Obstructive sleep apnea syndrome (OSAS) is characterized by repeated oropharyngeal occlusions occurring during sleep. Its estimated prevalence is 2% in women and 4% in men between the ages of 30 and 60 years.1 It is associated with an abnormally high frequency of cardiovascular disease (hypertension, stroke, coronary heart disease)2–4 and excessive daytime sleepiness. This excessive daytime sleepiness affects the patient’s quality of life5 and is responsible for an increased frequency of work and

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Study objective: To compare home unattended polysomnography (H-PSG) with polysomnography performed in a local hospital and telemonitored by a sleep laboratory (T-PSG) in the diagnosis of obstructive sleep apnea syndrome (OSAS).

Design: Randomized crossover trial.

Patients: Ninety-nine patients with suspected OSAS who underwent H-PSG and T-PSG on 2 consecutive nights, according to a randomized order.

Measurements: H-PSG and T-PSG were compared in terms of (1) effectiveness, only recordings providing interpretable signals from at least one EEG, the electro-oculograph, the electromyograph, air flow, thoracic or abdominal movements, and arterial oxygen saturation for 180 min of sleep were considered to be effective; (2) patient preference assessed by a questionnaire; and (3) polysomnographic indexes and final interpretative results in patients for whom both recordings were legible.

Results: Recordings were considered to be ineffective in 11.2% of T-PSG (95% confidence interval [CI], 4.9 to 17.4%) and in 23.4% of H-PSG (95% CI, 19.12 to 27.68%). Thermistor problems were the main cause of failure of H-PSG. Forty-one percent of patients preferred H-PSG, and 55% preferred T-PSG. H-PSG and T-PSG did not differ in terms of sleep and respiratory indexes in the 65 patients in whom both recordings were legible. H-PSG and T-PSG were concordant in 58 of 65 patients using a 10-event-per-hour apnea-hypopnea index cutoff value for the diagnosis of OSAS.

Conclusions: T-PSG is clearly superior to H-PSG from a technical point of view and tends to be preferred by patients. The site of recording (home vs hospital) has no influence on polysomnographic indexes.

Key words: home polysomnography; obstructive sleep apnea syndrome; telemetry

Abbreviations: AHI = apnea-hypopnea index; BMI = body mass index; CI = confidence interval; CPAP = continuous positive airway pressure; EMG = electromyogram; EOG = electro-oculogram; H-PSG = home unattended polysomnography; OSAS = obstructive sleep apnea syndrome; REM = rapid eye movement; SaO2 = arterial oxygen saturation; T-PSG = polysomnography performed in a local hospital and telemonitored by a sleep laboratory; TST = total sleep time

Obstructive sleep apnea syndrome (OSAS) is
road accidents in this population than in the general population.6,7 OSAS must be diagnosed early, as an effective treatment is available, especially on daytime sleepiness—continuous positive airway pressure (CPAP).8 This diagnosis is classically based on polysomnography performed in a sleep laboratory equipped with qualified personnel (technicians and physicians) able to perform, monitor, and interpret the examination under good conditions.

However, the reception capacities of currently existing sleep laboratories are overwhelmed by a growing demand related to a better understanding of the disease and its risks for the individual and for the community. This demand has doubled over 3 years in some regions of the United States.9 In France, the number of patients receiving diagnoses and being treated by CPAP is increasing by 20% each year. Sleep laboratory waiting lists are becoming longer, with delays of up to 6 months before polysomnography can be performed. A possible solution to this situation would be to increase the capacity for in-laboratory studies by developing the capacity of existing sleep laboratories or creating new laboratories.

Technological advances are now providing other alternatives such as miniaturization of recorders such that polysomnography can be performed in the patient’s home. However, the advantages of home unattended polysomnography (H-PSG) in the diagnostic strategy of OSAS are still debated, with failure rates varying from 5 to 20% depending on the study and the recording legibility criteria adopted.10–14 Polysomnography performed in a local hospital and telemonitored by a sleep laboratory (T-PSG) could possibly constitute an organizational alternative to ensure better quality recordings than H-PSG. Indeed, in parallel with his routine activity in the sleep laboratory, a qualified technician can periodically monitor one or several recordings performed in another center and, in the case of a technical incident, guide the intervention of nonspecialized personnel in the department conducting the examination. However, this new organizational solution has never been evaluated. We conducted a prospective, randomized crossover trial to compare H-PSG and T-PSG, two replacement solutions for conventional polysomnography performed in a sleep laboratory.

**Materials and Methods**

**Patients**

One hundred eleven patients were included in a three-center, prospective, crossover study comparing H-PSG with T-PSG performed in two respiratory medicine units (Hôpital Tenon, Paris; Hôpital A. Mignot, Versailles) and telemonitored by the Hôpital Saint Antoine sleep laboratory in Paris. Patient inclusion criteria were clinical suspicion of OSAS (snoring plus excessive daytime sleepiness plus apneas described by the patient’s relatives), and physical capacity to comply with the two diagnostic strategies. Before inclusion, patients gave their written consent to participate in this study, and the protocol was approved by the Comité Consultatif de Protection des Personnes dans la Recherche Biomédicale (ethics committee). Patients with decompensated concomitant disease, mentally retarded patients, or patients failing (or unable) to give their consent were excluded from the study. All patients were allocated to two polysomnographic studies (H-PSG and T-PSG) on 2 consecutive nights, according to a randomized order, by use of a series of opaque sealed envelopes prepared in advance of the trial.

**H-PSG and T-PSG**

The polysomnographic recording device used for both home and telemonitored examinations was a Minisomno (Mallincrodt; Les Ulis Courtabouef; France). This portable device, weighing 600 g, is able to record and store 8 h of data from 8 to 18 channels. It is the portable version of the Respisomnographe (Mallincrodt) that we used daily at this time in our laboratory. The Minisomno was equipped with a modem adapted to the frequency of the signals recorded and to the France Telecom telephone network. This modem allowed periodic televisualization of the signals recorded (two EEG, one chin electromyogram [EMG], one electro-oculogram [EOG], oronasal air flow, thoracic or abdominal movements, and SaO2) and ECG, and, at the end of the night, teletransmission of the recordings performed in telemonitored centers for analysis by the telemonitoring center.

For H-PSG, after application of the electrodes by the sleep laboratory technician, the patient returned home fitted with the device and was asked to return the material and the recording the following morning. For T-PSG, the patient was fitted at the end of the afternoon by a technician of the Hôpital Tenon or Hôpital de Versailles EEG laboratory and was then hospitalized in the respiratory unit for telemonitoring. During telemonitoring, the sleep laboratory technician called the telemimonitored polysomnography recording device every 30 min and checked the quality of the recordings. The nurse at Hôpital Tenon or Hôpital de Versailles had to strictly comply with the Hôpital Saint Antoine technician’s instructions to reposition electrodes giving faulty signals.

The next morning, the anonymous recording was sent by modem via the Integrated Services Digital Network to Hôpital Saint Antoine to be interpreted by an experienced sleep physician. Recording interpretation was performed blinded to the patient identification and to the site of recording (home or hospital). Sleep stages were scored according to the guidelines developed by Rechtschaffen and Kales.15 Apneas were defined by complete interruption of oronasal flow lasting at least 10 s. Hypopneas were defined by a reduction of at least 50% in the amplitude of respiratory movements lasting at least 10 s. Apneas were classified as obstructive, mixed, or central, according to the presence or absence of respiratory efforts.

**Analysis**

H-PSG and T-PSG were compared in terms of effectiveness, patient preference, and polysomnographic indexes and final interpretation.

**Effectiveness:** Only recordings providing interpretable signals from at least one EEG, the EOG, the EMG, air flow, thoracic or abdominal movements, and SaO2 for 180 min of sleep were
considered to be effective. This criterion is very similar to the legibility criterion defined by Whitney et al.\textsuperscript{13} in the Sleep Heart Health Study. A 3-h recording appeared to be necessary to allow correct assessment of the patient’s sleep architecture and abnormal respiratory events, according to the sleep recording guidelines of the American College of Chest Physicians.\textsuperscript{17}

**Patient Preference:** Patients completed a self-questionnaire including three questions: (1) during which recording did you feel more comfortable, (2) which recording did you consider to be of the better technical quality, and (3) which method would you prefer if another recording had to be performed?

**Polysomnographic Indexes and Final Interpretation:** In the patients for whom both recordings met the legibility criterion, concordance between H-PSG and T-PSG for apnea-hypopnea index (AHI) measurement was evaluated according to the Bland and Altman method.\textsuperscript{18} An AHI cutoff value of 10 events per hour was used for the diagnosis of OSAS.

The $\chi^2$ test was used to compare qualitative variables. Student’s $t$ test was used to compare the means of continuous variables. A paired $t$ test was used to compare polysomnographic indexes obtained at home and in the hospital in the same patient.

**Results**

Ninety-nine of the 111 patients included actually participated in the study; 55 patients were enrolled in Hôpital Tenon, and 56 patients were enrolled in Hôpital de Versailles. The male overrepresentation (83%), the mean age (52 years), and the relative obesity (mean body mass index [BMI], 27.5 kg/m\(^2\)) corresponded to the anthropometric profile usually observed in OSAS patients. Six of the remaining 12 patients refused the recording at the last moment (4 patients refused both T-PSG and H-PSG, and the other 2 patients only refused H-PSG), and 1 patient forgot the scheduled recording dates. Finally, technical failures before starting the recording (three oximeter failures, one battery failure, and one EMG failure) prevented one of the two recordings in five patients.

**Effectiveness According to the Legibility Criterion**

Two recordings, one H-PSG and one T-PSG, for which battery failure occurred at the beginning of the night, were excluded from the analysis. Eleven of the 98 T-PSGs (11.2%; 95% confidence interval [CI], 4.9 to 17.4%) and 23 of the 98 H-PSGs (23.4%; 95% CI, 19.12 to 27.68%) were considered to be ineffective. The difference between T-PSG and H-PSG in terms of legible recording was 12.2% (statistically significant), with a 95% CI of 1.8 to 22.6% in favor of T-PSG ($p = 0.02$). Table 1 summarizes the causes of failures of T-PSG and H-PSG. Apart from the 3 inevitable failures related to insufficient total sleep time (TST), 4 of the 11 T-PSG failures were not avoided despite detection of a defective recording by the technician, as the nurses were unable to take effective measures. Another four failures were not avoided due to failure of the technicians to detect a faulty electrode. However, in the absence of telemonitoring, eight additional failures would have been observed in hospitalized patients, related to the thermistor in six cases, EMG in one case, and EOG in one case, making the T-PSG failure rate fairly similar to that of H-PSG. No overrepresentation or underrepresentation of illegible examinations was observed among the first polysomnography of the sequence compared with the second polysomnography (18.1% vs 18.1%, respectively).

**Patient Preference**

Forty-two percent of patients felt more comfortable during T-PSG vs 43% during H-PSG (15% had no opinion). Sixty-six percent of patients considered the technical quality of the recording to be better during T-PSG vs 12% during H-PSG (22% had no opinion). Finally, 55% of patients declared that they would prefer T-PSG, while 41% would prefer H-PSG if another recording had to be performed (4% had no opinion).

**Polysomnographic Indexes and Final Interpretation**

Comparison of H-PSG and T-PSG indexes was performed in 65 patients representative of the whole population (84% male patients; mean age, 53 years; mean BMI, 28 kg/m\(^2\)) for whom both recordings met the legibility criterion. No significant difference was observed between H-PSG and T-PSG in terms of AHI, mean $\text{SaO}_2$, patient position, TST, and sleep composition (Table 2).

Concordance for AHI between H-PSG and T-PSG according the method of Bland and Altman is shown in Figure 1. The mean AHI difference between H-PSG and T-PSG was $-0.75$ (95% CI, 28 to 26.5). In 28 of the 65 patients (43%), the AHI difference between H-PSG and T-PSG was $> \pm 10$: 15 patients had a higher AHI at home, and 13 patients had a higher AHI during T-PSG. In both cases, the AHI difference between the two recordings could not be explained by either TST or by the percentage of rapid eye movement (REM) or by the

<table>
<thead>
<tr>
<th>Table 1—Causes of Failure of T-PSG and H-PSG*</th>
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<tbody>
<tr>
<td>Causes of Failure</td>
</tr>
<tr>
<td>TST &lt; 180 min</td>
</tr>
<tr>
<td>Thermistor problem</td>
</tr>
<tr>
<td>Specific EMG problem</td>
</tr>
<tr>
<td>Specific EOG problem</td>
</tr>
<tr>
<td>Multiple electrode detachments</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

*Data are presented as No.
percentage of dorsal supine position. OSAS was more severe in the 28 patients presenting a high variability of AHI than in the 37 patients with an AHI difference \( \leq 10 \) (mean AHI, 47/h vs 15/h, respectively; Table 3).

With an AHI cutoff value of 10/h, 44 of 65 patients presented OSAS on the basis of one of both of the two recordings. H-PSG and T-PSG findings were discordant in 7 of 65 patients in whom the diagnosis of OSAS was based on H-PSG in 5 patients and T-PSG in 2 patients. Six of these seven patients had mild OSAS (AHI between 11/h and 21/h), and one patient had moderately severe OSAS (AHI = 34/h).

**DISCUSSION**

This study demonstrates that T-PSG is clearly superior to H-PSG in terms of recording legibility, and tends to be preferred by the patients. The site of recording, whether at home or in the hospital, has no overall influence on TST, sleep composition, and frequency of abnormal respiratory events. With an AHI cutoff value of 10/h for the diagnosis of OSAS, H-PSG and T-PSG findings were concordant in 58 of 65 patients.

Our results in terms of ambulatory polysomnography failures are very similar to those reported by Portier et al., using the same legibility criterion and the same polysomnography device. The main cause of H-PSG failure (9 of 23 patients), displacement of the thermistor, could probably be limited by improving the electrode design. It should also be noted that “home fitting” of the patient by a technician could probably improve the effectiveness of H-PSG (better positioning of the electrodes with no risk of detachment while traveling between the hospital and home), as previously described. To our knowledge, this is the first published experience of telemonitored polysomnography. Despite some failures that could probably have been avoided, for example by better training of the nurses or more motivated technicians, telemetry was found to be clearly superior, in terms of legible recordings, to unattended ambulatory polysomnography. White and Gibb previously showed that telemetry could be used to titrate CPAP at home with equal success to that of full-night CPAP titration in the sleep laboratory. Apart from technical considerations, telemetry also allows nonspecialized centers to obtain help from

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**Table 2—Mean Respiratory and Sleep Indices (n = 65) for T-PSG and H-PSG**

<table>
<thead>
<tr>
<th>Variables</th>
<th>T-PSG</th>
<th>H-PSG</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apneas-hypopneas, No.</td>
<td>152 ± 148</td>
<td>156 ± 158</td>
<td>NS</td>
</tr>
<tr>
<td>AHI, per h</td>
<td>29 ± 31</td>
<td>29 ± 32</td>
<td>NS</td>
</tr>
<tr>
<td>Mean SatO₂, %</td>
<td>91 ± 3</td>
<td>92 ± 3</td>
<td>NS</td>
</tr>
<tr>
<td>Duration of supine position, %TST</td>
<td>76 ± 18</td>
<td>72 ± 19</td>
<td>NS</td>
</tr>
<tr>
<td>TST, min</td>
<td>327 ± 67</td>
<td>337 ± 71</td>
<td>NS</td>
</tr>
<tr>
<td>Stages I–II, %TST</td>
<td>64 ± 15</td>
<td>64 ± 13</td>
<td>NS</td>
</tr>
<tr>
<td>Stages III–IV, %TST</td>
<td>17 ± 12</td>
<td>17 ± 14</td>
<td>NS</td>
</tr>
<tr>
<td>REM, %TST</td>
<td>18 ± 4</td>
<td>18 ± 2</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD. NS = not significant; %TST = percentage of TST.

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**Figure 1. Bland and Altman plots.** Difference vs mean AHI determined by H-PSG (H-AHI) and T-PSG (T-AHI).
sleep laboratories for interpretation of polysomnography recordings and treatment decisions. The cost of T-PSG is comparable to that of in-laboratory polysomnography, 307.6 Euros (approximately $272). One can estimate H-PSG 40% less costly than T-PSG once removing telemonitoring (personnel and equipment) and hospitalization-related costs. However, this overexpenditure of T-PSG could be balanced out by greater effectiveness and less transport costs. In our study, it did not seem appropriate to take travel into account due to the bias inherent to the experimental context, as the three study centers were actually situated very close to each other.

A survey in Europe showed that sleep physicians expected ambulatory monitoring to be more easily accepted by the patient. Interestingly, only 41% of our patients preferred H-PSG compared to 55% who preferred T-PSG, which they considered to be of better technical quality. Our patients also did not feel more comfortable at home than during T-PSG. These results are in agreement with those reported by Fry et al and Portier et al, who both found that, contrary to a popular belief, the majority of patients preferred laboratory polysomnography. Apprehension regarding home recording is probably due to perception of procedure difficulties concerning acquisition and transmission of adequate data.

Hospital polysomnography can potentially disturb sleep and influence nocturnal respiratory disorders to a greater degree than a recording performed at home under the patient’s usual sleeping conditions. However, no significant difference was observed between H-PSG and T-PSG for AHI, mean \( \text{Sa}_2 \), patient position, TST, or sleep composition. In contrast, Portier et al reported a higher TST at home than in the laboratory. It is possible that our patients were more likely to adopt their usual sleep pattern in a local hospital than they would in a sleep laboratory. Although recording conditions did not have any influence on polysomnographic indexes, our study revealed an interrecording variability of AHI. Twenty-eight of the 65 patients (43%) had an absolute AHI difference > ± 10 compared to 35% in the study by Portier et al. As previously described, our study revealed a greater variability of AHI in patients with more severe OSAS. The variability between two readings of the same recording was not evaluated in our study. This parameter may play a role in the interrecording variability of AHI but has been poorly evaluated in the literature. Despite this variability, H-PSG and T-PSG were concordant for the diagnosis of OSAS in 58 of 65 patients with an AHI cutoff value of 10/h. Six of the remaining seven patients had mild OSAS with an AHI close to 10/h.

In conclusion, T-PSG is clearly superior to H-PSG from a technical point of view and tends to be preferred by patients. The site of recording (home vs hospital) has no influence on polysomnographic indexes.

### References


### Table 3—Comparison of Patients with High Variability (AHI Difference > ± 10) and Low Variability (AHI Difference ≤ ± 10)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>High Variability</th>
<th>Low Variability</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>55 ± 11</td>
<td>51 ± 10</td>
<td>NS</td>
</tr>
<tr>
<td>Male gender, %</td>
<td>89.6</td>
<td>75.6</td>
<td>NS</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>28.6 ± 4.9</td>
<td>27.5 ± 4.6</td>
<td>NS</td>
</tr>
<tr>
<td>Epworth sleepiness scale</td>
<td>9.5 ± 4.4</td>
<td>11 ± 4.7</td>
<td>NS</td>
</tr>
<tr>
<td>AHI†</td>
<td>47 ± 35</td>
<td>15 ± 16</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>TST, min†</td>
<td>318 ± 65</td>
<td>342 ± 65</td>
<td>NS</td>
</tr>
<tr>
<td>REM, %TST†</td>
<td>18.3</td>
<td>18.6</td>
<td>NS</td>
</tr>
<tr>
<td>Supine, %TST†</td>
<td>72.5</td>
<td>74</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD unless otherwise indicated. See Table 2 for expansion of abbreviations.
†Average of H-PSG and T-PSG values.


16 Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research; the report of an American Academy of Sleep Medicine Task Force. Sleep 1999; 22:667–689


