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Editorial

How to use the nasal pressure in clinical practice

Assessment of breathing flow is crucial to the evaluation of respiratory sleep disturbances [1]. To avoid a cumbersome pneumotachograph that requires the patient to wear a mask, the use of thermistors/thermocouples placed at the mouth/nostrils opening is the most widespread procedure to monitor flow disturbances in routine sleep studies. Airflow detection with these thermal sensors is based on recording the temperature change in the air flowing through the mouth/nostrils during inspiration (room temperature) and expiration (body temperature). Thermistors are particularly suitable for detecting apneas, since a complete cessation of breathing flow results in a constant temperature signal. However, given the non-linear relationship between breathing flow and the thermistor signal and given the slow response time of these thermal sensors, thermistors are not suitable for quantitative assessment of the changes in flow amplitude during hypopneas or the detection of abnormal flow pattern during flow limitation [2,3].

Another simple method to assess breathing flow is the use of nasal prongs connected to a pressure transducer [2]. A number of studies published in recent years yield evidence that the nasal pressure measure provides a reliable assessment of airflow disturbances during sleep [4–9]. Since the recorded signal of the measurement—the pressure induced by the airflow turbulences around the nasal prongs—is the difference between the flow-induced pressure in the sensor and the atmospheric pressure, nasal prongs act like a pneumotachograph. In accordance with airflow dynamics, nasal prongs have the important advantage of an excellent response time, as has been verified by several authors [4–6]. Furthermore, the relationship between the pressure signal recorded at the nasal prongs and actual breathing flow is quadratic [4]. Compared with thermistors/thermocouples [3], nasal prongs allow a more accurate assessment of dynamic upper airway flow disturbances such as hypopneas, inspiratory flow limitation and RERAS [1]. Although nasal prongs also have some limitations (e.g. mouth breathing is not detected), their use as an alternative to thermal devices has progressively increased. However, given the limited experience available to date, care should be taken to avoid misinterpretation of the recorded signal [10]. Moreover, the comparison of the results obtained with nasal prongs and with thermistors/thermocouples raises some clinical questions that are open to discussion.

The setting to assess breathing flow with nasal prongs is simple. Any conventional prongs used for oxygen therapy are suitable. It should be mentioned, however, that some types of nasal prongs may induce an increase in nasal resistance in patients with nare narrowness and/or deviated nasal septum [11]. Accordingly, nasal prongs with an optimized design for this specific application are advisable. As the pressure to be recorded is of the order of magnitude of 1 cm H_2O, and as the frequency band of the signal is that of spontaneous breathing, any conventional pressure transducer for respiratory medicine can be connected to the nasal prongs. To make full use of the excellent response time of nasal prongs, the transducer should be connected to a DC channel with a low-pass filter with a cutoff frequency greater than 10 Hz. The sampling rate should be high enough (e.g. greater than 30 Hz) to detect the details of the flow signal during normal and obstructive events, particularly flow limitation. The offset of the transducer signal should be adjusted so that zero signal corresponds to no flow. The gain should be adjusted to obtain a full-scale signal when the patient hyperventilates. In this regard, it is important to notice that although the relationship between actual flow and nasal pressure is quadratic, the scale factor in this relationship critically depends on geometric characteristics such as the position of the prongs inside the nares and the size of the patient's nares [4,6,7]. Given that the calibration scale factor depends on the patient, and that this may vary throughout the night as the position of the prongs change, it is not possible to reliably calibrate the nasal prongs signal in flow units (e.g. liters per second), preventing their use to measure minute ventilation during the night. The impossibility of a reliable calibration of nasal prongs in absolute flow units is of minor relevance when monitoring sleep disturbances since the main aim is to detect changes in the breathing pattern. Taking into account that the normal breathing pattern is the control signal for the sleep events, and that modification of the calibration constant is expected to be negligible in the short term, reliable assessment of flow disturbances can be achieved by comparison between the signal in a given event and that of the preceding normal cycles. Improvement in the quantification of the amplitude of hypopneas and in the severity of flow limitation is

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possible by linearizing the signal to compensate for the quadratic pressure-flow relationship [5,6]. This procedure can be achieved by computing the square root of the pressure signal or by adequately modifying the threshold in signal amplitude reduction to define hypopneas [5,6]. Better quantification of flow assessment will facilitate both the detection of inspiratory flow limitation and the study of its clinical impact [1,10].

The greatest potential source of misinterpretation of the signal is detection of false positive disturbed events [9]. False apneas or hypopneas could be the result of three main factors: mouth breathing, occlusion of the prongs by secretions and displacement of the nasal prongs outside the nares. The occurrence of the last two factors is rare and, more importantly, easily detected because they affect the normal and the disturbed flow signals in a similar manner. Mouth breathing is the most relevant problem. Normal subjects infrequently breathe continuously through the mouth during sleep, and the phenomenon occurs in less than 5% of recordings for SAHS patients [9,12]. By contrast, mouth expiration is frequent in certain sleep phases of healthy subjects (40%) and even more common in SAHS patients (70%), although the duration and number of episodes of mouth expiration is variable [9].

The use of bucal or oro-nasal thermistors in addition to nasal prongs may help to avoid most of the potential misinterpretation of the signals. Should the patient breath mainly through the mouth, the signal of nasal prongs would indicate apnea but the oro-nasal thermistor signal would record the breathing flow. As regards the combined use of nasal prongs and thermistors, in this issue of the journal Teichtahl et al. [13] evaluate the clinical usefulness of nasal prongs and oro-nasal thermal sensor recordings, alone and in combination, for scoring respiratory events during routine diagnostic polysomnography. Like other published reports [2,5–9], this paper emphasizes the usefulness of nasal prongs. The main findings here indicate that, with an apnea–hypopnea index (AHI) below 50 event/h, nasal prongs plus thermistor appear to detect respiratory events better than nasal prongs or thermistor alone, and that nasal prongs detected more events than thermistor if only one airflow signal was used. Given that thermistors and nasal prongs are equally well suited to detecting apneas but not hypopneas, the absence of differences when using both devices in severe sleep apnea patients (AHI $>$ 50 events/h) could be attributed to the fact that these patients probably experienced a greater number of apneas than hypopneas. This paper and other published works addressing this issue highlight the importance of improving the assessment of breathing flow in routine studies. To this end, it should be stressed that experience with the different techniques available (thermistors, nasal prongs as well as thoracoabdominal motion bands) is essential [1]. Improved quantification of sleep events will be useful to standardize sleep studies and to reduce the variability in the assessment of respiratory sleep disorders [14].

As nasal prongs are progressively used, the new data obtained on respiratory flow disturbances raise some controversial issues. First, the clear identification of mouth breathing or mouth expiration during sleep poses the question of its pathophysiological significance. In this regard, it is well known that mouth breathing or mouth opening can play a role in the occurrence of respiratory events or can increase upper airway resistance during sleep, potentially increasing the number of respiratory events. Second, the use of nasal prongs has made possible the detection of prolonged periods ($>$2 min) of inspiratory flow limitation not always ending with an EEG arousal. This finding is more frequent during delta sleep, even in healthy subjects. In most subjects the average duration of the periods was 5–10 min, but with a broad range that could account for 70% of the total sleep time in some cases [9]. These periods could correspond to increases in upper airway resistance that did not reach the arousal threshold. The pathophysiological significance of these prolonged periods of inspiratory flow limitation has not been corroborated and further investigation is warranted. However, increases in the negative intrathoracic pressure presumably associated with these periods could have cardiovascular consequences [15,16], especially in the subgroup of patients with a compromised left ventricular function and other problems such as hypoventilation [17–19]. A final question arising from the use of nasal prongs is whether the higher sensitivity of this device shows an increase in actual abnormal respiratory events or simply overestimates normal physiological respiratory features. The close association with an EEG arousal or a decrease in Sa,O_2, implicit in the non-apneic respiratory event definition, supports their pathophysiological significance. Therefore, the limit defining the number of normal respiratory events per hour should probably be modified.

In conclusion, the published data available strongly suggest that nasal prongs, alone or combined with oral thermistor, is the best system to assess respiratory flow disturbances during sleep in routine studies.

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