelectric accelerometer, or actimetry, has been widely used in clinical and basic-science studies of sleep. Actimetry for total sleep-time measurement has been validated comparatively to polysomnography.¹⁰⁻¹³ Kushida and colleagues¹⁴ reported close agreement between polysomnography and actimetry for measuring total sleep time, sleep efficiency, and number of awakenings in their clinic patients, most of whom had OSAS.

Disclosure Statement

The actimeters were supplied free of charge by Cambridge Neurotechnology Ltd., Cambridge, UK

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We investigated whether evaluation of sleep/wake periods by actimetry used with the Sleepwatch algorithm improved the diagnostic capabilities of polygraphy in consecutive patients with clinically suspected OSAS.

PATIENTS AND METHODS

Patients

We studied 20 consecutive adults (15 men and 5 women) undergoing all-night polysomnography for suspected OSAS. All patients agreed to wear an actimeter during the study night.

Polysomnography

Computerized polysomnography (Nightingale, Judex TM, Denmark; or RespiSomnograph, Mallinckrodt, USA) included electroencephalography (C4-A1, C3-A2), electrooculography, chin electromyography, oronasal airflow assessment using a nasal cannula, thoracoabdominal movement assessment using strain gauges, electrocardiography (V2), and pulse oximetry (Mallinckrodt, N200).

The recording started at the patient's usual bedtime, and the lights were turned off at the patient's request.

Actimetry

Actimetric recording (Actiwatch, Cambridge Neurotechnology Ltd., Cambridge, UK) was performed during the same night at the nondominant wrist. Actimeter settings were chosen so that data were stored in 1-minute epochs. The polysomnographic and actimetric recordings were started at the same time, and the two were carefully synchronized. The Actiwatch is a lightweight, wrist-worn activity-monitoring system in which an accelerometer monitors the occurrence and extent of motion. The extent and speed of motion are integrated to produce activity counts. The system works as follows. A bar-shaped accelerometer flexes when the Actiwatch is moved, pro-

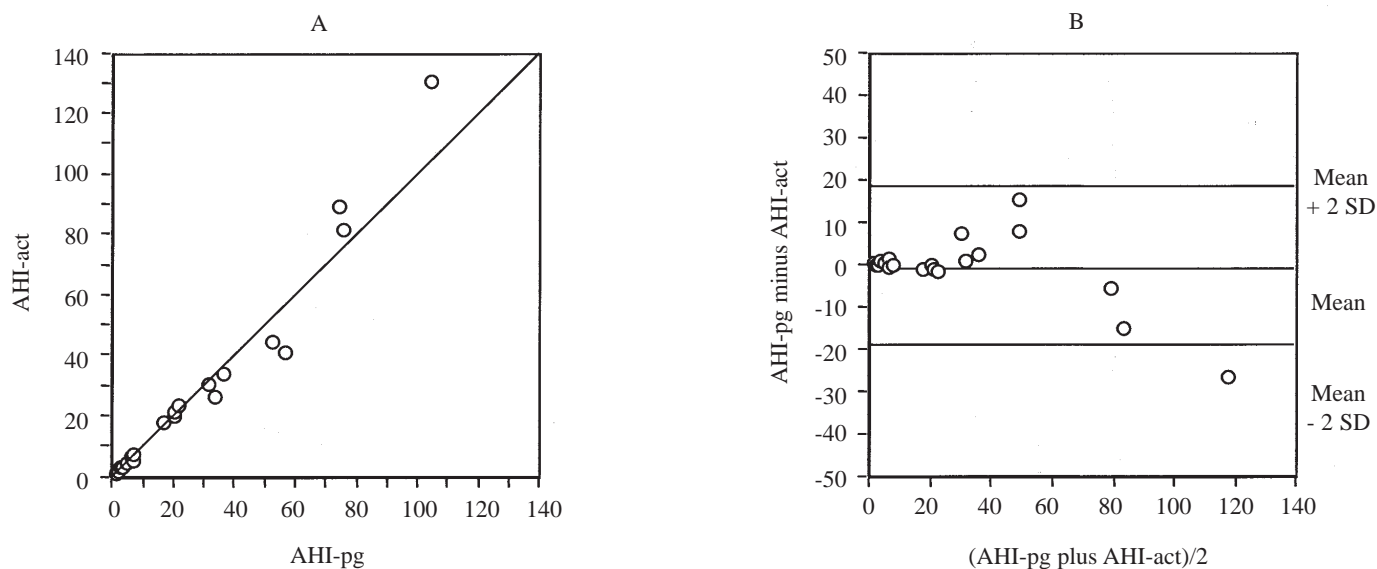


Figure 1—AHI determined using polysomnography (AHI-pg) and polygraphy + actigraphy (AHI-act). Panel A: Line of identity. Panel B: Agreement between the two techniques as assessed using the Bland and Altman method, in one patient, AHI was overestimated when polygraphy + actigraphy was used, as compared to polysomnography.

ducing a voltage in the sensor. The degree and force of flexing influence the voltage, which is translated into activity counts. The maximum sampling frequency is 32 Hz. Although the sensor is more sensitive to motion in some directions than in others, it detects motion in all directions.

Data analysis

Polysomnography and actimetry data were assessed by two independent scorers who had no information on patient identity or on the reasons for the sleep studies. Sleep stages were scored according to international criteria.¹⁵ Apnea was defined as airflow cessation for at least 10 seconds and hypopnea as airflow reduction for at least 10 seconds with a 4% or greater decrease in SaO₂.

The actimeter data were assessed using the algorithm supplied by Sleepwatch sleep analysis software for Windows (Cambridge Neurotechnology Ltd). The Actiwatch arousal threshold was set at an integrated activity count of 40 movements within a 1-minute epoch. The patient indicated lights off and lights on by pressing a button on the Actiwatch. Sleep onset was determined manually by the scorer as initiation of a sequence of 10 or more consecutive epochs of inactivity after lights off. End of sleep was defined as the start of a sequence of 10 consecutive minutes containing activity counts above the threshold of 40 activity counts at get-up time, followed by continuous activity.

The AHI was calculated using three different sets of data. When assessing the polysomnographic data, the AHI was calculated as the number of apneas and hypopneas per hour of sleep. This was the reference standard for the AHI (AHI-pg). When using simplified polygraphy, defined as recording of respiratory parameters (airflow, thoracic and abdominal movements, and pulse oximetry) but not of neurophysiologic sleep parameters, the AHI was calculated as the number of apneas and hypopneas per hour of time in bed (tib) after lights off (AHI-tib). When simpli-

fied polygraphy and actimetry were used in combination, the AHI was the number of apneas and hypopneas per hour of the actimetry-derived total sleep time after lights off (AHI-act).

Statistics

Statistical analysis was done using the Systat 5.03 for Windows statistical package (Systat Inc, Evanston IL, USA 60201). Descriptive statistics (mean±standard deviation) are reported for the demographic characteristics of the population. The Pearson correlation test was used to correlate AHI-pg with AHI-tib and AHI-act. Agreement among the three AHI values was examined using the Bland and Altman statistical method,¹⁶ in which the difference between two methods is plotted against the means.

We classified our patients as having OSAS or severe OSAS if their AHI-pg was greater than 10 per hour or was equal to or greater than 30 per hour, respectively. The AHI-tib and AHI-act were compared with AHI-pg in terms of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for classifying the patients correctly as having OSAS or severe OSAS.

RESULTS

Patients

The patient population included 15 men and 5 women with an age range of 16 to 76 years (mean age, 52±15 years). Body mass index (BMI, weight [kg]/height [m²]) ranged from 19 to 39 kg/m² (mean BMI, 28±5 kg/m²). All patients snored and 16 reported excessive daytime somnolence. By polysomnography, eight patients did not have OSAS (AHI-pg <10), four had moderate OSAS (AHI-pg, > 10 to 29), and eight had severe OSAS (AHI-pg ≥30).

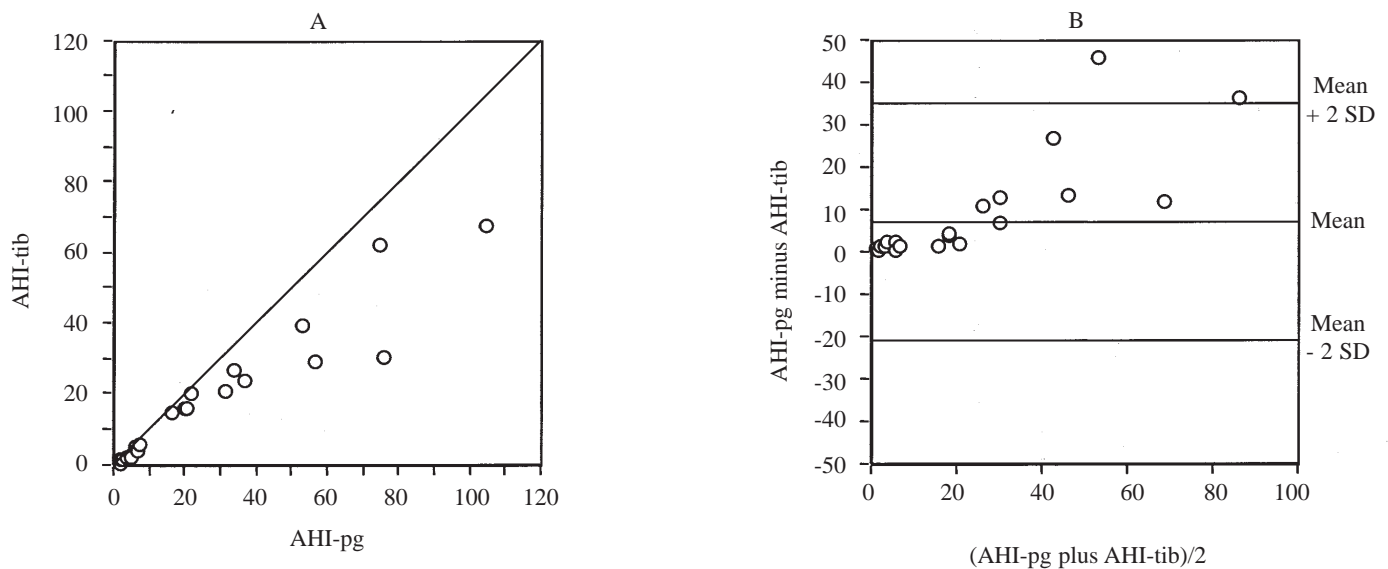


Figure 2—AHI determined using polysomnography (AHI-pg) and polygraphy (AHI-tib). Panel A: Line of identity. Panel B: Agreement between the two techniques as assessed using the Bland and Altman method: in two patients, AHI were underestimated when AHI-act was used.

Polysomnography and Actimetry

Mean tib after lights off was 530 ± 65 minutes. Mean clock time at sleep onset was 22.69 ± 0.9 hours.

By polysomnography, mean total sleep time was 368 ± 81 minutes (range, 201-478 minutes), mean sleep efficiency was $79\% \pm 10\%$ (range, 61%-92%), and mean percentages of sleep stages relative to total sleep time were as follows: stage 1, $20\% \pm 12\%$ (range, 2%-42%), stage 2, $53\% \pm 14\%$ (range, 26%-87%), stages 3 and 4 combined, $9\% \pm 9\%$ (range, 0%-38%), and rapid eye movement sleep, $17\% \pm 7\%$ (range, 9%-31%). Mean percentage of total sleep time with an SaO_2 below 90% was $7\% \pm 9\%$ (range, 0%-32%)

Wrist actimetry data were recorded adequately in all patients. The Sleepwatch software indicated a mean total sleep time of 373 ± 88 minutes (range, 187-524 minutes) and a mean sleep efficiency of $83\% \pm 10\%$ (range, 58%-99%).

The Pearson correlation coefficient between the polygraphy-derived total sleep time and actimetry-derived total sleep time was 0.74, $p < 0.0001$.

Respiratory Disturbance Index

The AHI values were as follows: AHI-pg, 29 ± 29 (range, 1.5-104); AHI-act, 30 ± 35 (1.5-134); and AHI-tib, 19 ± 19 (1-68).

Agreement Among the Three Methods

Figures 1 and 2 show the correlation coefficients (panels A) and Bland and Altman plots (panels B) for AHI-act as compared to AHI-pg and for AHI-tib as compared to AHI-pg, respectively. AHI-act was more closely correlated to AHI-pg than was AHI-tib ($r = 0.976$, $p < 0.0001$; and $r = 0.940$, $p < 0.0001$, respectively). In addition, the slope of the identity line was closer to the slope of the AHI-act/AHI-pg correlation line than to the slope of the AHI-tib/AHI-pg correlation line (Figures 1 and 2, panels A).

Results obtained using the Bland and Altman method (Figures 1 and 2, panels B) showed that two patients were underestimated when AHI-tib was used, whereas only one patient was overestimated when AHI-act was used.

The specificity, sensitivity, PPV, and NPV for the diagnosis of moderate OSAS (AHI-pg > 10 to 29) were 100% when both AHI-tib and AHI-act were used. For the diagnosis of severe OSAS (AHI-pg ≥ 30), specificity and PPV were 100% with both methods; however, sensitivity and NPV fell to 50% and 75%, respectively, with AHI-tib but remained high, at 88% and 92.5%, respectively, with AHI-act.

DISCUSSION

The diagnosis of OSAS is usually achieved by all-night polysomnography. Sleep laboratories have long waiting lists for this expensive, time-consuming, and labor-intensive procedure. Few sleep clinics can afford to perform polysomnography in every patient presenting with snoring. Given the high prevalence of snoring and the steady increase in the number of patients visiting sleep clinics for snoring, relying entirely on polysomnography for the diagnosis of OSAS seems unrealistic.

With the goal of reducing the number of all-night polysomnographies, several studies examined whether OSAS can be diagnosed based on the clinical impression of physicians specialized in sleep disorders.¹⁷⁻²⁰ Neither sensitivity nor specificity was high enough to make this a reliable method for diagnosing OSAS in the individual patient.

An appealing approach is simplified polygraphy, which consists of respiratory monitoring without neurophysiologic sleep recording. A study conducted by Douglas et al.²¹ in a predominantly respiratory sleep laboratory showed that conventional neurophysiologic sleep recording failed to improve the diagnosis of OSAS when added to respiratory monitoring. Since then, many studies have found that simplified polygraphy compared very favorably with full polysomnography and that neurophysiologi-

cal sleep recording was probably a waste of resources.³⁻⁹ However, simplified polygraphy uses TIB as the denominator for the AHI. Given that TIB is usually longer than time asleep, simplified polygraphy may produce spuriously low AHI values, thereby missing some cases of OSAS. Using a more reliable indicator of total sleep time should bring the diagnostic performance of simplified polygraphy closer to that of full polysomnography. Estimation of time spent to fall asleep can be evaluated subjectively by the patients, but it is very difficult for patients to subjectively evaluate wake after sleep onset. In contrast, actimetry is objective and easy to use in clinical practice. Actimetric estimates of total sleep time take into account both the time taken to fall asleep and periods of wake after sleep onset.

In keeping with previous studies, we found close agreement between simplified polygraphy and polysomnography. Furthermore, adding actimetry to simplified polygraphy resulted in better diagnostic performance.

Aubert-Tulkens et al used actimetry to screen patients for sleep apnea-hypopnea.²² They had shown that wrist actigraphy was a simple and well-tolerated method for obtaining repeated and objective measurements of sleep disruption in OSAS. They computed a movement index (MI) and a fragmentation index (FI). The MI was the number of minutes with one or more movements divided by the TIB and multiplied by 100. The FI was the ratio of the number of phases of 1-min immobility to the total number of immobility phases of all duration multiplied by 100. Patients with OSAS had significantly higher MI and FI values than did controls ($p < 0.001$). The FI and MI reflect different sleep characteristics in controls: the MI elevation occurs when sleep (and immobility) is interrupted by nocturnal awakenings, and a high MI can coexist with a low FI if, once asleep, the individual remains immobile for prolonged periods. By contrast, in OSAS, the periodic arousals caused by respiratory events increase both MI and FI. Accordingly, Aubert-Tulkens et al.²² found that the variable with the least overlap between controls and patients was the sum of MI and FI, or MFI. This sum had a sensitivity of 89% and a specificity of 95% for diagnosing sleep apnea syndrome when all-night polysomnography was used as the reference standard.

In our study, we used a commercially available algorithm (Sleepwatch) with the arousal threshold set at 40 activity counts within a 1-min epoch. This value is intermediate between the lowest threshold (20 activity counts) and the highest threshold (80 activity counts) used in a study by Kushida et al.¹⁴ of relations linking total sleep time, sleep efficiency, and number of awakenings as measured by polysomnography and actigraphy in 100 consecutive clinical patients. Forty patients had OSAS. The low-threshold algorithm provided the best overall accuracy and specificity for detecting arousal. The high-threshold algorithm was more sensitive but less accurate and less specific.

In studies investigating whether actigraphy adds information to home polygraphy recordings, it may be preferable to perform the recordings at home. The patients studied by Aubert-Tulkens et al.²² underwent polysomnography and actimetry at the laboratory followed one month later by actimetry at home. Agreement between the two methods was not as good when actimetry was done at home. In our study, full polysomnography and actimetry were done at the laboratory, during the same night. This protected our findings from effects of the substantial AHI variation that occurs from night to night in patients with mild sleep-disordered

breathing²³ and from variations related to the influence on sleep of external conditions (home vs laboratory).²⁴ Factors incriminated in night-to-night variability include differences in posture, medication, and alcohol use; in nasal congestion; and in psychological status. Thus, we evaluated only the reliability of actimetry for estimating total sleep time and OSAS severity independently from external factors.

An alternative to actimetry may be the method of White et al.,⁹ which adds eye, body, and limb movement monitoring to polygraphy. However, with this method, the time required to hook up the patient was similar to that for polysomnography, and about one hour was needed to read the results. Actimetry with polygraphy clearly saves time.

Actimetry underestimated total sleep time in two patients with severe OSAS (AHI, 104 and 74, respectively), probably because of movements related to severe and frequent apnea.

Actimetry did not improve the sensitivity and specificity of simplified polygraphy for the diagnosis of not severe OSAS (AHI-gs > 10 and < 30). However, clear improvements were seen for the diagnosis of severe OSAS.

We used a cut-off of at least 30 apneas or hypopneas per hour of sleep to define severe OSAS. The universal health insurance system in France reimburses the cost of nocturnal continuous positive airway pressure therapy in patients with at least 30 apneas and hypopneas per hour of either sleep or recording. In addition, this cut-off is used in recently published guidelines.²⁵ With this cut-off, both methods were 100% specific but adding actimetry to simplified polygraphy increased sensitivity twofold.

In clinical practice, comparing a new measurement technique with an established one is often needed to see whether they agree sufficiently for the new to replace the old. Correlation coefficients are often used for these comparisons but can be misleading.¹⁶ We found a strong correlation between the AHI measured with polysomnography and AHI measured by polygraphy alone. However, of the eight patients whose AHI was above the cut-off (30 or more) by polysomnography, five were below the cut-off by polygraphy alone, as compared to only one by polygraphy plus actimetry. In conclusion, this study conducted using the Sleepwatch algorithm, suggests that adding actimetry to simplified polygraphy may assist in the diagnosis and follow-up of suspected OSAS.

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