The diagnosis of sleep apnea syndrome (SAS) requires expensive and complex instrumentation. The purpose of the present study was to determine the value of end-tidal CO₂ (EtCO₂) in screening for sleep apneas. Thirty-nine patients referred to our sleep laboratory because of suspected SAS and ten normal subjects were studied. The EtCO₂ was measured using an infrared spectrometer (POET) designed for simultaneous measurement of CO₂ and pulse oximetry. In 29 subjects, expired gas was sampled with a nasobuccal mask (Respiron) with lateral orifices. In the other 20 subjects, sampling was done with nasobuccal prongs (Criticare) comprising a four-channel plastic tube to the mouth and the nostrils. Data from an 8-h night were transferred the following day to a microcomputer (Apple Macintosh) for processing. Apnea was defined as an absence of detection of CO₂ for more than 10 s. Conventional polysomnography was performed (Respisomnographe). The number of apneas in 8 h and the apnea index (number of apneas in 1 h) were calculated after visual analysis on the screen of the polysomnograph and also with EtCO₂ analysis. For recordings made with a nasobuccal mask, the regression curve between the apnea indices computed with EtCO₂ and polysomnography was an order 2 polynomial curve (r = 0.76; p < 0.001), with an inflection point at 39 apneas per hour. For recordings with nasobuccal prongs, the correlation was very significant (r = 0.95; p < 0.0001), and the regression curve was linear. The EtCO₂, with nasobuccal prongs appears to be a simple and reliable method for screening for SAS.

(Chest 1993; 103:129-31)

### Materials and Methods

**Patients**

Thirty-nine patients (35 men and 4 women) referred to our sleep laboratory because of suspected SAS and 10 normal subjects (5 men and 5 women) were studied. The characteristics of these patients are shown in Table 1. Six had a PaO₂ below 60 mm Hg due to chronic obstructive airway disease.

**Methods**

**End-Tidal CO₂.** The EtCO₂ was measured using an infrared spectrometer (POET) designed for derived sampling and simultaneous measurement of CO₂ and pulse oximetry. Sampling of CO₂ is repeated every 25 ms. In 29 subjects, expired gas was sampled with a nasobuccal mask (Respiron) with lateral orifices. In the other 20 subjects, sampling was done with nasobuccal prongs (Criticare) comprising a four-channel plastic tube to the mouth and the nostrils. Prongs were fitted on the patient by cutting and modeling the metal framework. Data from an 8-h night were stored in the internal memory of the spectrometer every 5 s and were transferred the following day to a microcomputer (Apple Macintosh) for processing by specially written macros (Microsoft Excel).

### Statistical Analysis

The characteristics of the two groups of patients were compared using Student's t test. The correlation between the AIs obtained with each method was evaluated by the correlation coefficient method, and regression curves were established. In addition, we also calculated the sensitivity (TP/[TP + FN]), specificity (TN/[TN + FP]), the positive predictive value (TP/[TP + FP]), the negative predictive value (TN/[TN + FN]), and the global value ([TP + TN]/[TP + TN + FP + FN]) of the AI obtained with the EtCO₂ analysis compared to the polysomnographic one (TP = true positives; FP = false positives; TN = true negatives; FN = false negatives). The analysis was done at different levels of SAS severity (AI > 5, 10, or 20) (Table 2).
Table 1—Mean Values and Characteristics of Subjects*

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean ± SD (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>55 ± 12 (31-77)</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>32 ± 7 (17-54)</td>
</tr>
<tr>
<td>FEV₁</td>
<td>80 ± 21 (34-126)</td>
</tr>
<tr>
<td>FVC₁</td>
<td>80 ± 18 (50-121)</td>
</tr>
<tr>
<td>TLC₁</td>
<td>86 ± 13 (59-114)</td>
</tr>
<tr>
<td>PaO₂, mm Hg</td>
<td>71 ± 10 (53-99)</td>
</tr>
<tr>
<td>PaCO₂, mm Hg</td>
<td>43 ± 5 (32-62)</td>
</tr>
</tbody>
</table>

*FVC = forced vital capacity; TLC = total lung capacity.
†Values are expressed as percent of theoretical value.

RESULTS

The mean values and characteristics of all patients are shown in Table 1. The values were the same whether recordings were made with nasobuccal prongs or a facial mask.

Polysomnography

An AI above 10 was found in 23 patients, with a maximum of 80 apneas per hour. Several patients without SAS suffered from chronic obstructive pulmonary disease. All subjects slept (mean total sleep time = 380 ± 100 min).

End-Tidal CO₂

For recordings made with a nasobuccal mask, the regression curve was an order 2 polynomial curve (r = 0.76; p < 0.001), with an inflection point at 39 apneas per hour (Fig 1). Below 39 apneas per hour (polysomnography), the regression curve obtained was linear (r = 0.86; p < 0.0001). Above this threshold, EtCO₂ values decreased as the polysomnographically determined AI increased. Sensitivity, specificity, and predictive values are shown in Table 2.

For recordings with nasobuccal prongs, the correlation was very significant (r = 0.95; p < 0.0001), and the regression curve was linear (Fig 2). Sensitivity, specificity, and predictive values are shown in Table 2.

DISCUSSION

Sleep apnea syndrome was discovered by Gastaut et al² in 1965 and was characterized by Guilleminault et al.¹ The exact prevalence of this potentially serious but currently treatable disorder is unknown. Diagnosis requires polysomnography,¹-³ an expensive and labor-intensive examination that requires an overnight stay in a sleep laboratory. The complexity of polysomnography and the overcrowding of existing facilities explains the current interest in screening.³⁷,⁸

No satisfying screening method is now available. Clinical data are often inadequate. Respiratory sound recordings, cardiac rate, or oximetry measurements⁵,⁶ have been proposed. None of these tests has been evaluated in a large enough randomized sample or shown to possess the necessary sensitivity. All three methods measure the consequences, rather than the absence of respiratory airflow, and hence lack specificity. Nonapneic desaturation can be observed in chronic obstructive pulmonary disease.¹⁰ Mathematical processing of the SaO₂ signal improves the detection of apneic events by SaO₂.¹¹

The EtCO₂ partial pressure measurement, which has been used in physiology laboratories,³,⁴ is now a current technique for monitoring respiration during anesthesia and intensive care.⁴,¹² In association with percutaneous oximetry and the Vitalog system, capnography has been used to successfully detect SAS in a few patients.¹³

The EtCO₂ is a much easier method of measuring airflow than polysomnography. Rapid new computer-
Figure 2. Apnea index by EtCO$_2$ as function of polysomnographic AI (nasobuccal prongs).

ized devices have been designed to determine EtCO$_2$ from a few points of the capnometer, rather than the whole curve. These instruments, which store digitalized data in an internal memory, may provide a convenient method of screening subjects at risk for SAS.

Using a nasobuccal mask, EtCO$_2$ was in agreement with polysomnography when the AI was below 39. Above that level the two methods gave discordant findings. Thus, this method lacks sensitivity for patients with the most serious symptoms. Poor results were probably due to the accumulation of CO$_2$ in the mask in spite of the lateral orifices. Indeed, when data were recorded with nasobuccal prongs, which avoid CO$_2$ stagnation, results were excellent regardless of the AI. Passive diffusion of CO$_2$ during apnea, which is not taken into account by thermocouples or by continuous airflow monitoring, is not measured by EtCO$_2$

The AI by EtCO$_2$ was lower than the polysomnographic AI, especially for the two patients with the most severe symptoms (Fig 1). This finding could be explained by differences in the criteria used to separate two successive apneas with the visual method and EtCO$_2$. The visual method takes into account duration, amplitude, and pattern of recovery between apneas. The EtCO$_2$ considers two successive apneas to be separate when CO$_2$ is detected more than 5 s between two apneas. If the duration is shorter or if the quantity of CO$_2$ is too low, no EtCO$_2$ is recorded, and only one apnea is counted. In fact, the difference between the two methods is slight, especially for moderate SAS, which is important for a screening method.

The EtCO$_2$ findings correlate well with polysomnography. The sensitivity and specificity are one, with a threshold of ten apneas per hour. Nevertheless, EtCO$_2$ does not allow classification of apneas as obstructive, central, or mixed and does not take hypopneas into account, and a sleep study is needed to confirm the diagnosis of SAS. Thus, EtCO$_2$ cannot replace polysomnography; however, with nasobuccal prongs, it appears to be a simple and reliable screening method for SAS.

ACKNOWLEDGMENT: We thank Mr. Andy Corsini for his help in translation.

REFERENCES

5 Gastaut H, Tassinari C, Duron B. Etude polygraphique des manifestations episodiques (hypniques et respiratoires) du syndrome de Pickwick. Rev Neurol 1965; 112:508-79
10 Fletcher EC, Miller J, Divine G, Fletcher JG, Miller T. Nocturnal oxyhemoglobin desaturation in COPD patients with arterial oxygen tensions above 60 mm Hg. Chest 1987; 92:604-08