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A Cost-Effective Two-Step Strategy for the Diagnosis of Sleep Apnoea Syndrome

Eine kosteneffiziente Zwei-Stufen-Strategie zur Diagnostik des Schlafapnoesyndroms

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Summary

Question of the study In order to lower the costs of the diagnosis of sleep apnoea syndrome (SAS), we compared recordings of respiratory polygraphy (RP) and full polysomnography (PSG) and conducted a cost-effectiveness study on recordings in the laboratory and at home.
Patients and methods A total of 157 patients referred for investigation of suspected SAS prospectively underwent full PSG using the same equipment (Cidelec 102-108) at home ($n = 56$) or in the laboratory ($n = 101$) according to their wish and physical and mental abilities.
Results The apnoea–hypopnoea index analysed by PSG was higher than that measured by RP analysis ($P < 0.01$). For a cut-off of AHI > 10/h, the sensitivity of RP at home and in the laboratory was similar (92.9 % and 85.5 %, respectively).
Conclusions To minimize costs, we propose a two-step diagnostic strategy: RP followed, when negative, by a full PSG. This procedure is cost advantageous when the prevalence of SAS in the sleep clinic is above 45 % at home or 55 % in the laboratory. This strategy could save 35–67 % of the laboratory PSG costs when the prevalence of SAS rises from 45 % to 100 % in the clinic population.

Keywords sleep apnoea syndrome – diagnostic methods – cost – sensitivity.

Zusammenfassung

Fragestellung Mit dem Ziel der Kostenreduzierung für die Diagnostik des Schlafapnoesyndroms (SAS) verglichen wir die Analysen einer respiratorischen Polygraphie (RP) und einer kompletten Polysomnographie (PSG) innerhalb ein- und derselben Aufzeichnung und führten dabei eine Kosteneffizienz-Studie im Vergleich „Laboruntersuchung" und „Ambulante Heimuntersuchung" durch.
Patienten und Methodik Insgesamt wurden 157 Patienten mit dem Verdacht auf SAS untersucht, die sich alle einer kompletten Polysomnographie unter Anwendung derselben technischen Ausstattung (Cidelec 102-108) unterzogen und sich unter Berücksichtigung des persönlichen Wunsches oder der physischen bzw. psychischen Verfassung für eine Laboruntersuchung (101 Patienten) oder eine Heimuntersuchung entschieden (56 Patienten).
Ergebnisse Der Apnoe-Hypopnoe-Index der PSG-Analyse lag höher als derjenige der RP-Analyse ($P < 0.01$). Für den Grenzwert des AHI > 10/h betrug die Sensitivität der RP 92.9 % zu Hause und 85.5 % im Labor.
Schlussfolgerung Zur Kostenminimierung empfehlen wir eine Zwei-Stufen-Strategie für die Diagnostik: Die RP wird nur durch eine komplette PSG ergänzt, sofern sie negativ ausfällt. Dieses Verfahren ist kostengünstig, wenn die Prävalenz des SAS in der schlafmedizinischen Ambulanz über 45 % bei der Heimuntersuchung bzw. über 55 % bei

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der Laboruntersuchung liegt. Mit dieser Strategie lassen sich 35 % bis 67 % der Laborkosten für PSG einsparen, wenn die Prävalenz über 45 % bis 100 % in der allgemeinen Ambulanz steigt.

Schlüsselwörter Schlafapnoesyndrom – diagnostische Methoden – Kosten – Sensitivität.

Introduction

Sleep apnoea syndrome (SAS) is a common sleep disorder and a serious public health problem [22]. It might be considered an important cause of morbidity and mortality [23]. SAS is indeed associated with an abnormally high frequency of cardiovascular disease and traffic accidents. Nasal continuous positive airway pressure (CPAP), the most commonly prescribed therapy, improves excessive daytime sleepiness and patient survival [24]. However, it is estimated that the vast majority of patients remains undiagnosed [23, 24].

SAS is a condition where the widely accepted standard diagnostic method (overnight full polysomnography [PSG] attended by trained personnel in a sleep laboratory) is intrusive and costly. Long waiting lists in sleep laboratories contribute to a lack of diagnosis and untreated SAS. It would seem more practical, less expensive, and less time consuming to carry out studies limited to respiratory polygraphy (RP) and also under home or unattended hospital conditions [17].

These limited techniques are proposed to reduce costs and make the diagnosis of SAS more accessible. However, they may be less accurate as they do not allow the identification of sleep stages and the calculation of total sleep time (TST) and therefore do not permit an actual assessment of the respiratory disturbance index (RDI) per hour of sleep. Furthermore, they record a limited number of parameters and are more susceptible to data loss as compared with attended laboratory PSG [17]. One study, however, concluded that recording sleep electrophysiologically has no diagnostic value over respiratory monitoring with added anterior tibialis EMG recording; however, no actual cost evaluation was provided [6]. Only two studies thus far have reported the sensitivity of respiratory polygraphy versus full PSG in the diagnosis of SAS, but only in a laboratory setting [2, 5].

Although during night studies at home patients sleep in their normal environment and thus may have a better quality of sleep, the advantages of unattended home PSG in the diagnostic strategy of SAS are still debated, with failure rates varying from 5 % to 20 % depending on the study and the recording legibility criteria adopted [8, 14]. Therefore, questions remain concerning the feasibility and quality of data obtained under home conditions.

Recent research also rejects the assumption that home RP is cost advantageous; however, the prevalence of sleep disorders in the study population has not been taken into account in the results [16].

We compared RP and PSG for the overall population and reported values at home and in the laboratory. We hypothesized that it would be advantageous to use a two-step strategy: RP first, followed, if negative, by a PSG either at home or in the laboratory. In order to test this hypothesis, we first determined the sensitivity of RP versus PSG at home and in the lab and then compared the costs of recordings in the laboratory versus at home to propose a cost-effective diagnostic strategy for SAS taking into account the clinic prevalence of the disease.

Patients

We prospectively studied 157 patients with a mean age of 52 ± 12 years (18 to 88 years), 111 men and 46 women, referred by their general practitioner, ENT or respiratory specialist to the sleep clinic (Hôpital Antoine Béclère, Clamart, France) on account of habitual snoring and a variable degree of excessive daytime sleepiness. All patients gave their consent to the institutionally approved protocol.

After being instructed on the procedures, patients who had no disability preventing their collaboration and who lived within a one-hour drive to the hospital were given the choice of a full PSG recording either in the laboratory or at home. Patients with physical or mental disability or residing far from the hospital were recorded in the laboratory. Of the 157 consecutive patients who entered the study and gave their informed consent, 56 patients (35.7 %) were self-allocated to home and 101 (64.3 %) to overnight full PSG in the laboratory; of the latter, allocation was based either on choice (81 patients) or on physical or mental disability (20 patients).

Methods

The same device (CID 102-108®; Cidelec, St Gemmes-sur-Loire, France) was used for all studies. It was able to collect and store data from 18 channels in a solid-state memory or a hard disk and was previously validated [20].

For home studies, the portable version of the device was used. Patients came to the laboratory in the afternoon for sensor setting, then slept at home and returned the equipment the next morning. The recording time was automatically set from the device connection when the patient went to bed until disconnection upon waking up. In the laboratory, the same equipment was linked to a desktop computer. Patients came to the laboratory at 19.30 hours and were monitored from around 22.30 to 6.30 hours.

In all patients, the device recorded three electroencephalographic (EEG) derivations (C4-A1,C3-A2,T4-O2), submental and tibialis electromyograms (EMGs), two electro-oculograms (EOGs), tracheal sounds by a microphone affixed to the skin at the upper sternal notch, nasal pressure through a nasal cannula, body position, heart rate and oxygen saturation by a finger probe, and breathing movements by thoracic and abdominal belts. For home recordings, placement of the microphone, position sensor and belts was performed at the hospital during the afternoon, and the set-up of the finger probe and the nasal cannula was demonstrated to the patient for self-use at home.

At each recording, the subjects were asked to report their use of medications, daily consumption of cigarettes and alcohol, and any intercurrent disease or medical problem.

Scoring was made on validated sections of the recordings including all legible signals of oxygen saturation and of nasal cannula. For RP analysis, a visual validation of respiratory events automatically scored by the system was made on the screen without displaying EEG channels, i.e. blinded to sleep staging and arousal analysis. This analysis was based on the

following criteria: apnoea was defined when the flow signal decreased more than 10 s below 10 % of the preceding 1-min average; hypopnoea, when a reduction of flow of more than 50 % of baseline was associated with at least 3 % desaturation. For PSG analysis, sleep staging was carried out according to the rules of *Rechtschaffen* and *Kales* [15]; additional respiratory scoring of hypopnoeas was visually performed on the nasal pressure recording when a greater than 50 % reduction of flow was associated with an EEG arousal even in the absence of a fall in oxygen saturation. Flow limitation was scored as a non-significant reduction of flow (above 50 % of baseline) without a fall in oxygen saturation but associated with an EEG arousal [1].

The apnoea–hypopnoea index (AHI) was determined in two ways: firstly, AHI-PSG was computed using TST and the visually scored events by PSG analysis, i.e. apnoeas, hypopnoeas with desaturation and/or arousal; secondly, AHI-RP, using respiratory events scored by RP analysis and total recording time (TRT), without taking into account sleep scoring and arousals, i.e. as usually performed in respiratory polygraphy. Flow limitations were not included in AHI computation. All studies that fulfilled at least one of the following criteria were judged unreliable and excluded from further analysis:

- insufficient sleep, defined as TST less than or equal to 120 min;
- more than 30 % of TRT with a poor airflow signal or artefacted oximetry;
- sleep staging impossible due to poor EEG signals.

Statistical analysis

Agreement between indices computed by PSG and PR analysis for home and laboratory studies was plotted according to the *Bland* and *Altman* method [4]. Patients' characteristics and sleep data between home and laboratory were compared using the unpaired *t*-test or the Mann–Whitney rank sum test when the normality test failed.

Comparisons between AHI-PSG and AHI-RP were processed with a two-way ANOVA taking into account home versus laboratory recording.

The significance level was defined as $P < 0.05$. Values are reported as mean ± SD.

Cost analysis

Direct medical costs were assessed as follows.

Salary costs: we evaluated in detail all the basic tasks required for the production of a polysomnography and measured the effective working time of the personnel involved (physician, nurse and secretary) for each task. The time spent by the nurse to set up and check neurophysiological sensors was estimated in addition to the basic set-up for respiratory sensors. All recordings have been analysed by a trained sleep physician: sleep staging and respiratory event validation have been performed visually. The extra time necessary for sleep staging has been evaluated separately for the PSG cost analysis. The associated salaries were determined according to the Paris hospital administration salary scale.

Equipment costs were established on the basis of manufacturers' price lists including maintenance costs for the polysomnograph and computers. As some equipment necessary for polysomnography was used for other activities not specific to sleep (the department has other medical activities related to cardiopulmonary and neurophysiological studies), percentages of these equipment costs were attributed to the total cost in proportion to the time used for this activity.

Costs of disposable items were established from the price lists of the manufacturers. The costs of medical and office equipment not specifically devoted to sleep studies were taken into account proportionally as described above.

Hospital costs were evaluated based on the mean price per square meter in the area; the lighting and heating costs were based on Hôpitaux de Paris (AP-HP) official costs. Accommodation costs (meal, laundry, cleaning, etc.) were calculated from AP-HP bed costs.

Direct medical costs for PSG were based on an annual production of 235 PSGs in the laboratory, which is the average figure obtained with one night-nurse caring for two beds and taking into account annual leave and maintenance days.

Direct non-medical costs (related to loss of production) and also indirect costs were not evaluated since they were nearly identical for all procedures when the patients were fitted in the hospital during the late afternoon (less than half-a-day leave) or in the evening in the laboratory.

The mean cost of each strategy was computed from:

- the cost of the PSG or RP calculated as above;
- the respective rate of effectiveness of PSG and RP;
- the number of repetitions of PSG for a patient in the case of PSG failure.

All negative RPs were systematically followed by a PSG to obtain a diagnosis of sleep disorders in patients with sleep-related complaints.

Results

Characteristics of the patients (table 1)

Of the 157 patients who were included in the analysis, the male overrepresentation (72.4 %), the mean age (52 years), and the relative overweight (mean body mass index [BMI], 27.8 kg/m^2) corresponded to the anthropometrical profile usually observed in SAS patients.

Technical failures

Technical failures occurred only with home recordings and not with laboratory PSG. Because of hardware or software problems, eight patients over 56 (14.3 %) had a failure of EEG signals, preventing sleep staging; two of these patients nevertheless had satisfactory respiratory signals throughout the night. These eight patients had to be recorded twice to obtain satisfactory EEG and respiratory data. The second recording was used for analysis.

Sleep data

Table 2 shows the total recording time and the total sleep time and their comparison between home and laboratory conditions: TRT was significantly lower at home than in the laboratory but TST was not different; sleep efficiency was significantly higher at home.

Table 1. Characteristics of the patients.

Characteristics	Home ($n = 56$)	Laboratory ($n = 101$)	*P*
Age (years)	51.2 ± 11. 6	52.7 ± 12.1	NS
Sex ratio, male	78.5 %	66.3 %	0.04
BMI (kg/m^2)	27.8 ± 5.6	27.8 ± 5.4	NS
Epworth scale	10 ± 5	12 ± 5	NS

BMI = body mass index

Table 2. Polysomnographic sleep data.

	Home ($n = 56$)	Laboratory ($n = 101$)	*P* value
Total recording time (min)	430.3 ± 50.2	465 ± 31.5	<0.0001
Total sleep time (min)	361 ± 59.6	358.8 ± 63.5	NS
Sleep efficiency (%)	89.1 ± 9.0	81.3 ± 12.0	<0.0001

Diagnosis of sleep-related breathing disorders

In the patients recorded in the laboratory, the mean AHI, determined with PSG, was 26.8 ± 26/h versus 16.0 ± 16.4/h for the patients recorded at home ($P = 0.006$). Twenty-eight out of 56 patients (50 %) recorded at home had SAS (AHI-PSG > 10/h), whereas 69 out of 101 patients (68.3 %) recorded at the hospital were apnoeic ($P = 0.017$). Among the SAS patients, the mean AHI-PSG was 25.3 ± 16/h in those recorded at home and 37 ± 25/h in those recorded in the laboratory ($P < 0.01$).

Other diagnoses in non-SAS patients were the following: uncomplicated snoring in 23 patients; periodic leg movements, three patients; narcolepsy, two patients; upper-airway resistance syndrome (UARS), 20 patients; and hypersomnolence (psychiatric or idiopathic), 11 patients.

In the overall patient population (adding all recordings at home and in the laboratory in SAS and non-SAS patients), the comparisons between AH indices were as follows:

- AHI analysed with PSG (22.9 ± 23.5/h) was significantly higher than the AHI determined with RP (18.1 ± 18.8/h) ($P < 0.001$).
- The differences between AHI-PSG and AHI-RP for each patient are shown in figure 1. In home studies, RP analysis gave an adequate diagnosis in 26 of the 28 SAS patients (93 %), defined as AHI-PSG >10/h. In the laboratory, the diagnosis obtained by RP analysis was adequate in 59 of the 69 SAS patients (86 %).

Sensitivity and negative predictive values of AHI evaluated with RP for several cut-off values of 'gold-standard' AHI computed with PSG are shown in figure 2. Sensitivities fell with increasing AHI to 93 % and 85 % at an index of 10/h at home, and 73 % and 76 % at an index of 20/h in the laboratory.

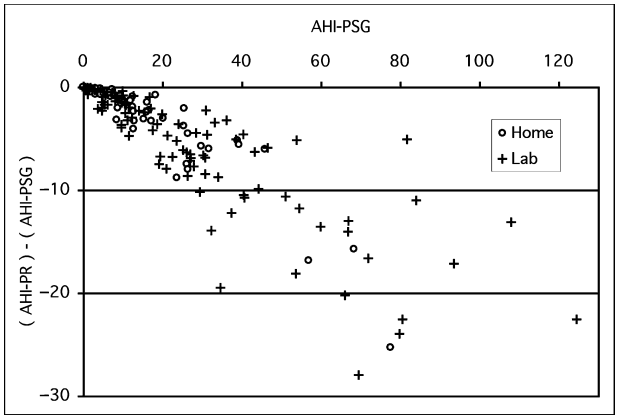

Figure 1. Bland and Altman plots of the differences between apnoea–hypopnoea indices obtained with polysomnography analysis (AHI-PSG) and with respiratory polygraphy analysis (AHI-RP) as a function of the reference AHI-PSG.

Medical costs

The estimation of medical costs is reported in table 3. In the hospital, the cost of a PSG was EUR 303 and an RP, EUR 144. The cost at home was initially estimated at EUR 193 for a PSG and EUR 86 for an RP. Taking into account the observed failure rates in home recordings, the actual cost of home PSG was EUR 220 (i.e. 72 % of laboratory PSG cost) and home RP was EUR 95 (i.e. 65 % of laboratory RP).

In our population, the mean cost of diagnosing a patient positive for SAS was EUR 111 at home as compared with EUR 191 in the laboratory (i.e. 72 % difference), whereas the cost of diagnosis for an SAS-negative patient was EUR 315 at home versus EUR 454 in the laboratory (i.e. 44 % difference).

Therefore, we propose a cost-efficient, two-step diagnostic strategy where a patient clinically suspected of SAS first undergoes a simple respiratory polygraphy and, only when this test is negative for SAS, secondarily receives a full polysomnography. The cost functions are plotted in figure 3 according to the type of procedures used: home RP followed (when negative for SAS) by home PSG or lab PSG and lab RP followed (when negative for SAS) by lab PSG. The cost function is also dependent on the prevalence of SAS patients in the sample population and on the AHI cut-off as shown in figure 3.

The two-step procedure, i.e. home RP followed, when negative, by home PSG, is cost advantageous over a unique home PSG as soon as the prevalence of SAS in the study population is above 45 % (figure 3a). The later double home procedure is always less expensive than the lab PSG alone even when technical failures are taken into account. Above a prevalence threshold of 30 %, home RP followed when negative by lab PSG is cost advantageous over lab PSG as a first choice (figure 3b). Finally, the two-step laboratory procedure is also advantageous over laboratory PSG alone when the SAS prevalence is above 55 % in the clinic population (figure 3c).

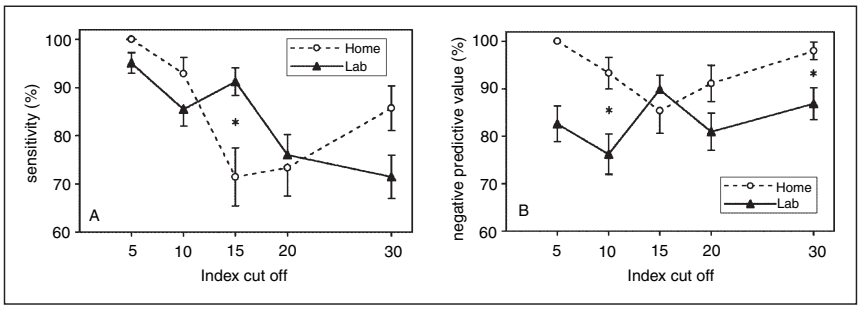

Figure 2. Sensitivity and negative predictive values (respectively) of respiratory polygraphy (RP) versus polysomnography (PSG) at several diagnostic cut-offs (5, 10, 15, 20 and 30/h). Apnoea–hypopnoea indices obtained with PSG.

Table 3. Costs.

Type of cost	PSG Lab	PSG Home	RP Lab	RP Home
Medical time	2.5 *h*	2.5 *h*	1 *h*	1 *h*
Medical cost (EUR 20/h)	50	50	20	20
Nurse time	5 *h*	1.5 *h*	45 *min*	45 *min*
Nurse cost (EUR 15/h)	75	23	11	11
Nursing aide time	37 *min*	0 *min*	37 *min*	0 *min*
Nursing aide cost (EUR 13)	8	0	8	0
Disposable	41	41	23	23
Non-specific investment	9	9	9	9
Specific investment	70	70	23	23
Room cost	2	0	2	0
Building + energy	14	0	14	0
Meals and hostel	34	0	34	0
Raw total (EUR)	**303**	**193**	**144**	**86**
Total incl. failures (EUR)		**220**		**95**

Discussion

Our main results can be summarized as follows. (i) AHI analysed by RP was significantly lower than AHI obtained by PSG; (ii) nevertheless, for an AHI cut-off > 10/h, the sensitivity of RP was 92.9 % at home and 85.5 % in the laboratory when PSG is taken as the gold standard; (iii) for a patient complaining of daytime hypersomnolence associated with snoring, a two-step diagnostic strategy involving RP first, followed, when negative for SAS, by a full PSG is cost advantageous when performed at home as soon as the prevalence of SAS in the studied population exceeds 45 %. In all cases, the double home procedure is the least expensive even when including the cost of repeated tests due to technical failure. Using this strategy could save 35–67 % of the cost of laboratory PSG when the prevalence of SAS rises from 45 % to 100 % in the clinic population.

Data quality

Our results underline a 14.3 % failure rate and difficulties in obtaining technically accurate night studies at home. Total failure occurred in eight of our patients and led to repeated night studies and increased cost.

There are few reported studies that evaluated home RP data quality. *Whittle* and colleagues, using the EdenTrace® system, reported 18 % unsuccessful home recordings [21]. *Portier* et al. had a 20 % failure rate at home using a Minisomno® device and a 5 % failure rate in the laboratory using the Respisomnographe® [14].

In recent publications, recordings were considered to be ineffective in 23.4 % of home PSGs using the Minisomno® system, and telemonitoring did not improve failure rate [9]. In another study, 8 % of PSGs and RPs simultaneously performed on the same night were invalid [5].

However, *Fry* and colleagues had no failures in home PSG recordings and each parameter could be scored in more than 95 % of all epochs using the DigiTrace® Home Sleep System [8].

In contrast, in our laboratory PSG, no recording was lost due to equipment failure or software problems.

These differences in home and laboratory failure rates may be explained by our use of a more recent and more reliable device and/or by technicians' training in explaining the set-up to the patients.

Data quality is improved when a technician sets up the device at the patient's home; however, this method is time consuming for the technician, particularly if patients live far away, and greatly increases the cost of home studies [9].

In our study, more patients were recorded in the laboratory than at home. In this sample, 20 patients had a mental and/or physical disability or lived too far from the hospital, making it difficult for them to carry out the home procedure. The remaining valid patients more often preferred laboratory over home recording, generally claiming a

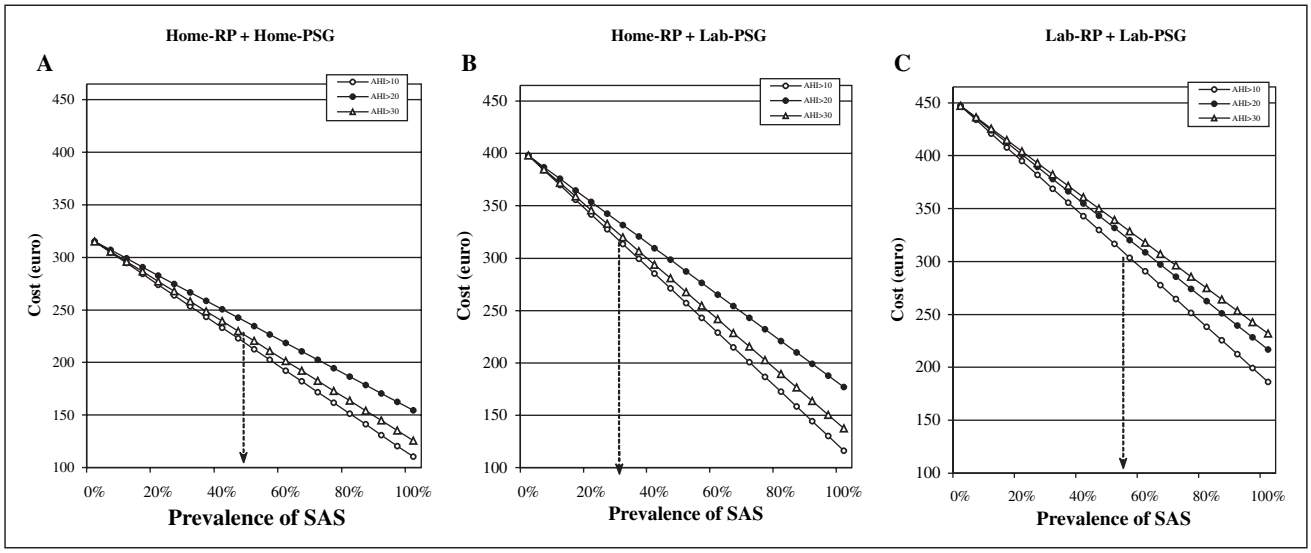

Figure 3. Cost functions for three types of diagnostic procedures according to the prevalence of SAS in the sample population and to the AHI cut-off. For each value of SAS prevalence in the clinic population, the cost of each combination strategy is reported on the corresponding line for AHI cut-off values of 10, 20, and 30/h. In each figure, the arrow outlines the prevalence corresponding to equal costs for the two-step strategy and the PSG recording: for a lower prevalence, an initial PSG is cost efficient, whereas for a higher prevalence the two-step strategy is cheaper. (A) Home RP followed when negative by lab PSG; (B) lab RP followed when negative by lab PSG; (C) home RP followed when negative by home PSG.

greater feeling of safety related to the equipment when recorded in the laboratory.

Sleep data

In our patients, TRT was longer in the laboratory but sleep efficiency was higher at home. This may be explained by the fact that patients recorded at home had less severe symptoms than those recorded in the laboratory. Also, they were in their habitual environment and may have adapted their recording time to their sleeping habits. *Fry* and colleagues observed a longer TRT and TST in the laboratory [8], whereas *Portier* et al. obtained a longer TST and TRT at home [14].

SAS diagnosis and sensitivity

This study shows that, in our clinical setting, up to 92.9 % of patients with SAS can be accurately diagnosed using home RP recordings. Therefore, theoretically only seven patients of over 100 recorded at home by RP would need a full PSG for the diagnosis of SAS. Although the correlations between AHI and indices of severity of disease such as hypersomnolence and cardiovascular complications are known to be limited, the AHI remains the diagnostic standard for sleep societies and is extensively used as the gold standard in epidemiological studies.

As it has been shown that visual analysis of RP is more reliable than automatic analysis, in all tracings we used visual validation of events. In our study, AHI determined with RP was significantly lower than that determined with full PSG. As few events were actually scored during waking periods in RP analysis, and hypopnoeas scored on arousal alone (i.e. without at least 3 % fall in oxygen saturation) were seldom, the main difference between computed AHI was due to the fact that TST was significantly shorter than TRT (table 2). In most cases, RP underestimated the AHI but more so in severe SAS cases. This may be due to poorer sleep quality in severe sleep apnoea patients who had a larger difference between AHI-RP and AHI-PSG (figure 1).

Other studies have shown good correlations between the RDI obtained with RP portable devices and that obtained with full PSG, but there were significant differences between indices [5, 10, 12, 21]. Our results show that values of sensitivity of RP at home ranged between 71.4 % and 100 % for cut-off values of 30/h to 5/h, respectively (figure 2). Therefore, the threshold could be set at an AHI of 5/h in RP to ascertain a positive diagnosis at a PSG cut-off of 10/h. For *Lloberes* et al., taking AHI > 10 on full PSG as a reference, sensitivity and specificity of RP for SAS diagnosis were 82 % and 90 %, respectively [12], as compared with 92.9 % sensitivity in our patients. Other authors proposed simpler tests, such as pulse oximetry to screen for SAS, and several studies have sought to compare its use with PSG [6, 19]. But there are wide variations in the criteria used to determine a positive oximetry trace. The best results are obtained by a visual interpretation of the traces, which is strongly observer dependent [19]. *Douglas* et al. showed that oximetry detected 66 % of SAS patients, with no false-positive results [6]. This result provided support for the British guidelines, which state that oximetry alone or oximetry plus videorecording is sufficient to diagnose SAS [18]. It should be emphasized that pulse oximetry is not validated by the ASDA [1] as it often gives false-negative results in younger and thinner SAS patients. *Douglas* et al. also stated that SAS can be diagnosed accurately by RP and time in bed, but they noted that results are different when computed per hour of sleep [6].

Home and laboratory recording conditions

In our study, we used devices, sensors, and software from the same company; the portable device is only a lighter version of the laboratory system. The portable respiratory polygraphic device is commonly used as a standalone in clinical practice.

Home recording conditions were associated in our study with a low failure rate, but in the case of failure a second recording was performed for these patients. The main cause of home PSG failure for *Gagnadoux* and co-workers was displacement of the thermistor [9]. It should be noted that 'home setting' of the patient by a technician could probably improve the effectiveness of home PSG (better fitting of the electrodes with no risk of detachment while travelling between the hospital and home). *Gagnadoux* and co-workers compared home PSG with hospital-attended but out-of-laboratory PSG under telesurveillance and were able to improve the quality of data by this second technique [9].

A survey in Europe showed that sleep physicians expected ambulatory monitoring to be more easily accepted by the patient [7]. Nevertheless, for *Gagnadoux* et al., only 41 % of patients preferred home PSG as compared with 55 % who preferred telemonitored PSG [9]. These results are in agreement with those reported by *Fry* et al. [8] and *Portier* et al. [14], both of whom found that, contrary to popular belief, the majority of patients preferred laboratory PSG. Apprehension regarding home recording is probably due to the perception of procedural difficulties concerning recording and transmission of adequate data.

Limitations of the study

Using the same equipment for AHI computation from PSG and RP does not allow data on specificity to be obtained, as respiratory events are not scored independently on either device. But it has the advantage of limiting the sleep disturbance of recordings with duplicate sensors on the same night. This burden could increase the time awake, therefore raise the difference in AHI obtained by both duration estimations. The respiratory polygraph used in our study included more electrodes (for PSG) than purely respiratory devices described in other studies, but the main discomfort reported by patients was due to the finger probe for oxygen saturation; none specifically complained about the EEG electrodes. In fact, the monitoring on the same night is one strength of this study as it removes the night-to-night variability of SAS observed especially in patients with lower AH indices [3, 13]. The use of a single device also allows a better quality of monitoring to be obtained, as it avoids duplicate sensors such as superimposed nasal and oral thermistors, which deteriorate signal quality [5].

Patients with upper-airway resistance syndrome (UARS) have not been included in the sample of SAS patients in order to allow comparison with previous studies recorded with thermistors. We wished also to differentiate between disorders with different treatment outcomes; contrary to SAS, UARS treatment is not yet clearly accepted.

In any case, taking into account flow limitations would tend to increase the difference between RP and PSG indices, because at the moment, reliable flow limitation scoring depends on arousal detection on EEG recording.

Limitations of cost studies

Costs have been computed on the basis of costs for Paris hospital administration, which entail a particularly low medical salary for part-time practitioners. The cost

differences with other countries is probably small because scoring, usually performed by physicians in France, is often performed by technicians in other countries whose salary levels are close to the public salary for physicians in France.

The evaluation of costs does not take into account the treatment issue of the SAS patients. But this point is very dependent upon local practice for CPAP initiation. Clearly, if split-night protocols for CPAP titration are used, there will be no reduction of sleep centre nights. But if laboratory or home CPAP titrations are performed, the two-step strategy will bring significant savings as it may save on a home or lab PSG.

It is noteworthy that a study reported lower CPAP compliance in patients diagnosed with a simplified procedure [11], but this point has not been confirmed in other settings.

Conclusion

The sensitivity of RP for the diagnosis of SAS (AHI > 10/h) was good at home (92.9 %) and in the laboratory (85.5 %) as compared with PSG.

We propose a two-step diagnostic strategy: RP followed when negative by a full PSG. This strategy is cost advantageous given a prevalence of SAS above 45 % in the study population when done at home, and 55 % when done in the laboratory. Using this strategy could save 35–67 % of the cost of a laboratory PSG when the prevalence of SAS rises from 45 % to 100 % in the clinic population.

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References

[1] American Sleep Disorders Association: Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. Sleep 22: 667–689, 1999.

[2] Ballester E et al.: Evaluation of a portable respiratory recording device for detecting apnoeas and hypopnoeas in subjects from a general population. Eur Respir J 16(1): 123–127, 2000.

[3] Bittencourt LR et al.: The variability of the apnoea-hypopnoea index. J Sleep Res 10: 245, 2001.

[4] Bland JM, Altman DG: Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1(8476): 307–310, 1986.

[5] Calleja JM et al.: Comparison of a cardiorespiratory device versus polysomnography for diagnosis of sleep apnoea. Eur Respir J (20): 1505–1510, 2002.

[6] Douglas NJ et al.: Clinical value of polysomnography. Lancet 339(8789): 347–350, 1992.

[7] Escourrou P et al.: Needs and costs of sleep monitoring. Stud Health Technol Inform 78: 69–85, 2000.

[8] Fry JM et al.: Full polysomnography in the home. Sleep 21: 635–642, 1998.

[9] Gagnadoux F et al.: Home unattended vs hospital telemonitored polysomnography in suspected obstructive sleep apnea syndrome. A randomized crossover trial. Chest 121: 753–758, 2002.

[10] Golpe R et al.: Home sleep studies in the assessment of sleep apnea–hypopnea syndrome. Chest 122(4): 1156–1161, 2002.

[11] Krieger J, Sforza E, Petiau C, Weiss T: Simplified diagnostic procedure for obstructive sleep apnoea syndrome: lower subsequent compliance with CPAP. Eur Respir J 12(4): 776–779, 1998.

[12] Lloberes P et al.: Comparison of partially attended night time respiratory recordings and full PSG in patients with suspected sleep apnoea/hypopnea syndrome. Thorax 51: 1043–1047, 1996.

[13] Meyer TJ et al.: One negative polysomnogram does not exclude obstructive sleep apnea. Chest 103: 756–760, 1993.

[14] Portier F et al.: Evaluation of home versus laboratory polysomnography in the diagnosis of sleep apnea syndrome. Am J Respir Crit Care Med 162: 814–818, 2000.

[15] Rechtschaffen A, Kales A: A manual of standardized terminology: techniques and scoring system for sleep stages of human subjects. Public Washington DC, USA, 1968.

[16] Reuveni H et al.: A cost-effectiveness analysis of alternative at-home or in-laboratory technologies for the diagnosis of obstructive sleep apnea syndrome. Medical decision making 21: 451–548, 2001.

[17] Ross SD et al.: Systematic review and meta-analysis of the literature regarding the diagnosis of sleep apnea. Sleep 23: 519–532, 2000.

[18] Ryan PJ et al.: Validation of British Thoracic Society guidelines for the diagnosis of the sleep apnoea/hypopnea syndrome: can polysomnography be avoided? Thorax 50: 972–975, 1995.

[19] Sériès F et al.: Utility of nocturnal home oximetry for case finding in patients with suspected sleep apnea hypopnea syndrome. Ann Intern Med 119(6): 449–453, 1993.

[20] Van Surell C et al.: Evaluation of an ambulatory device, CID 102, in the diagnosis of obstructive sleep apnoea syndrome. Eur Respir J 8: 795–800, 1995.

[21] Whittle AT et al.: Use of home sleep studies for diagnosis of the sleep apnea/hypopnea syndrome. Thorax 52: 1068–1073, 1997.

[22] Young T et al.: The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 328: 1230–1235, 1993.

[23] Young T et al.: Estimation of the clinically diagnosed proportion of sleep apnea syndrome in middle-aged men and women. Sleep 20: 705–706, 1997.

[24] Young T et al.: Epidemiology of obstructive sleep apnea. Am J Respir Crit Care Med 165: 1217–1239, 2002.