ORIGINAL ARTICLES

Split-Night Versus Full-Night Polysomnography: Comparison of the First and Second Parts of the Night

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BACKGROUND AND OBJECTIVE: In a split-night study, the first part consists of standard polysomnography (PSG) for the diagnosis of obstructive sleep apnea syndrome while the second part is used to establish a suitable level of continuous positive airway pressure. The aim of our study was to compare the sleep and respiratory parameters during the first 3 hours of the night with the values found during the remainder of sleep and during the whole night.

PATIENTS AND METHODS: Forty-five patients were included in the study. Each patient underwent a standard full-night PSG and the PSG data for each patient was divided into 2 periods: PSG_1, defined as the initial 3 hours of the total sleep time and PSG_2, defined as the remaining period. Sleep and breathing data from PSG_1 and PSG_2 were then separately computed and compared with each other and with data for the total sleep time (PSGt).

RESULTS: The percentage of total sleep time in stage III-IV and the apnea–hypopnea index (AHI) were significantly higher and the percentage of time in rapid eye movement (REM) sleep was significantly lower during PSG_1 than during PSG_2 ($P<.001$). Similarly, the percentage of time in stage III-IV sleep was significantly higher and the percentage of REM sleep was significantly lower during PSG_1 than during PSGt ($P<.001$), but there was no significant difference in the AHI between PSG_1 and PSGt.

CONCLUSION: The diagnosis for the first 3 hours of the night will give a reliable reflection of the whole night. In addition, optimal positive airway pressure titrated during the second half of the night is also optimal for the first half of the night.

Key words: *Polysomnography. Split-night. Sleep apnea.*

Polisomnografía de parte de la noche y polisomnografía de toda la noche: comparación entre la primera y la segunda partes de la noche

OBJETIVO: En el estudio de las partes inicial y final de la noche, la primera parte corresponde a la polisomnografía (PSG) estándar, que se utiliza para el establecimiento del diagnóstico del síndrome de apneas obstructivas durante el sueño, mientras que la segunda se usa para determinar el nivel adecuado de presión positiva continua de la vía aérea. El objetivo de nuestro estudio ha sido comparar los parámetros del sueño y respiratorios durante las primeras 3 h de la noche con los valores de estos mismos parámetros obtenidos a lo largo del resto del sueño y durante toda la noche.

PACIENTES Y MÉTODOS: En el estudio participaron 45 pacientes. Todos ellos fueron evaluados mediante PSG estándar durante toda la noche. El registro y los datos de la PSG de cada paciente se dividieron en 2 períodos: PSG_1, definido como las 3 h iniciales del tiempo total de sueño, y PSG_2, definido como el período restante. Después se calcularon por separado los datos correspondientes al sueño y a la respiración en los períodos PSG_1 y PSG_2, y se compararon entre sí y con los datos obtenidos en el registro de la PSG total (PSGt).

RESULTADOS: El porcentaje del tiempo total de sueño en las fases III-IV y el índice de apneas-hipopneas fueron significativamente mayores durante el período PSG_1 que durante el período PSG_2 ($p < 0,001$), mientras que el porcentaje de tiempo del sueño con movimientos oculares rápidos (REM, de *rapid eye movements*) fue significativamente menor durante el primero que durante el segundo ($p < 0,001$). De la misma manera, el porcentaje de tiempo en las fases III-IV fue significativamente mayor y el sueño REM fue significativamente menor durante el período PSG_1, en comparación con el período PSGt ($p < 0,001$), aunque no hubo diferencias significativas entre los períodos PSG_1 y PSGt respecto al índice de apneas-hipopneas.

CONCLUSIONES: El diagnóstico durante las primeras 3 h del sueño es fiable, pues refleja lo que ocurre a lo largo de toda la noche. Además, la presión positiva respiratoria óptima determinada durante la segunda mitad de la noche también es óptima respecto a la determinada en la primera mitad.

Palabras clave: *Polisomnografía. Primera mitad de la noche. Segunda mitad de la noche.*

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Introduction

Sleep apnea, a common disorder affecting children and adults, is characterized by both apneas and hypopneas. They have similar pathophysiology and similar impact on patients. Obstructive sleep apnea-hypopnea syndrome (OSAHS), the most common type, is caused by partial or complete collapse of the upper airway. Severity can be measured by counting the number of apneas and hypopneas per hour of sleep (the apnea–hypopnea index, AHI).[1,2] Data from the Wisconsin Sleep Cohort Study showed the prevalence of an AHI >5 to be 24% in men and 9% in women in the age range of 30 to 60 years.[3] Symptomatic sleep apnea (including excessive daytime somnolence) was found to be 4% in men and 2% in women in that study.

Diagnosis usually takes place in a technician-attended polysomnography (PSG) laboratory and it is labor-intensive and time-consuming. This situation impedes timely access, affecting a large number of individuals, given that as many as 93% of women and 82% of men with moderate-to-severe sleep apnea go undiagnosed according to estimates from the Wisconsin study.[4] In many locations around the world patients suspected of having sleep apnea face challenges accessing diagnostic services and treatment because of the discrepancy between demand and capacity. Recently, Flemons et al[5] studied the annual number of sleep studies performed, the range of wait times, and the strategies used for dealing with the mismatch between demand and capacity in 5 countries. They concluded that the capacity required to deal with the expected rate of undiagnosed cases, spread over a 10-year period, would be an additional 555 polysomnograms yearly for a population of 100 000 (based on 82% of 9% of the male population and 93% of 4% of the female population).

The time taken to investigate and treat patients can be reduced by using split-night studies in which diagnostic PSG and continuous positive airway pressure (CPAP) titration are done on the same night rather than on 2 nights (a full-night diagnostic PSG session followed by a CPAP titration on a different night). The protocol recommended by the American Academy of Sleep Medicine (AASM) for conducting split-night studies calls for a minimum of 2 hours of diagnostic PSG.[6] An AHI of at least 40, or an AHI of 20 to 40 with associated clinical factors such as long obstructions and major desaturations, must be documented during the diagnostic component. CPAP titration is carried out for more than 3 hours and PSG documents that CPAP eliminates or nearly eliminates the respiratory events during both rapid eye movement (REM) and non-REM sleep, including during REM sleep in supine position. In this study, these AASM criteria were used.

In controlled studies, the split-night protocol and full-night protocol are generally compared directly in terms of the rates of accurate diagnosis,[7] determination of sufficient CPAP pressure,[8] and CPAP compliance.[9] The aim of our study was to compare the sleep and respiratory parameters during the first 3 hours of the night with the values observed in the remaining hours of sleep and during the entire night. Thus, our intention was to answer 2 main questions: *a)* does the first half of the night demonstrate all features of the whole night, therefore making it possible to diagnose the whole night by evaluating the first half of it?, and *b)* does the second half of the night demonstrate features similar to those of the first half, making it possible to resolve the problems observed in the first half of the night by improving the parameters in the second half?

Patients and Methods

PSG was performed after clinical evaluation in the presence of the following criteria: *a)* classical clinical features of OSAHS (presence of loud snoring, witnessed apneas, and excessive daytime sleepiness), and *b)* an Epworth score greater than 10.

All patients underwent a standard full-night PSG, performed in a quiet, partially sound-proofed room with stable humidity and temperature. The procedure usually started at 10:00 PM and the operator switched off the light at the patient's request. The procedure was terminated at 7:00 AM. PSG was performed with a computerized system (Somnostar Alpha; Sensormedics, Los Angeles, California, USA) and included the following variables: electro-oculogram (2 channels), electroencephalogram (4 channels), electromyelogram of submental muscles (2 channels), electromyelogram of the anterior tibialis muscle of both legs (2 channels); electrocardiogram and airflow (with an oronasal thermistor). Chest and abdominal movements (2 channels) were recorded using inductive plethysmography, arterial oxyhemoglobin saturation by pulse oximetry with a finger probe (SpO_2, 1 channel). Recordings were conducted at a paper speed of 10 mm/s, and sleep stages were scored according to the standard criteria of Rechtschaffen and Kales.[10] Arousals were scored according to published definitions.[11] The arousal index (ARI) was defined as the number of arousals per hour of sleep. Apneas were defined by the complete cessation of airflow for at least 10 seconds. Hypopneas were defined as the reduction of more than 50% in airflow signal or either respiratory or abdominal signals of respiratory inductance plethysmography, with an associated fall of at least 3% in SpO_2 or an arousal. The AHI was defined as the number of apneas and hypopneas per hour of sleep. Patients with an AHI of 5 or more were considered as having OSAHS.[1] Patients with a sleep efficiency rating ([total sleep time/total time in bed] × 100) of less than 75% were excluded. Patients with sleep disorders other than OSAHS, such as upper airway resistance syndrome, periodic leg movements, and narcolepsy were also excluded.

The PSG file for each patient was divided into 2 periods: PSG_1, defined as the initial 3 hours of the total sleep time and PSG_2, defined as the remaining period of sleep. Sleep and breathing data from PSG_1 and PSG_2 were then separately computed and compared with data collected over the full night (PSGt).

Statistical Analysis

The following variables were compared (*t* test) between PSG_1 and PSG_2 and between PSG_1 and PSGt: sleep times in stages I, II, III and IV (each expressed as a percentage of the total sleep time); rapid eye movement (REM) sleep (percentage of total sleep time); the apnea and hypopnea indices; the AHI; mean SpO_2; and minimum SpO_2 during sleep. Correlations between indices of breathing pattern during the 3 study periods were evaluated using the Pearson correlation coefficient.

All analyses were performed using the SPSS 11.5 for Macintosh (SPSS Inc, Chicago, Illinois, USA). A *P* value of less than .05 was considered significant.

Results

Forty-five patients were included in the study. Demographic and polysomnographic data of the study population are shown in Table 1. Table 2 shows sleep and respiratory data separately reported for PSG_1, PSG_2, and PSGt. The mean time in stages III and IV expressed as a percentage of the total sleep time and the AHI was significantly higher, and mean time in REM sleep was significantly lower, during the PSG_1 period than during the PSG_2 period (P<.001). The comparisons between PSG_1 and PSGt showed more time in stages III and IV and less time in REM sleep in the PSG_1 period; however, AHI did not differ significantly. Sleep efficiency, mean SpO_2, and ARI values were similar between PSG_1 and PSG_2 and also between PSG_1 and PSGt.

TABLA 1
Demographic and Polysomnographic Data for the Study Population (n=45)[a]

Age, y	49.15 (9.43)
Sex, F/M	11/34
TST, min	386.61 (60.08)
Sleep efficiency,[b] %	86.4 (7.34)
ARI	24.69 (14.02)
Stage I, % TST	12.6 (8.36)
Stage II, % TST	63.21 (10.18)
Stage III and IV, % TST	9.7 (10.14)
REM sleep, % TST	14.74 (4.78)
SpO_2, %	86.77 (6.11)
SpO_2, minimum, %	73.11 (11.2)
AHI	64.12 (25.67)
AHI-REM	61.93 (27.14)
AHI, non-REM	66.05 (26.49)
Apnea index	32.1 (34.81)
Hypopnea index	35.2 (21.73)

Abbreviations: AHI, apnea-hypopnea index; ARI, arousal index; F, female; M, male; REM, rapid eye movement; SpO_2, arterial oxyhemoglobin saturation by pulse oximetry; TST, total sleep time.
[a]Values are expressed as mean (SD), with the exception of sex, for which numbers are given.
[b]Sleep efficiency is (TST/total time in bed) × 100.

A strong correlation was observed between mean AHI over the full night and AHI in the PSG_1 and PSG_2 portions, as well as a correlation between the mean AHI in the early part of the night and the second part (Figure).

Discussion

The reliability of the split-night sleep study has been evaluated by only a few authors. Yamashiro et al[9] studied 107 patients with sleep-disordered breathing to confirm that a comparably effective level of CPAP could be identified during the split-night protocol. They suggested that a split-night protocol could be as effective in reducing the AHI as a full-night titration especially when the baseline AHI was >40. McArdle et al[7] evaluated 138 patients (46 split-night patients matched with 92 full-night patients). According to their results, a split-night study resulted in similar CPAP use and posttreatment Epworth scores compared to standard full nights of diagnostic PSG and then titration. It was concluded that the reduction in overnight admissions without any increase in follow-up intervention suggested that the split-night protocol might result in significant cost savings. Iber et al[12] found that a single night study was sufficient to establish effective CPAP therapy in 78% of their patients and offered considerable savings in resources compared to full-night studies. Sanders et al[13] showed that the split-night study is an appropriate method for evaluating sleep-disordered breathing, having noted a strong correlation of respiratory disturbance indices between data from the first part and the whole night. In their study, no analyses were performed between the first and second parts of the night.

In the present study, a strong correlation was observed between the AHI (PSGt) and the AHI (PSG_1), between the AHI (PSGt) and the AHI (PSG_2) and between the AHI (PSG_1) and the AHI (PSG_2). We found that the AHI was higher during PSG_1 than during PSG_2. This suggests that the disease is more manifest in the first part of the night and therefore PSG during 3 hours of sleep is an appropriate

TABLE 2
Polysomnographic Data in PSG1, PSG2, and PSGt (n = 45)[a]

	PSG_1	PSG_2	PSGt	*P*	
				PSG_1 vs PSG_2	PSG_1 vs PSGt
TST, min	158.71 (14.16)	223.38 (62.57)	386.61 (60.08)	.001[b]	.001[b]
Sleep efficiency,[c] %	87.87 (7.7)	85.64 (8.2)	86.4 (7.34)	.56	.64
ARI	28.1 (12.7)	25.43 (14.1)	24.69 (14.02)	.23	.09
Stage I, % TST	13.07 (8.26)	12.32 (9.51)	12.6 (8.36)	.46	.43
Stage II, % TST	65 (12.99)	61.39 (10.82)	63.21 (10.18)	.42	.061
Stage III and IV, % TST	13.92 (15.07)	7.1 (8.27)	9.7 (10.14)	.001[b]	.001[a]
REM sleep, % TST	8.3 (5.62)	19.3 (8.66)	14.74 (4.78)	.001[b]	.001[b]
SpO_2, %	87.35 (10.71)	88.02 (6.86)	86.77 (6.11)	.68	.71
SpO_2, minimum, %	79.57 (10.05)	78.33 (10.55)	73.11 (11.2)	.22	.001[b]
AHI	69.06 (27.61)	60.23 (24.01)	64.12 (25.67)	.004[b]	.098
Apnea index	30.23 (36.05)	30.75 (21.78)	32.1 (34.81)	.94	.29
Hypopnea index	36.59 (22.73)	31.11 (33.14)	35.2 (21.73)	.46	.4

Abbreviations: AHI, apnea-hypopnea index; ARI, arousal index; REM, rapid eye movement; SpO_2, arterial oxyhemoglobin saturation by pulse oximetry; TST, total sleep time.
[a]Values are expressed as mean (SD). [b]Statistically significant, *t* test. [c]Sleep efficiency is (TST/total time in bed) × 100.

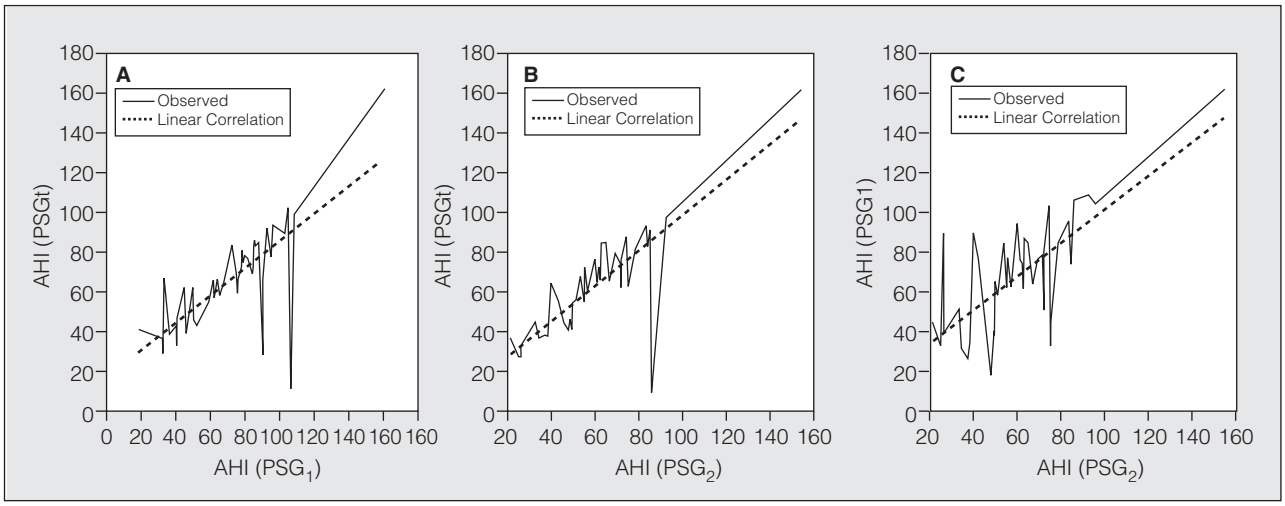

Figure. Linear correlations between A) the AHI in the PSG_1 and PSGt data sets; B) the AHI in PSG_2 and PSGt; and C) the AHI in PSG_1 and PSG_2. PSG indicates polysomnography; PSGt, values reflecting the total sleep time; PSG_1, values from the first 3 hours; PSG_2, values from the remainder of the night; AHI, apnea-hypopnea index.

method for evaluating sleep-disordered breathing. There was no difference between PSG_1 and PSGt in terms of the AHI. Therefore, the diagnosis of the first part of the night can reflect the diagnosis of the whole night. We found that the percentage of stage III-IV sleep is higher in the first part of the night and the amount of REM sleep is greater in the second part, consistent with our classical understanding of the distribution of sleep stages.[14] In the study by Fanfulla et al[15] comparing PSG profiles obtained in the first and second parts of the night, the authors showed that in patients who experienced REM phase sleep during the first part of the night, the AHI during the full-night PSG was quite homogeneous. In contrast, patients without REM-phase sleep in the first part showed lower AHIs in the first part. In the present study, we did not evaluate the conclusions of Fanfulla et al because there were no patients without REM sleep during PSG_1. In addition, when we compared PSG_1 and PSG_2, the AHI was found to be higher in PSG_1 even though the percentage of REM sleep was lower. Similarly, when we compared PSG_1 and PSGt, no significant difference was observed in AHI even though the percentage of REM sleep was lower in PSG_1.

Another finding of the present study was that there was no significant difference between PSG_1 and PSG_2 in sleep efficiency, arousals, or mean SpO_2. The similarity between mean SpO_2 values and arousals caused by apnea and hypopnea in PSG_1 and PSG_2 leads us to consider the possibility of solving the problems in the first half by carrying out CPAP titration in the second half of the night.

Although evidence suggests that OSAHS can be successfully diagnosed and CPAP effectively prescribed during split-night PSG in a majority of patients,[16,17] a number of studies address patient acceptance and adherence to CPAP following split-night PSG. Fleury et al[9] concluded that patients undergoing split-night studies had similar CPAP use to those undergoing full-night studies. The experience of Fleury et al was supported by that of Rausher et al,[18] who observed long-term adherence (80%) and a daily rate of home use of 6.5 hours after a split-night study. There was, however, some concern in the small study of Strollo et al[19] that patients in their split-night protocol had a lower CPAP acceptance rate (62%-67%) than did the patients studied by Fleury and coworkers. In our study, we did not evaluate the acceptance and compliance of the patients after the split-night protocol.

When we included the patients with OSAHS in the study, we diagnosed based on an AHI of more than 5, following the recommendations of the AASM.[1]. If we had used the guidelines of the Spanish Society of Pulmonology and Thoracic Surgery (SEPAR)[20,21] to identify more than 10 respiratory events during nighttime PSG, our results might have been different.

In conclusion, diagnosis in the first 3 hours of the night will be reliable, and a reflection of the whole night. In addition, the optimum pressure determined in the second half of the night can be valid for the first half. However; the present study adds no information regarding CPAP acceptance and compliance. One of the notable disadvantages of the split-night protocol compared to the 2-day protocol is that the patient awakens during the transition to the second half of the night.

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