

Combined Effects of a Nasal Dilator and Nasal Prongs on Nasal Airflow Resistance*

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Study objectives: Nasal prongs (NPs), when used to assess nasal flow, can result in dramatic increases in nasal airflow resistance (NR). The aim of this study was to investigate whether the NP-induced increases in NR could be corrected by the simultaneous use of an internal nasal dilator (ND).

Design: NR was estimated by posterior rhinomanometry, in the basal state (NRb), and while breathing with NP (NRp), with ND (NRd), and with both ND and NP (NRd + p).

Participants: The study was performed in 15 healthy subjects.

Measurements and results: NR (mean NRb [\pm SEM], 2.5 ± 0.4 cm H₂O/L/s) significantly decreased with ND (NRd = 1.4 ± 0.2 cm H₂O/L/s; $p < 0.001$) and significantly increased with NP (NRp = 3.8 ± 0.8 cm H₂O/L/s; $p < 0.001$). A significant logarithmic relationship was found between NRd and NRb ($r^2 = 0.95$; $p < 0.0001$), and a significant exponential relationship was found between NRp and NRb ($r^2 = 0.99$; $p < 0.0001$). While breathing with both ND and NP, NRd + p was significantly lower than NRb (1.9 ± 1.4 cm H₂O/L/s; $p < 0.02$).

Conclusions: Our results demonstrate that the ND tends to slightly overcorrect the NP-induced increase in NR and suggest that, in view of the possible effects of NPs on upper airway resistance, the combination of both devices might be used for nasal airflow monitoring during nocturnal polysomnography in patients presenting with highly resistive nares.

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Key words: nasal airflow resistance; nasal dilator; nasal prongs; posterior rhinomanometry

Abbreviations: ND = nasal dilator; NP = nasal prong; NR = nasal airflow resistance; NRb = nasal airflow resistance in the basal state; NRd = nasal airflow resistance with nasal dilator; NRd + p = nasal airflow resistance with nasal dilator and nasal prongs; NRp = nasal airflow resistance with nasal prongs; OSAS = obstructive sleep apnea syndrome; Ptn = transnasal pressure; \dot{V} = nasal flow

The diagnosis of obstructive sleep apnea syndrome (OSAS) is established on the basis of nocturnal polysomnographic studies during which thermistors have been routinely used for oronasal airflow monitoring. Recommendations for measurement techniques have been published,¹ in which the use of qualitative sensors for air flow estimation is discouraged. Airflow measured by a pneumotachograph remains the reference signal for the detection of obstructive sleep respiratory events, including inspiratory flow limitation, which is a predictive index for upper airway narrowing.^{2,3} Nasal pressure mea-

sured via nasal prongs (NPs) connected to a pressure transducer is now recommended as an alternative, since it has been demonstrated to provide a semi-quantitative estimate of nasal airflow⁴ and to allow a fair detection of flow limitation.^{5,6}

However, a recent study⁷ has shown that NPs could dramatically increase nasal airflow resistance (NR) in certain patients presenting with high NR values due to nare narrowness and/or deviated nasal septum. Such increases in NR, which result in additional increases in upper airway resistance,⁸ might promote the occurrence of sleep respiratory events associated with brief arousals.⁹ The present study was therefore designed to determine whether the NP-induced increase in NR could be counterbalanced by the effect of a mechanical internal nasal dilator (ND) that previously had been demonstrated to significantly decrease NR in healthy subjects.^{10,11} For this purpose, we evaluated the isolated and

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combined effects of the ND and NPs on NR assessed by posterior rhinomanometry.

MATERIALS AND METHODS

Subjects

The study was performed in a group of 15 asymptomatic healthy volunteers (3 men and 12 women), aged 22 to 54 years, who had no upper or lower respiratory complaints. Seven subjects had normal nasal morphology, and eight subjects had nasal anatomic abnormalities such as nare narrowness and/or deviated nasal septum.

Nasal Resistance Measurement

NR was measured by posterior rhinomanometry. The subjects breathed quietly through a nasal mask, with the mouth occluded by a closed mouthpiece in which a 3-mm internal diameter catheter was inserted to measure pharyngeal pressure. Transnasal pressure (Ptn) was measured by a differential pressure transducer (model DP 45 [± 14 cm H₂O]; Validyne; Northridge, CA) with one port connected to the nasal mask and the other to the catheter. Nasal flow (\dot{V}) was sensed by a pneumotachograph (No. 1; Fleisch; Lausanne, Switzerland) connected to a differential pressure transducer (model DR 45 [45 ± 2.25 cm H₂O]). Pressure and flow signals were sampled at 32 Hz by an A-D converter. To determine the nonlinear nasal inspiratory airflow resistance, Ptn and \dot{V} inspiratory data were analyzed by linear regression analysis of Ptn over $\dot{V} |\dot{V}|$, according to the following equation:

$$P_{tn} = K\dot{V} |\dot{V}| \quad (1)$$

where K is the slope of the regression line.

NR then was calculated at an airflow of 0.5 L/s, as $NR = 0.5 K$. Three to four consecutive measurements were performed within a 1-min period, and NR was taken as the average of the NR estimates corresponding to an r^2 value of $> 99\%$.

Experimental Protocol

In each subject, NR was measured under four conditions: (1) in the basal state (NRb); (2) while breathing with NPs (NRp; Pro-Tech; Woodinville, WA); (3) while breathing with a mechanical internal nasal dilator (NRd) (Nozovent; Prevancure; Sté Pouret, France), which consists of a plastic bar, each extremity of which ends in a tab to be placed inside each nostril; and (4) while breathing with both the mechanical dilator and the NPs (NRd + p). The order of the three latter conditions was randomly selected, and for each condition a 10-min stabilization period was observed prior to NR measurements.

NPs are normally held in place with side tubing over the ears. This tubing may induce air leaks when worn with a nasal mask. To avoid such leaks, the NP side tubing was shortened so that subsequently it could be placed inside the mask, and a thin strip was introduced into the tubing for fastening to the ears. The NPs are normally connected to a pressure transducer. The side tubing ends were sealed with silicone gel to reproduce this arrangement. The tips of the NPs were inserted into the nostrils. The two ends of the strip were passed over both ears and tied together under the chin to simulate the usual placement of the NPs. Then the nasal mask was positioned and was checked for a tight seal.

Statistical Analysis

Statistical analysis was performed using nonlinear regression analysis and nonparametric tests. NR values were compared by

the Friedman test (nonparametric analysis of variance) and the Wilcoxon signed rank sum test. A p value of < 0.05 was considered to be significant. Values are given as the mean \pm SEM, except when otherwise indicated.

RESULTS

Typical Ptn- \dot{V} curves that were obtained in a representative subject in the basal state and with the different devices are shown in Figure 1. In the basal state, NRb ranged from 0.8 to 6.5 cm H₂O/L/s, with a mean value of 2.5 ± 0.4 cm H₂O/L/s.

When breathing with the ND, NR significantly decreased (NRd = 1.4 ± 0.2 cm H₂O/L/s; $p < 0.001$) and was $61 \pm 4\%$ of its basal value. The intersubject variability was lower for NRd than for NRb (Fig 2), and in 12 of the 15 subjects NRd was < 2 cm H₂O/L/s (Fig 2). A significant logarithmic relationship was found between NRd and NRb ($r^2 = 0.87$; $p < 0.0001$) (Fig 3).

When breathing with the nasal prongs, NR significantly increased (NRp = 3.8 ± 0.8 cm H₂O/L/s; $p < 0.001$) and was $146 \pm 7\%$ of its basal value. A wide intersubject variability was observed for NRp (Fig 2), and a significant exponential relationship was found between NRp and NRb ($r^2 = 0.99$; $p < 0.0001$) (Fig 4).

When breathing with both the ND and the prongs, NR was significantly lower than NRb (NRd + p = 1.9 ± 1.4 cm H₂O/L/s; $p < 0.02$) and was $78 \pm 6\%$ of its basal value. However, individual data analysis showed that, in one subject, the effect of the ND undercorrected the effect of the nasal prongs (Fig 2).

The difference NRb - NRp + d ($22 \pm 6\%$ of

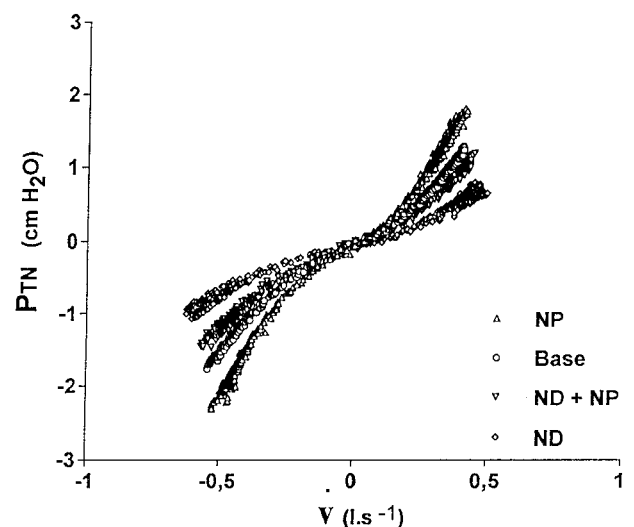


FIGURE 1. Illustrative Ptn- \dot{V} curves obtained in a representative subject in the basal state (Base), with the internal ND, with the NPs, and with the combination of ND and NPs (ND + NP).

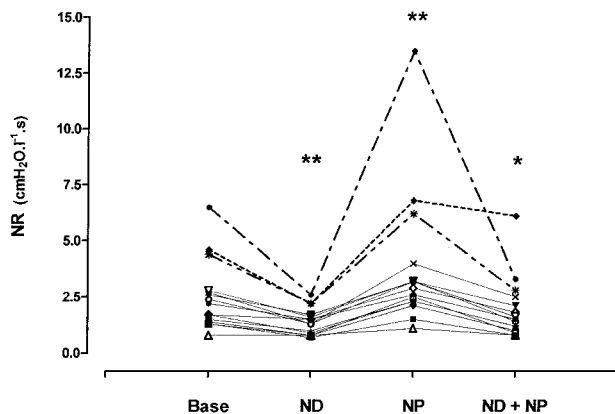


FIGURE 2. Individual values for NR observed in the 15 subjects in the basal state (Base), with the internal ND, with NPs, and with the combination of the ND and the NPs. See the legend for Figure 1 for any abbreviations not used in the text. * = significance at $p < 0.02$. ** = significance at $p < 0.001$.

NRb) was found to be significantly lower than the differences NRb – NRd ($39 \pm 4\%$ of NRb; $p < 0.01$) on the one hand, and NRp – NRb ($46 \pm 7\%$ of NRb; $p < 0.05$) on the other hand.

DISCUSSION

NPs have been demonstrated to be a convenient device for ventilation monitoring during polysomnographic studies, because nasal pressure provides a semiquantitative evaluation of airflow and, thereby, allows the detection of sleep respiratory events, including inspiratory flow limitation.^{12,13} However, a recent study⁷ demonstrated that NPs could induce dramatic increases in NR in certain patients who presented with high NRb values. This suggests that the use of NPs might result in an erroneous apnea/hypopnea index during the diagnosis night. The present study therefore was initiated to investigate whether the NP-induced increases in NR could be corrected by the effect of an ND.

Posterior rhinomanometry allows direct NR measurement during normal tidal breathing. As NR is flow dependent, a choice has to be made concerning the flow or pressure level at which it is calculated. In the present study, NR was calculated at the 0.5-L/s flow level because this NR index has proved suitable in previous studies for assessing the effects of nasal mechanical dilators^{10,11} and NPs⁷ on NR. Furthermore, the main advantage of assessing NR at a constant flow level is that it ensures that any change in NR only can be attributed to a modification of the nasal space available for flow. To avoid any influence of diurnal variation on nasal resistance,¹⁴ all our subjects were studied at the same time of day.

The Pro-Tech NPs that were originally designed to measure the CO₂ concentration in the expired gas are now widely used with most of the commercially available polysomnographic recording devices. They are characterized by short and narrow soft tips, which limit the reduction of the nasal cross-sectional area available for airflow. Previously, their use has been demonstrated to result in lower increases in NR than most of the conventional O₂ NPs.⁷ These are the reasons why they were selected for this study. Similarly, the internal ND was chosen because it has been proved to be more efficient in reducing NR than an external ND.¹⁰

The wide range of our NRb values (0.8 to 6.5 cm H₂O/L/s) was due to the great diversity of our subjects' nose morphology and nasal anatomy. This allowed us to investigate the potential influence of the different nasal devices on a wide range of NRb values. It is worth noting that 20% of our 15 healthy subjects had NRb values of > 4 cm H₂O/L/s and that a higher percentage would probably be observed in an OSAS population.

The ND resulted in a significant decrease in NR (Fig 2), which was in the range of those previously observed with the same device.^{10,11} The highly significant logarithmic relationship found between NRd and NRb demonstrates that the dilator effect on NR is all the more marked as the subject's NRb increases (Fig 4) (*ie*, that the expanding force of the ND and the resulting increase in the nasal cross-sectional area are all the more pronounced as the nares are narrow).

In this connection, it is worth noting that when using NPs for airflow monitoring, the physiologist faces a dilemma, since the higher the NRp value, the more accurate the airflow assessment. Nevertheless,

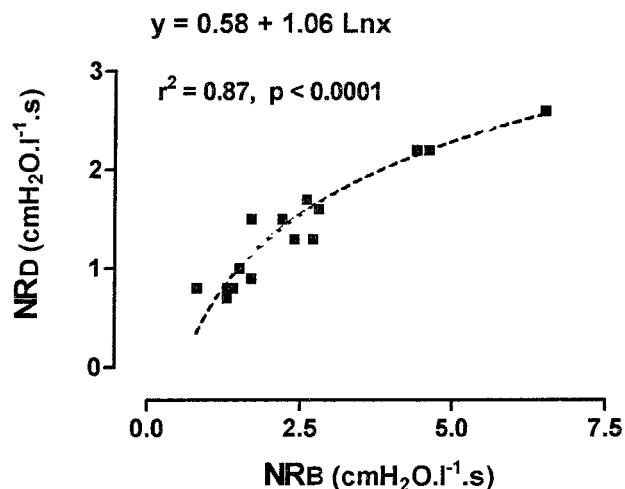


FIGURE 3. NRd plotted in relation to NRb. Squares = data from individual subjects. Dashed curve = logarithmic regression curve.

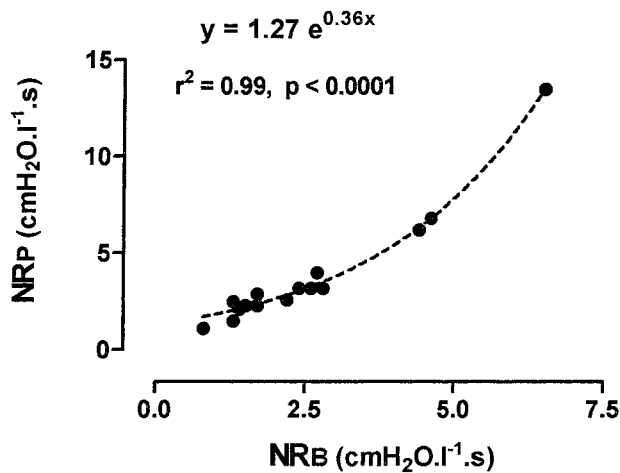


FIGURE 4. NRp plotted in relation to NRb. Circles = data from individual subjects. Dashed curve = exponential regression curve.

as discussed below, it does not seem reasonable to give preference to measure accuracy at the risk of disturbing the patient's ventilation and sleep, biasing the polysomnographic study.

The combination of the ND and NPs resulted in NR values significantly lower than basal values, which illustrates the tendency of the ND to overcorrect the effects of NPs. Interestingly, this overcorrection could be predicted by both the NRd-NRb logarithmic relationship and the NRp-NRb exponential relationship (see "Appendix"). In fact, the ND undercorrected the effects of NPs on NR in only one subject (symbolized by the diamond and the dashed line in Fig 2). This discrepant result might be explained by the nasal morphology of this subject, in whom nare shortness and narrowing were associated with a deviated nasal septum. One may indeed assume that NPs resulted in the total occlusion of one nare, limiting the effects of the ND to the contralateral nare.

As previously mentioned, in subjects with low NRb values, NP induced relatively small increases in NR, and in those subjects the simultaneous use of a ND appears to be unnecessary. On the contrary, in subjects with high NRb values, the combination of NPs and dilator might be recommended. It has indeed been demonstrated that external resistive loads result in increases in upper airway resistance of about 75% of the load, during non-rapid eye movement sleep in healthy men.⁸ One can therefore calculate that the total increase in upper airway resistance resulting from the use of NPs during sleep could exceed 12 cm H₂O/L/s in the subject with the highest NRb values. Now, it has been reported that although nasal obstruction may not be a main factor, it can be a cofactor of OSAS during sleep.¹⁵ Conse-

quently, as NRd + p was found to be closer to NRb than NRp, one may assume that the occurrence of obstructive sleep respiratory events should be less influenced by the decrease in NR induced by the use of both devices than by the increase in NR induced by NPs. However, in subjects whose NRb is unknown, the combination of NPs and dilator might be considered, since, as mentioned above, NRd + p is closer to NRb than NRp. Furthermore, the fact that NRd + p was found to be lower than NRb would not affect the occurrence of obstructive sleep respiratory events in subjects with low NRb values. Indeed, the decrease in NR presently observed with the combination of both devices was lower than the one observed with the ND alone, and no effect of the internal ND device on the number of obstructive respiratory events during sleep has been reported in OSAS patients with normal noses, despite a significant decrease in nasal airflow resistance.¹⁶ Thus, the simultaneous use of both devices should be preferred to the use of NPs alone in patients whose NR values are unknown. It is worth noting that, contrary to what could be supposed, NPs and ND are easily placed together in small and/or narrow nares. Besides, most subjects reported a subjective increase in ease of breathing with both devices by comparison with NPs only, which was indeed objectified by the corresponding decrease in NR.

In conclusion, our results demonstrate that the ND tends to slightly overcorrect the NP-induced increase in NR. However, in view of the possible side effects of NPs on upper airway resistance and the easy use of the ND, the combination of both devices might be recommended for nasal airflow monitoring during polysomnographic studies in patients whose basal NR value is either unknown or abnormally high.

APPENDIX

It has been found that NRd could be predicted from NRb by the logarithmic relationship

$$\text{NRd} = 1.06 \ln \text{NRb} + 0.58 \quad (\text{A1})$$

and that NRp could be predicted from NRb by the exponential relationship

$$\text{NRp} = 1.27 e^{0.36 \text{NRb}} \quad (\text{A2})$$

Consequently, NRd + p can be calculated from equation A1, taking NRp as the new NR basal value as:

$$\text{NRd} + p = 1.06 \ln \text{NRp} + 0.58 \quad (\text{A3})$$

On substituting NRp from equation A2 into equation A3, NRd + p can be expressed as

$$\text{NRd} + p = 1.06 \ln (1.27 e^{0.36 \text{NRb}}) + 0.58 \quad (\text{A4})$$

thereby giving

$$\text{NRd} + p = 0.38 \text{NRb} + 0.83 \quad (\text{A5})$$

Thus, equation 5 allows one to predict that the NRd + p value should be lower than the NRb value for NRb values > 1.3 cm H₂O/L/s. All our subjects had NRb values > 1.3 cm H₂O/L/s, except one whose NRb was 0.8 cm H₂O/L/s. In this subject, no effect of the dilator could be observed on NR, and NRd + p was found to be equal to NRb, probably because changes in such dramatically low NR values are lost in the NR physiologic variability.

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