Performance of Nasal Prongs in Sleep Studies*

Spectrum of Flow-Related Events

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Objectives: The use of nasal prongs connected to a pressure transducer is a noninvasive, sensitive method to detect respiratory events, and can be easily implemented in routine sleep studies. Moreover, its good time response allows the detection of several flow-related phenomena of high interest, in addition to apnea and hypopnea. The aims of the study were to examine the quality and performance of the nasal prong flow signal, and to describe other flow-related events during full-night polysomnography studies.

Methods: Twenty-seven subjects were studied (16 male subjects; mean ± SD age, 49 ± 14 years; mean body mass index, 27 ± 4 kg/m²): 15 subjects recruited from the general population and 12 consecutive patients with suspected sleep apnea/hypopnea syndrome (SAHS).

Results: A blind analysis of the respiratory events detected both by nasal prongs and thermistor was done. The quality of the nasal prong signal recordings was considered optimal for scoring purposes in 78% of cases, and no recording was considered uninterpretable. The nasal prong signal detected additional flow-related events not observed by the thermistor: (1) short and long (> 2 min) periods of inspiratory flow limitation morphology without decrease in the amplitude of the signal; (2) periods of mouth expiration; and (3) snoring. The apnea/hypopnea index was significantly higher with the nasal prong scoring (18 vs 11 [p < 0.05] in the general population and 37 vs 27 [p < 0.001] in the group with suspected SAHS).

Conclusions: The incorporation of nasal prongs in routine full-night studies is an attainable technical option that provides adequate recordings in most cases. Additionally, relevant information not scored by thermistors is obtained on flow-related respiratory events, thus increasing diagnostic accuracy.

Key words: full-night polysomnography; nasal airflow recording; nasal cannula; sleep apnea-hypopnea syndrome; sleep monitoring

Abbreviations: AHI = apnea/hypopnea index; EMG = electromyogram; EOG = electro-oculogram; IFL = inspiratory flow limitation; ME = mouth expiration; SAHS = sleep apnea/hypopnea syndrome; SaO₂ = arterial oxygen saturation; UARS = upper-airway resistance syndrome

Sleep-disordered breathing is commonly evaluated on the basis of conventional polysomnography or simplified systems that record only respiratory parameters.1,2 In such studies, thermistors or thermocouples are usually used to monitor airflow, since the routine use of a pneumotachograph, the “gold standard” for measuring airflow, is inconvenient (need for a well-fitting mask, patient discomfort, possible sleep disruption). The thermistor/thermocouple signal provides a semiquantitative estimation of airflow based on temperature differences between inspiration and expiration. However, these devices have a nonlinear, slow response; consequently, their signal depends on the respiratory frequency, the shape of the airway waveform, the distance between the nose and the sensor, and the section of the nares.3 Although these features may not be a problem for the detection of apneas (absence of flow), their accuracy in the detection of nonapneic respiratory events has

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been questioned. Our group and others have demonstrated that the use of nasal prongs connected to a pressure transducer is a reliable technical method to measure flow. Nasal prongs allow an indirect measurement of flow based on the recording of the pressure at the prongs placed in the nares relative to the atmospheric pressure. This differential pressure depends on the inspiratory and expiratory flow. However, due to the complex geometry and airflow regime in the orifices where pressure is recorded, the relationship between the recorded pressure and breathing flow is not linear. Instead, nasal prong pressure approximates a quadratic relationship. However, due to the complex geometry and airflow regime in the orifices where pressure is recorded, the relationship between the recorded pressure and breathing flow is not linear. Instead, nasal prong pressure approximates a quadratic relationship.

Accordingly, the square root of the pressure recorded in the nasal prongs is a linearized signal, which more closely reflects breathing flow than the raw pressure recorded. Moreover, nasal prongs have an excellent time response, allowing the analysis of the morphology of inspiratory flow, which other authors and our group have demonstrated to be a reliable noninvasive alternative to estimate the upper-airway resistance during continuous positive airway pressure titration. Experimentally, nasal prongs measure airflow accurately, and previous studies have demonstrated that nasal prongs improve detection of respiratory events in sleep studies. Thus, nasal prongs appear to be a simple and easy tool for assessing airflow in sleep-related breathing disorders. However, there are few studies that systematically examine nighttime flow-signal performance though nasal prongs and describe the occurrence of other flow-related events, aside from apneas or hypopneas, during a diagnostic polysomnography.

Accordingly, the aims of the present study were to (1) sample of 15 subjects from the general population recruited in the context of a prevalence study, and (2) 12 consecutive patients referred to the sleep laboratory with suspected sleep apnea/hypopnea syndrome (SAHS).

Study Subjects

Twenty-seven subjects were studied during an all-night polysomnography in our sleep laboratory. The subjects were recruited from two different groups: (1) a sample of 15 subjects from the general population recruited in the context of a prevalence study, and (2) 12 consecutive patients referred to the sleep laboratory with suspected sleep apnea/hypopnea syndrome (SAHS).

Sleep Study

Each patient was studied with full-night polysomnography, plus the addition of nasal prongs to the setting. The neurologic monitoring included central, frontal, and occipital EEG (C4A1, Fp1A2, O1A2), two channels of electro-oculogram (EOG), and the submental electromyogram (EMG). Sleep staging was performed on the basis of standard criteria. Arterial oxygen saturation (Sao2) was measured using a pulse oximeter (Criticare 504; Criticare Systems; Waukesha, WI). Respiratory effort was monitored with rib cage and abdominal bands and the sum of both by strain gauges (Nellcor Puritan Bennett; Minneapolis, MN). Airflow was measured simultaneously using a one-channel oronasal thermocouple (Jaeger; Wurzburg, Germany) and the nasal prongs. Other variables registered were the body position, a unipolar ECG derivation, and the anterior tibialis EMG. All the variables were recorded in a 16-channel polygraph (SleepLab 1000-P; Jaeger) during a minimum of 6.5 h.

Nasal Prongs Measurement

Nasal prongs were connected to a pressure transducer (176PC14HDZ; Honeywell; Freeport, IL). Before applying the nasal prongs to the patient, we set the pressure amplifier offset to zero. Once the nasal prongs were well adjusted in place at the patient’s nares, the amplifier gain was set to provide a pressure voltage corresponding to approximately two thirds of the range allowed by our data-acquisition system (12 bits, ± 5 V), with the patient breathing normally while awake. Subsequently, the pressure signal was fed into an analog circuit that provided a real-time signal, which was the square root of the input pressure. In our system, this signal ranged ± 1.82 V during normal breathing (which corresponds to a good resolution better than 9 bits, ie, resolution of about 1/744 = 0.13%). Therefore, even during the nonapneic events, the system has enough sensitivity to quantify flow abnormalities.

Study Design and Definition of Sleep Respiratory Events

In all cases, the same investigator scored the polysomnographic recordings. The neurologic scoring, using standard criteria, was subsequently followed by two independent blinded analyses of the respiratory events. In both analyses, all the variables were displayed in the monitor, but the airflow signal was the thermistor in one case, and the nasal prongs in the other case. Epoch by epoch, a systematic evaluation was done on the behavior and specific characteristics of the nasal prong flow signal. The quality of the nasal prong signal was assessed with a functional ordinal scale: (1) optimal signal, no problems in the identification of abnormalities in the flow signal and no significant loss of signal; (2) poor signal, difficulty in the identification of respiratory events and/or loss in the major part of the recording; (3) intermediate signal, brief problems in the quality of the nasal prong flow signal not influencing the correct identification of respiratory events. Any loss of signal or possible limitations of this methodology was also registered. In the same way, the quality of the thermistor flow signal was assessed with the same ordinal scale. Furthermore, the number, length, and frequency of all other respiratory phenomena seen in the nasal prong airflow signal not corresponding to apneic or nonapneic respiratory events were documented.

In the evaluation of respiratory events, an apnea was defined as the absence of airflow of ≥ 10 s, detected either by thermistor or nasal prongs. The nonapneic respiratory events were defined for the thermistor as any discernible reduction in the amplitude of the airflow signal ending with an arousal and/or associated with a 3% desaturation, with a length of at least 10 s, but < 2 min. In addition to the above-mentioned criteria, nasal prong nonapneic respiratory events included periods of inspiratory flow-limitation morphology (flattened contour of the airflow inspiratory waveform), without any significant change in the amplitude of the signal, with the same association with duration, arousal, or 3%
desaturation. The variables analyzed both with the thermistor and nasal prongs were the apnea/hypopnea index (AHI; the number of apneas plus nonapneic respiratory events per hour of sleep), the total number and different types of apneas, and the total number of nonapneic respiratory events.

Statistical Analysis

Statistical analysis was performed (Statistical Package for Social Sciences version 6.1.3 for Windows; SPSS; Chicago, IL). Data were expressed as mean ± SD. A paired t test was applied to the respiratory variables obtained from the thermistor and nasal prongs. Statistical significance was accepted at p < 0.05. Agreement analysis was performed following the methodology of Bland and Altman14 to compare both systems of measuring airflow analysis was performed following the methodology of Bland and Altman14 to compare both systems of measuring airflow during sleep studies. The ethics committee of our hospital approved this study. Written consent was obtained in all cases.

RESULTS

The general characteristics and the sleep parameters of the two groups included in this study are shown in Table 1. There were no significant differences between them, with the exception of a greater neck circumference in the group of patients with suspected SAHS.

Quality of Nasal Prongs and Thermistor Airflow Signals

The quality of the nasal prong signal throughout the night was assessed taking into account the clinical experience acquired during the last years. In only 3 of 27 subjects (11%), a loss of signal was observed in some period of the trace. However, the total length of the loss of signal was never >10 min. The loss of signal was also registered in the thermistor signal and was mainly due to technical blocking signal problems or rarely for displacement of both sensors from the nose corrected by the technician. In 21 of 27 recordings (78%), the nasal prong signal was considered optimal to identify all types of respiratory events. In 6 of 27 recordings, the signal performance was considered intermediate; 2 of them (7%) had technical problems, such as artifacts or a low amplitude signal, that did not have any influence in the scoring of respiratory events. In the remaining four recordings (15%), we had difficulties in the evaluation of nasal prongs due to a low and/or irregular signal in amplitude and/or morphology. This situation was more common in delta-wave and rapid eye movement sleep, and usually did not interfere with the adequate identification of respiratory events. These four recordings occurred in heavy snorers, and three of them were moderate-to-severe SAHS. We did not find any recording with a poor or uninterpretable nasal prong signal.

Figure 1 shows one of these flow recordings with an intermediate performance of nasal prongs, in which the nasal prong signal is of low amplitude and the high frequency of the severe snoring is superimposed. In the same way, the quality of the thermistor flow signal was optimal in 22 of 27 recordings and intermediate in the remaining 15% of cases, due to irregular amplitude signal or technical problem in short periods of the recording not able to be solved by the technician.

Airflow-Related Phenomena

The review of the nasal prong signal provided information on other airflow-related phenomena not identified by the thermistor, such as snoring, prolonged and short periods of inspiratory flow limitation (IFL), and changes in the breathing route (Fig 2). Nasal prongs identified snoring as a high-frequency signal in the inspiratory and/or expiratory branch of the airflow signal (Fig 2).

The prolonged IFL periods exhibited a flattened contour of the inspiratory flow morphology (with or without additional snoring) of >2 min, which could end up with an EEG arousal and usually were seen in delta-wave sleep (Fig 3). Table 2 shows the frequency and characteristics of the prolonged IFL periods. IFL was a frequent phenomenon seen in nearly 80% of all the subjects. Prolonged periods of IFL (usually between 5 min and 10 min) represented about 20% of the total sleep time (range, 0 to 73%) and were variable in duration. Short periods of IFL (between 10 s and 2 min) were computed as nonapneic respiratory events when they were associated with an arousal or 3% desaturation. Figure 4 shows 3 min of a polysomnographic recording in which no significant changes appear in the thermistor signal, whereas nasal prongs detected nonapneic respiratory events. Moreover, it is not unusual to observe short periods of flow-limited breaths followed by a rounded inspiratory breath with no apparent effect on the EEG or oxygen saturation, a feature previously described by Hosselet et al,15 but not systematically documented in our study.

Table 1—General Characteristics and Sleep Parameters of the Two Groups Studied

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<tr>
<th>Variables</th>
<th>General Population</th>
<th>Suspected SAHS Population</th>
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<tbody>
<tr>
<td>Age, yr</td>
<td>48 ± 13</td>
<td>51 ± 15</td>
</tr>
<tr>
<td>Sex, % male</td>
<td>53</td>
<td>67</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>27.4 ± 5.0</td>
<td>27.3 ± 4.0</td>
</tr>
<tr>
<td>Neck circumference, cm</td>
<td>37 ± 4.0</td>
<td>41.0 ± 4.0</td>
</tr>
<tr>
<td>Sleep efficiency, %</td>
<td>74.3 ± 15.0</td>
<td>79.7 ± 20.7</td>
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<tr>
<td>Light sleep (stages 1–2)</td>
<td>65.6 ± 11.5</td>
<td>69.8 ± 10.9</td>
</tr>
<tr>
<td>Delta-wave sleep (stages 3–4)</td>
<td>21.2 ± 10.9</td>
<td>13.6 ± 7.9</td>
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<tr>
<td>Rapid eye movement sleep</td>
<td>13.1 ± 7.8</td>
<td>16.5 ± 10.4</td>
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*Data expressed as mean ± SD unless otherwise indicated. t p < 0.005.
Changes in the breathing route were readily identified. The most frequent phenomenon observed was mouth expiration (ME), detected as a complete flattening of the expiratory branch of the flow signal (Fig 2, 5). As seen in Table 2, > 40% of the subjects showed periods of ME during the full-night polysomnography. The number of ME periods did not usually exceed 20/night, and their length varied from < 1 min to nearly 1 h. ME was present for as much as 35% of total sleep time, but in general it was closer to 5%.

![Figure 1](http://publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21958/)

**Figure 1.** Three minutes of full-night polysomnography recording. Note the low amplitude of the nasal prong signal, probably due to the heavy snoring that provokes a nonoptimal flow signal. In this situation, the thermistor signal is better than the nasal prong signal.

![Figure 2](http://publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21958/)

**Figure 2.** Summary of the most relevant flow-related phenomena detected by nasal prongs. The individual figures correspond to a 60-s nasal prongs flow recording, in which the inspiration is always the upper part of the flow signal.
Apneic and Nonapneic Respiratory Events Detection

Table 3 shows the AHI and the number of the respiratory events scored with thermistor and nasal prongs in the group of subjects from the general population and from subjects with suspected SAHS. In both groups, the number of obstructive events (apneas plus nonapneic respiratory events) was higher with the nasal prongs. Accordingly, the AHI by nasal prongs was significantly increased compared to thermistor (p < 0.05). As the number of mixed and central apneas was similar, the difference was related to the obstructive apneas and the nonapneic obstructive events. Furthermore, we have found that nasal prong catalogued nonapneic respiratory events by thermistor as obstructive apneas (Fig 6). In this situation, nasal prongs failed to detect airflow through the mouth that is detected by thermistor and, accordingly, classified incorrectly nonapneic respiratory events as apneas.

The relationship between the two different scorings showed a systematic bias that could be observed in the Bland and Altman agreement analysis (Fig 7). For the whole group, the AHI was almost always under the identity line, reflecting an underrecognition of global obstructive events by the thermistor. The AHI mean difference was −8, and the limits of the agreement were ±14.5. The agreement analysis was the same if we individually evaluated the two groups of study. Using as a cutoff point to define abnormality of AHI ≥10 (according to conventional criteria based on thermistor), 6 of 27 subjects (thermistor) and 8 of 27 subjects (nasal prongs) were considered as abnormal.

![Figure 3. The last 3 min of a prolonged period of inspiratory flow limitation recorded by the nasal prongs ending with an arousal (squared mark in the EEG signal plus increase in EMG activity) and followed by a normal nasal prong morphology. Inspiratory snoring is also detected.](http://publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21958/)
mistor AHI, 6 ± 1.6; range, 4 to 8) were classified as having SAHS by nasal prongs (nasal prong AHI, 21 ± 5.5; range, 16 to 31). The opposite situation (SAHS patient detected by thermistor with a negative result by nasal prongs) was not observed.

**Discussion**

Flow measured through nasal prongs was easily implemented in full-night studies and provided technically optimal recordings in most cases. None of them showed an uninterpretable nasal prong trace, and only in a small number of sleep studies were there some difficulties in nasal prong scoring. In addition, nasal prongs allowed us to obtain further information on flow-related events that were not identified with the conventional thermistor signal: snoring, prolonged and short periods of inspiratory flow limitation, and changes in the breathing route, especially ME.

![Figure 4](http://publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21958/)

**Figure 4.** Three minutes of polysomnographic recording showing nonapneic respiratory events detected by nasal prongs and unrecognized by the thermistor. Note the short period of inspiratory flow-limited breaths followed by a rounded flow-contour morphology associated with an EEG arousal (squared mark in the EEG signal plus increase in EMG activity).

![Figure 5](http://publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21958/)

**Figure 5.** Transition from nasal breathing to ME in the nasal prong flow signal. At the beginning of the ME episode, expiratory snoring is also detected. The thermistor signal also decreased its amplitude due to the isolated reception of the oral flow.
As expected, nasal prongs had a higher detection rate of respiratory events (apneas and nonapneic respiratory events) compared to thermistor. This increase of nasal prong sensitivity was evident in both SAHS patients and general population subjects. Our group\textsuperscript{10} had previously addressed this issue in a 2-h period of conventional polysomnography, and Norman et al\textsuperscript{5} demonstrated in full-night studies that nasal prongs detected 98\% of events defined by thermistor in SAHS patients and 83\% in patients with upper-airway resistance syndrome (UARS). In the study by Norman et al\textsuperscript{5} the thermistor missed a substantial number of events and the higher sensitivity of nasal prongs was especially evident in mild-severity disease. Other authors\textsuperscript{11} have recently published data in the same direction, showing this increase of sensitivity. A question arises on whether this increase in sensitivity is due to real abnormal respiratory events or alternatively corresponds to an overestimation of “normal” physiologic respiratory features. It is our belief that the close association with an EEG arousal or to a decrease \( \text{Sao}_2 \), which is implicit in our nonapneic respiratory event definition, is in support of its pathophysiologic significance.

An interesting issue observed in our study was the detection of ME. This phenomenon was usually detected as an amputation of the expiratory branch of the nasal prong flow signal (Fig 5). This observation was frequent in subjects from the general population (40\%) and even more common in SAHS patients (70\%), but the duration and number of episodes of ME was rather variable. However, the

### Table 3—Apneas, Nonapneic Respiratory Events, and AHI Detected by Thermistor and Nasal Prongs in the Two Populations Studied\textsuperscript{a}

<table>
<thead>
<tr>
<th>Variables</th>
<th>General Population</th>
<th>Suspected SAHS Subjects</th>
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<tbody>
<tr>
<td></td>
<td>Thermistor</td>
<td>Nasal Prongs</td>
</tr>
<tr>
<td>AHI</td>
<td>11.2 ± 17.0</td>
<td>17.8 ± 21.1\dagger</td>
</tr>
<tr>
<td>Total No. of apneas</td>
<td>17.4 ± 37.2</td>
<td>35.6 ± 59.6\dagger</td>
</tr>
<tr>
<td>Obstructive</td>
<td>11.9 ± 25.6</td>
<td>32.3 ± 52.3\dagger</td>
</tr>
<tr>
<td>Mixed</td>
<td>1.8 ± 5.0</td>
<td>2.6 ± 8.3</td>
</tr>
<tr>
<td>Central</td>
<td>3.6 ± 8.8</td>
<td>3.3 ± 4.4</td>
</tr>
<tr>
<td>Total No. of nonapneic respiratory events</td>
<td>36.7 ± 52.7</td>
<td>50.6 ± 49.2\dagger</td>
</tr>
<tr>
<td>Inspiratory flow-limitation events</td>
<td>ND</td>
<td>16.6 ± 24.0</td>
</tr>
</tbody>
</table>

*Data expressed as mean ± SD; ND = nondetectable.
\( \dagger p < 0.001. \)
\( \dagger p < 0.05. \)

Figure 6. Misclassification of nonapneic events in the thermistor signal as apneas detected by nasal prongs during 2 min of recording.
pathophysiologic significance of mouth breathing or ME during sleep is actually not well known. In our experience, some patients showed short episodes of ME that can finish with an EEG arousal. Furthermore, it is known that mouth breathing or mouth opening can contribute to the occurrence of respiratory events or increase the upper-airway collapsibility during sleep.16,17

Complete oral breathing could be a limitation in nasal prong flow detection, appearing as apneas. However, it is infrequent for normal subjects to breathe exclusively through the mouth during sleep; in SAHS patients, it occurs in < 5% of the recordings.5,18 In this study, an unexpected finding was the higher number of obstructive apneas detected by nasal prongs, which could be explained in part by the presence to some extent of mouth breathing that was detected by the thermistor. In our experience, these incorrectly scored apneas usually follow a cyclical pattern in association with an EEG arousal or oxygen desaturation, suggesting that the amount of mouth breathing is not enough to maintain an adequate level of ventilation. This misclassification of nonapneic event as apneas by nasal prongs does not preclude its scoring as an abnormal event. Moreover, Sériès and Mercier11 found an increase in the inspiratory effort (measured by esophageal balloon) in these kind of events similar to that found in typical respiratory events.

An additional potential problem of nasal prongs is the loss of signal due to obstruction by secretions or by displacement from the nares. These type of artifacts could be misidentified as true respiratory events, but in our routine clinical use of nasal prongs, the former situation has never been seen; in case of nasal prong movement from the nares, the signal would not follow the characteristic pattern of apneas or nonapneic respiratory events. In our study, only three subjects had a brief loss of signal in some part of the recording, but never > 10 min. However, if the sleep study is performed in the laboratory, the loss of signal can be easily recognized and corrected by the technician.

The pressure at the nares (nasal prongs) is the most sensitive, nonperturbing measure of flow rate and flow limitation in a noninvasive assessment of flow limitation during sleep with different methods.9 The detection of a plateau on the nasal prong inspiratory flow morphology, as has been reported in continuous positive airway pressure titration studies,7,8 indicates an increase in airway resistance with a nonlinear flow/pressure relationship characteristic of flow limitation.15 In our study, > 30% of the nasal prong nonapneic respiratory events were characterized by a limited inspiratory flow ending with an arousal or a 3% desaturation (Fig 4).

Figure 7. Plot of the Bland and Altman14 agreement analysis. On the x axis are represented the mean values of the AHI between thermistor and nasal prongs (NP), while their difference (thermistor minus nasal prongs) are represented on the y axis. The dotted lines are the mean difference and the 95% confidence interval. The continuous trace represents the identity line. There is a systematic underrecognition of obstructive events by the thermistor scoring.
than in the general population (39.1 ± 32.5 vs 16.6 ± 24). Similarly, Hosselet et al.15 found a greater percentage of flow-limited breaths in the group of symptomatic patients than in the asymptomatic group. It should be noted that the nasal prong nonapneic respiratory events with inspiratory flow limitation could represent the kind of events seen in patients with UARS. Thus, the nasal prong approach could be the appropriate setting for UARS.16

A further interesting observation with nasal prongs is the detection of prolonged periods (>2 min) of limited inspiratory flow occasionally finishing with an EEG arousal (Fig 3). This finding is more frequent in δ-wave sleep. In most of the subjects, these periods lasted for an average duration of 5 to 11 min, but with a broad range that could account, in some cases, for 70% of the total sleep time. Possibly, these periods could correspond to increases in upper-airway resistance not reaching the arousal threshold, and with ventilation maintained into acceptable limits without oxygen desaturation. The pathophysiologic significance of these prolonged periods of inspiratory flow limitation has not been established, and further investigation is required. However, the increases in the negative intrathoracic pressure presumably associated with these periods could have cardiovascular consequences, especially in the subgroup of patients with compromised left ventricular function.20,21

In summary, the use of nasal prongs is a simple, easily implemented method to detect and score airflow abnormalities during sleep, and is more sensitive than thermistors currently in use. The use of nasal prongs to assess airflow in sleep studies identifies apneas and nonapneic respiratory events. Among nonapneic respiratory events, nasal prongs may distinguish two subtypes: (1) short periods of flow limitation with a clear reduction in ventilation followed by an arousal and/or desaturation (corresponding to classical hypopneas), and (2) short periods of flow limitation without a clear change in ventilation followed by an arousal, which probably identifies the UARS. In addition, the other flow-related events recognized by nasal prongs, such as prolonged periods of inspiratory flow limitation and ME, need further investigation to establish their clinical significance. The presence of mouth breathing is not a significant drawback in the analysis of nasal prongs, and the observation of additional flow-related events can improve our understanding of increased airway resistance and sleep-disordered breathing.

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