Predictive value of automated oxygen saturation analysis for the diagnosis and treatment of obstructive sleep apnoea in a home-based setting

V Jobin, P Mayer, F Bellemare

BACKGROUND: A portable monitor for the automated analysis of episodic nocturnal oxygen saturation or SpO2 (the Remmers Sleep Recorder, RSR) has been proposed for the diagnosis of obstructive sleep apnoea-hypopnoea (OSAH). A study was undertaken to compare the diagnostic performance of automated analysis with the manual scoring of polygraphic data by a more comprehensive respiratory monitor (the Suzanne recorder) used simultaneously in their intended home environment.

METHODS: The respiratory disturbance indexes of the two monitors were compared in 94 consecutive adult patients suspected of having OSAH and who were deemed eligible for home-based investigation.

RESULTS: The RSR overestimated the number of respiratory events associated with a ≥4% fall in SpO2 by 13% (p<0.005) but underestimated the number of apnoeas and hypopnoeas defined on the basis of respiratory variables alone or their association with a ≥4% fall in SpO2 or autonomic arousals by 38–48% (p<0.0001). In addition to these significant biases, the limits of agreement in all instances were wide, indicating a poor concurrence between the two monitors.

CONCLUSION: The automated analysis of SpO2 with the RSR cannot be substituted for the manual scoring of polygraphic data with the more comprehensive respiratory monitor in the diagnosis of OSAH in an ambulatory home-based setting.

Obstructive sleep apnoea-hypopnoea (OSAH) is a highly prevalent disorder affecting 2–4% of adult men and women. However, the standard diagnostic test for OSAH, that is, supervised in-laboratory overnight polysomnography (PSG), is time consuming and costly. Because of insufficient human, physical and financial resources, accessibility to this form of testing in some places is limited, and the diagnosis of OSAH is consequently delayed. To overcome such difficulties, several portable monitors have been proposed that range in complexity from full PSG to oximetry alone. Although portable monitoring does not constitute a standard of care, in specialised centres such as ours it can help to reduce the burden for full PSG studies. Monitors that record respiratory variables together with oximetry but without electroencephalography (EEG) and electromyography (EMG) are particularly attractive because the same definition of OSAH as in standard PSG can be employed, and the test can be self-administered by patients in their home, thereby increasing accessibility. This type of monitoring offers high diagnostic sensitivity and specificity (>90%). However, given the number of signals being recorded, and because these studies are unattended, the risk of technical failures is higher. Furthermore, the scoring of such studies remains labour intensive as it requires expertise and manual editing.

Although a diagnosis of OSAH can also be made by oximetry alone, wide variability in sensitivity and specificity (range 31–100%) has been reported for this type of monitoring. Furthermore, the reliability of automatic scoring algorithms present on some of these devices has been questioned. However, in a large prospective study of consecutive patients, Vasquez et al reported excellent agreement between the respiratory disturbance index (RDI) derived from the automated analysis of oxygen saturation (SpO2) of the Remmers Sleep Recorder or RSR (RDImrn) and the apnoea-hypopnoea index (AHI) derived from the manual scoring of standard PSG that was minimally altered when EEG-based arousals were incorporated in the definition of AHI. Compared with previous reports on oximetry, RDImrn offered excellent diagnostic sensitivity (>95%) and specificity (>85%). Because the analysis is automated and does not require a trained technician, it should be more widely applicable than more comprehensive respiratory monitors. The purpose of the present study was to assess the performance of this simpler monitor in comparison with the more comprehensive portable respiratory monitor currently employed in our ambulatory setting for the diagnosis of OSAH.

METHODS

Patients were recruited after referral to the sleep clinic of a university affiliated tertiary care centre. All patients who were prescribed an ambulatory trial by a sleep specialist were eligible for enrolment. In our centre, patients are generally considered eligible for an ambulatory investigation unless they meet one or more of the following exclusion criteria: inability to perform an ambulatory PSG, history of neuromuscular disease, severe lung disease (forced expiratory volume in 1 s (FEV1) <50% predicted), unstable coronary artery disease or referral for parasomnia. Of the 513 consecutive patients eligible for ambulatory investigation between March 2003 and May 2004, 104 were enrolled in the study. The limit for enrolment was set by the number of available monitors (six Suzanne recorders and one RSR; see below). The RSR was offered to patients on a “first come first served” basis. The protocol was approved by the Institutional Human Ethics Committee of CHUM-Hôtel Dieu and all participants provided written informed consent.

Abbreviations: AHI, apnoea-hypopnoea index; ESS, Epworth Sleepiness Scale; FEV1, forced expiratory volume in 1 s; OSAH, obstructive sleep apnoea-hypopnoea; PSG, polysomnography; RDI, respiratory disturbance index; RSR, Remmers Sleep Recorder; SpO2, oxygen saturation

See end of article for authors’ affiliations

Correspondence to: François Bellemare, PhD, Laboratoire du sommeil, CHUM–Hôtel-Dieu, 3840 St-Urbain, Montréal, Québec, Canada H2W 1T8; bellemare@videotron.qc.ca

Received 22 February 2006
Accepted 20 August 2006
Published Online First
24 January 2007
The number of patients recruited was sufficient to detect a difference in RDI of >5 events/h between the two monitors with a probability of 0.01 and a power of 90%.

**Data acquisition devices**

A computerised polysomnographic monitor (Suzanne Polysomnographic Recording System, Nellcor Puritan Bennett (Melville) Ltd, Ottawa, Ontario, Canada), hereafter referred to as the Suzanne recorder, and a standardised montage served as the reference for the study. Nasal pressure was recorded by means of a nasoanula, breathing movements by means of piezoelectric respiratory effort belts (Ultima Respiratory Effort Sensor, Model 0522S, Braedon Medical Corp, Carp, Ontario, Canada) and snoring by means of a miniature microphone attached to the garments (Suzanne Microphone, Model Y-70615, Nellcor Puritan Bennett (Melville) Ltd). With the RSR (SnoreSat, SagaTech Electronics Inc, Calgary, Alberta, Canada), SpO2 was recorded by means of a second finger probe (Oximax Durasensor, Model DS-100A, Tyco Healthcare, Pleasanton, California, USA) and snoring by means of adhesive tape over the sternal notch.

**Study protocol**

After medical assessment the patients were asked to complete a sleep quality questionnaire incorporating the Epworth Sleepiness Scale (ESS). They were then instructed how to use the two portable devices simultaneously at night. They were also asked to report whether they were still using their device and, on average, how many hours per night. They were also asked to report the number of months they had been on treatment, attending the sleep clinic. Specifically, patients were asked to indicate on a log the time they went to bed, the time they woke up, the time they used the two portable devices simultaneously at night. They were also asked to indicate on a log the time they went to bed, the time they woke up, the time they used the two portable devices simultaneously at night. They were also asked to report whether they were satisfied with their treatment and to complete the ESS questionnaire.

**Data analysis**

The data from the two monitors were analysed separately and in a blind fashion by one of three trained sleep technicians. Data from the Suzanne recorder were scored manually using Sandman software (Nellcor Puritan Bennett (Melville) Ltd). A RDI was calculated based on the number of apnoeas and hypopnoeas per hour of recording time (RDISuz). Apnoea was scored when no breathing could be detected on the nasal pressure trace for at least 10 s. Hypopnoea was scored when the amplitude of respiratory movements detected by the nasal pressure sensor or the thoracoabdominal effort belts decreased by more than 50% below baseline or when the amplitude of respiration was reduced by less than 50% but was followed by a fall in SpO2 of ≥4%. An extended RDI (RDSuz) was also calculated that incorporated, in addition to apnoeas and hypopnoeas, respiratory events associated with probable autonomic arousals, defined as increases in pulse rate of >5 beats/min immediately after a respiratory event characterised by the clear presence of inspiratory flow limitation, a decrease in flow of <30% of the baseline value and no change in SpO2. Finally, for direct comparison with RDRISuz a restricted RDI (RDISuz) was defined as the number of respiratory events associated with a fall in SpO2 of >4%. The Suzanne recorder samples the SpO2 signal at 12 Hz and reports the average value over the preceding second every second. For the RSR, no specific scoring was done since the recordings are automatically analysed by the software supplied with the instrument. With this software the raw data can be viewed but no editing is possible. RDRISuz is calculated automatically as the number of episodes per hour of oximeter probe-on time with falls in SpO2 ≥4% below baseline. The RSR samples the SpO2 signal at 1 Hz. Details concerning the detection algorithm of this monitor can be found elsewhere. RDRISuz appears automatically in the report sheet along with a graphic display of SpO2, snoring and body position as well as a series of related information including recording time, oxygen sensor probe-on time, minimum, maximum and mean SpO2. This report can be visualised and printed.

**Statistical analysis**

Differences between the two devices were compared using non-parametric statistics and the Wilcoxon signed rank test. The bias and limits of agreement between the two instruments were calculated and receiver operating characteristic (ROC) curves generated for selected diagnostic RDI cut-off values. Values are expressed as group mean (SEM) or median (interquartile range, IQR), depending on their distribution. The statistical level of significance was set at p<0.05.

**RESULTS**

**Patient characteristics**

Of the 104 patients studied, 10 returned technically inadequate studies, leaving a total of 94 patients (62 men) for final analysis (table 1).

**Technical considerations**

Differences in recording time between the two monitors, although significant, were small (table 2). By contrast, wide variations were found in the time spent in different body positions (data not shown), presumably related to the different features or displacement of body position sensors, preventing meaningful comparisons from being made in different body positions.

**Table 1 Characteristics of study subjects**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>21</td>
<td>76</td>
<td>49.27</td>
<td>1.12</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>51</td>
<td>178</td>
<td>89.51</td>
<td>2.20</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.47</td>
<td>2.16</td>
<td>1.72</td>
<td>0.01</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>16.1</td>
<td>55.9</td>
<td>30.47</td>
<td>0.78</td>
</tr>
<tr>
<td>Neck circumference (cm)</td>
<td>31</td>
<td>53</td>
<td>43.92</td>
<td>0.40</td>
</tr>
<tr>
<td>Adjusted neck circumference (cm)*</td>
<td>36</td>
<td>59</td>
<td>43.71</td>
<td>0.53</td>
</tr>
<tr>
<td>Epworth sleepiness score</td>
<td>0</td>
<td>21</td>
<td>11.72</td>
<td>0.53</td>
</tr>
</tbody>
</table>

BMI, body mass index calculated as the ratio of body weight (in kg) and height squared (in metres).

*Clinical prediction score which is equal to the value of neck circumference (in cm) adjusted for history of hypertension (i+4 cm) and reporting of frequent snoring (>3 cm) and of witnessed apnoeas (>3 cm). For details see Flemmons.

www.thoraxjnl.com
Table 2 Comparative results between the Suzanne and Remmers monitors

<table>
<thead>
<tr>
<th></th>
<th>Suzanne</th>
<th>Remmers</th>
<th><em>p Value</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>RDI (n/h)</td>
<td>12.9 (5.4–28)</td>
<td>8.8 (2.9–18.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Recording time (min)</td>
<td>431 (379–496)</td>
<td>429 (381–486)</td>
<td>&lt;0.022</td>
</tr>
<tr>
<td>SpO2 mean (%)</td>
<td>95.9 (94.9–96.8)</td>
<td>95.1 (93.9–96.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SpO2 min (%)</td>
<td>88.5 (84–91)</td>
<td>85 (80–87)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ΔSpO2 (%)</td>
<td>7.7 (4.8–11.1)</td>
<td>10.4 (7.9–13.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>% time SpO2 &lt;90% (%)</td>
<td>0.15 (0–1.4)</td>
<td>0.6 (0.1–1.6)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Wilcoxon signed rank test.*

Values are median (interquartile range).

RDI, respiratory disturbance index measured as the number of events/h recording time; SpO2 mean, mean oxygen saturation measured by pulsed oximetry over the recording time period; SpO2 min, minimum oxygen saturation recorded by pulse oximetry during the recording time period; ΔSpO2, arithmetic difference between SpO2 mean and SpO2 min.

Figure 1 Bland-Altman plots showing the distribution of the differences between the respiratory disturbance index (RDI) of the Remmers Sleep Recorder (RDIRem) and the RDI of the Suzanne recorder calculated according to several definitions of respiratory events (RDISuz, extended RDI; RDISuz2, restricted RDI). For a definition of the Suzanne recorder RDIs, see footnote to table 3. In each panel the horizontal solid line represents the mean difference and the broken lines ± 2SD of the observed differences.

Figure 2 Receiver operating characteristic (ROC) curves of the respiratory disturbance index (RDI) of the Remmers Sleep Recorder for two diagnostic cut-off values of the Suzanne recorder RDI calculated according to several definitions of respiratory events: Solid lines represent events defined on the basis of their association with a >4% fall in SpO2 (RDISuz2); Dotted lines represent events defined on the basis of a >50% reduction in mechanical variables or >4% fall in SpO2 (RDISuz). Dash-dotted lines represent events defined on the basis of their association with a >50% reduction in mechanical variables or a >4% fall in SpO2 or autonomic arousals (RDISuz2).
The sensitivity and specificity of RDI Rem varied with the diagnostic threshold where these differences mattered. Again, visual inspection indicated that large respiratory events included in RDI Suz and RDISuz definition (table 3, fig 2). Compared with RDISuz, RDI Rem had reasonable sensitivity at the same cut-off points but specificity (74%) and likelihood ratio for a positive test result (3.68) near the diagnostic threshold were low. When compared with RDI Suz and RDISuz, the sensitivity of RDI Rem was markedly reduced at all cut-off points, but specificity was minimally altered. Because of this lower sensitivity, the likelihood ratio for a negative test result increased markedly at all cut-off points. At the diagnostic cut-off value of 5 events/h, only between 76% and 77% of the patients were correctly classified by RDI Rem. At this cut-off point, a diagnosis of OSAH could be made with confidence (ie, 100% specificity) when RDLR Rem was 20 events/h (RDI Suz 5) or 10 events/h (RDI Suz 5). With these cut-off points, however, only between 29% and 53% of OSAH patients were identified by RDI Rem.

Outcome Of the 94 patients, 49 met the minimum diagnostic criteria (5 events/h) using RDISuz, of whom two had RDI Rem of <5 (Table 4). Adding respiratory events with >50% reduction in respiratory movements but <4% fall in SpO2 in the definition of RDISuz led to 25 additional patients meeting this criterion, of whom 16 had RDI Rem <5. Adding respiratory events associated with autonomic arousals in the definition of RDISuz led to 12 additional patients meeting the minimum diagnostic criteria, of whom 9 had RDI Rem <5.

Of these 94 patients, 13 were referrals from external centres. Of the 81 patients attending our clinic, 5 were lost to follow-up and 5 were referred for a second evaluation, leaving 71 new cases. Fifty-five patients with RDI Suz >5 events/h were prescribed a treatment trial with continuous positive airway pressure or a mandibular advancement prosthesis. A follow-up

### Table 3  Predictive value of automated analysis of the Remmers sleep recorder

<table>
<thead>
<tr>
<th>Diagnostic cut-off</th>
<th>ROC area</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Patients correctly classified (%)</th>
<th>LR+</th>
<th>LR-</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDI Suz 5</td>
<td>0.95</td>
<td>94.1</td>
<td>74.4</td>
<td>85.1</td>
<td>3.68</td>
<td>0.08</td>
</tr>
<tr>
<td>RDI Suz &gt;5</td>
<td>0.96</td>
<td>90.9</td>
<td>82.0</td>
<td>85.1</td>
<td>5.04</td>
<td>0.11</td>
</tr>
<tr>
<td>RDI Suz 10</td>
<td>0.99</td>
<td>92.2</td>
<td>87.7</td>
<td>89.4</td>
<td>7.72</td>
<td>0.05</td>
</tr>
<tr>
<td>RDI Suz 15</td>
<td>0.85</td>
<td>75.3</td>
<td>81.0</td>
<td>76.6</td>
<td>3.95</td>
<td>0.30</td>
</tr>
<tr>
<td>RDI Suz &gt;15</td>
<td>0.90</td>
<td>67.9</td>
<td>87.8</td>
<td>76.6</td>
<td>3.57</td>
<td>0.37</td>
</tr>
<tr>
<td>RDI Suz 20</td>
<td>0.91</td>
<td>62.8</td>
<td>96.1</td>
<td>80.9</td>
<td>3.90</td>
<td>0.39</td>
</tr>
<tr>
<td>RDI Suz &gt;20</td>
<td>0.84</td>
<td>73.7</td>
<td>83.3</td>
<td>75.5</td>
<td>4.42</td>
<td>0.31</td>
</tr>
<tr>
<td>RDI Suz 25</td>
<td>0.82</td>
<td>60.6</td>
<td>96.4</td>
<td>71.3</td>
<td>17.0</td>
<td>0.41</td>
</tr>
<tr>
<td>RDI Suz &gt;25</td>
<td>0.94</td>
<td>51.9</td>
<td>87.5</td>
<td>71.3</td>
<td>20.7</td>
<td>0.49</td>
</tr>
</tbody>
</table>

### Table 4  Patient distribution according to minimum required diagnostic criteria

<table>
<thead>
<tr>
<th>Criterion</th>
<th>n</th>
<th>RDI Rem</th>
<th>RDI Suz</th>
<th>RDISuz</th>
<th>ES</th>
<th>n/Rx</th>
<th>ΔESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDI Suz &lt;5</td>
<td>8</td>
<td>1.9 (0.7)</td>
<td>1.0 (0.3)</td>
<td>2.0 (0.3)</td>
<td>3.7 (0.3)</td>
<td>12.9 (2.1)</td>
<td>0 (Rx)</td>
</tr>
<tr>
<td>RDI Suz &gt;5</td>
<td>49</td>
<td>23.2 (2.5)</td>
<td>22.4 (2.8)</td>
<td>32.4 (2.9)</td>
<td>36.7 (2.8)</td>
<td>11.3 (0.7)</td>
<td>27/35</td>
</tr>
<tr>
<td>RDI Suz &gt;10</td>
<td>25</td>
<td>4.4 (0.5)</td>
<td>1.7 (0.2)</td>
<td>9.9 (1.0)</td>
<td>14.3 (1.5)</td>
<td>12.0 (1.1)</td>
<td>7/12</td>
</tr>
<tr>
<td>RDI Suz &gt;15</td>
<td>12</td>
<td>5.1 (1.7)</td>
<td>2.2 (0.5)</td>
<td>3.3 (0.4)</td>
<td>7.6 (0.8)</td>
<td>12.1 (1.1)</td>
<td>4/8</td>
</tr>
<tr>
<td>Total</td>
<td>94</td>
<td>14.1 (1.7)</td>
<td>12.5 (1.8)</td>
<td>20.1 (2.0)</td>
<td>24.2 (2.0)</td>
<td>11.7 (0.5)</td>
<td>38/55</td>
</tr>
</tbody>
</table>

Values are mean (SE); RDI Rem, respiratory disturbance index (RDI) of the Remmers Sleep Recorder; RDI Suz, restricted RDI of the Suzanne recorder; RDISuz, RDI of the Suzanne recorder; ΔESS, change in Epworth sleepiness score with treatment relative to baseline.
questioned the validity of the previous conclusion based on the different event definitions, its magnitude could not be predicted. In a previous investigation by Redline et al., adding a ≥4% desaturation criterion as a prerequisite for scoring a respiratory event reduced the median RDI by 85% (from 29.3 to 4.4) and the prevalence estimate by about 55% (from 100% to 45%). In that study, however, flow was measured with a thermocouple, a method which may not reflect flow accurately. The closest comparison in our investigation would be between RDSuz and RDSuz, showing a 66% reduction in median RDI (from 12.9 to 5.6) and a 26% decrease in the prevalence estimate (from 78% to 52%). The fact that, on average, 38–48% of respiratory events in the present study could be associated with a fall in SpO2 of <4% may be understood when considering that the duration of the events as well as the pre-event oxygen saturation level, end-expiratory lung volume and metabolic rate all contribute to determine the magnitude of the fall in SpO2 during obstructive events. Because these factors can be expected to vary substantially in different patients, they may also contribute to explain the large inter-individual variability in the difference in RDI and, hence, the poor agreement between the two monitors.

One could question the clinical significance of including respiratory events associated with <4% fall in SpO2 or with autonomic arousals in the definition of RDSuz. As shown by Guilleminault et al., sleep fragmentation can occur in a number of patients with OSAH in association with periodic increments of respiratory efforts but without significant oxygen desaturation. These patients can be very symptomatic and benefit from treatment. Furthermore, as demonstrated experimentally by Martin et al., even subclinical autonomic arousals can increase sleepiness. In the present study the inclusion of respiratory events with <4% fall in SpO2 or with autonomic arousals in the definition of RDSuz led to 37 additional patients being classified as having OSAH, of whom 50% were prescribed a treatment trial with benefits in most of them (table 4). These data suggest that a substantial number of patients with OSAH identified on the basis of these criteria can benefit from treatment, thereby justifying their inclusion in the definition of RDI.

**Implications of the findings**

Significant negative bias and poor agreement between the two monitors both contributed to reduce the diagnostic sensitivity and specificity of the RSR. Using a diagnostic cut-off value of ≥15 events/h, Vasquez et al reported 98% sensitivity, a value comparable to that of the present study when a ≥4% fall in SpO2 was required to define a respiratory event with the Suzanne recorder. However, when respiratory events associated with a <4% fall in SpO2 or with autonomic arousals were included in the definition of RDSuz, the sensitivity of the RSR at the same cut-off point was markedly reduced to between 52% and 63%. These sensitivity values are within the range previously for home oximetry (range 31–98%). The implication of this is that, for a substantial number of patients, additional investigations would have been required had the RSR been employed as the sole instrument. According to our results, for a positive diagnosis of OSAH (defined as ≥5 events/h) to be made with 100% confidence using the RSR, ≥20 or ≥10 events/h, depending on whether autonomic arousals are included or not in the definition of RDSuz. Because only between 33% and 49% of all cases met these criteria, a second study with a more comprehensive respiratory monitor would have been needed in 51% or more of patients. Although a cost-benefit analysis of the RSR under such circumstances has not been performed, the results are unlikely to show significant benefits. Furthermore, because a
second study would entail additional delay in the diagnosis of OSAH in a substantial number of patients, substitution of the more comprehensive respiratory monitor by the automated analysis of the RSR is not warranted.

With the RSR, no editing of RDIRem was possible. SpO2 traces, however, could be reviewed. Other signals such as flow and respiratory effort belts may also be added and reviewed. As several studies have pointed out, visual inspection of SpO2 tracings alone with no false positives. Using a Support Office, Research Center, CHUM.

The Remmers Sleep Recorder used in this study was provided by the RSR further, such a comparison is likely to reinforce our conclusions.

Another limitation of our study is that the performance of the RSR in the home environment was not compared with diagnostic in-laboratory PSG. Differences between EEG-based sleep time and recording time, night to night variability and different environments are all factors that can affect RDI and, hence, the diagnostic performance of the RSR. By using the two recorders simultaneously in the home environment, we avoided these potential confounders. While this has advantages with respect to defining the performance of automated analysis, further validation comparing home-based monitoring with in-laboratory PSG is warranted. However, because the added variability associated with the home environment can be expected to reduce the diagnostic sensitivity and specificity of the RSR further, such a comparison is likely to reinforce our conclusions.

In summary, this study shows that, in spite of a significant association between the RDI of the two monitors, the low diagnostic sensitivity and specificity of RDIRem near the diagnostic threshold are such as to deter substitution of the more comprehensive respiratory monitor.

ACKNOWLEDGEMENTS

The Remmers Sleep Recorder used in this study was provided by Sagatech Electronics Inc, Calgary, Alberta, Canada. The authors acknowledge the editorial assistance of Ovid Da Silva, Research Support Office, Research Center, CHUM.

REFERENCES


Authors’ affiliations

V Jobin, P Mayer, F Bellemore, Laboratoire du sommeil, Centre hospitalier de l’Université de Montréal (CHUM)—Hôtel-Dieu, Montréal, Québec, Canada

FB was supported by Medigas, OSR Medical and the Laboratoires Biron.

Competing interests: None.

www.thoraxjnl.com