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The Clinical Value of Peak Nasal Inspiratory Flow, Peak Oral Inspiratory Flow, and the Nasal Patency Index

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Objectives/Hypothesis: The aim of this study was to ascertain the most reliable objective measurement for the assessment of nasal patency by investigating the relationship between peak nasal inspiratory flow, peak oral inspiratory flow, and the nasal patency index in relation to the patient's subjective perception regarding nasal obstruction.

Study Design: Prospective cohort study.

Methods: This study included 131 volunteers of both genders, aged 18 years or older, with or without nasal symptoms, who were able to give informed consent, completed the study protocol, and could speak and write Dutch fluently. Peak nasal inspiratory flow and peak oral inspiratory flow were performed and nasal patency index was computed. The results were evaluated and compared with the subjective perception of nasal passage, using the validated Nasal Obstruction Symptom Evaluation scale and visual analog scale for nasal passage.

Results: Our study showed that peak nasal inspiratory flow, nasal patency index and nasal patency visual analog scale correlate with the Nasal Obstruction Symptom Evaluation scale in contrast to peak oral inspiratory flow. Peak nasal inspiratory flow and nasal patency index also showed significant association with the Nasal Obstruction Symptom Evaluation scale after adjustment for confounders.

Conclusions: Peak nasal inspiratory flow is the most reliable method for the assessment of nasal patency. It is quick, inexpensive, and easy to perform, and correlates significantly with the subjective feeling of nasal obstruction. There is no clinical need to measure peak oral inspiratory flow or to calculate the nasal patency index in the evaluation of nasal patency.

Key Words: Peak nasal inspiratory flow, peak oral inspiratory flow, nasal patency index, nasal obstruction, nasal airflow, pulmonary function, objective measurements, subjective measurements.

Level of Evidence: 4

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INTRODUCTION

Nasal obstruction, or impaired nasal breathing, is a common symptom that affects a large proportion of the population. Over the years, many articles have been published reporting different methods of measuring nasal patency. Objective measurements include tests like acoustic rhinometry[1] and rhinomanometry.[2] However, the correlation between rhinomanometry and acoustic rhinometry and the individual subjective sensation of nasal patency remains controversial.[3] Among the subjective measurements, questionnaires like the Sino-Nasal Outcome Test (SNOT)[4] and the Nasal Obstruction Symptom Evaluation (NOSE) scale can be used. The SNOT questionnaire, is a valid outcome measure for patients with rhinosinusitis, whereas the NOSE scale is a disease-specific and validated health status instrument for use in patients with nasal obstruction.[5] Apart from questionnaires, a visual analog scale (VAS)[6] can be applied for the evaluation of nasal obstruction in patients with compromised nasal patency.

In search for an easy, inexpensive, and quick objective measurement for nasal airflow, peak nasal inspiratory flow (PNIF) has been reported as a candidate method in the literature.[7,8] Up to now, several studies have been performed to establish normal rate values and normative data for PNIF in different populations, for instance in healthy adults, adolescents, and children.[9–12] Some studies examined determinants of PNIF such as sex, height, age, or ethnicity, but there is a lack of consensus.[9,11] Controversy also exists regarding the correlation between PNIF and objective[13,14] and subjective nasal patency measurements.[8,15,16] Recent studies show highly significant associations between the subjective feeling of nasal obstruction and PNIF outcomes,[8,15] whereas older studies do not.[16,17]

Peak oral inspiratory flow (POIF) measures peak inspiratory flow like PNIF, but bypasses the nasal cavity

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and therefore nasal airway resistance. PNIF depends on nasal patency and pulmonary function.[18] To our knowledge, only a limited number of studies concerning nasal patency were performed using POIF and the nasal patency index (NPI).[19–23] The NPI (PNIF/POIF) is higher in cases where nasal resistance is low, and lower in patients with nasal breathing difficulties.

The aim of this study was to ascertain the most appropriate objective measurement in the evaluation of nasal patency by investigating the clinical value of PNIF, POIF, and the NPI using the NOSE scale and VAS for nasal passage (NP-VAS). In such a study, the use of the NOSE scale is preferred to the use of SNOT. The reason is that the first is a validated test designed for the evaluation of nasal patency, whereas the second is not specifically designed for this reason, and most of the questions that it contains are not related to nasal patency. Moreover, rhinomanometry and acoustic rhinometry, although very useful objective measurements of nasal patency, do not always correlate with the subjective feeling of the patient as well as validated tests like the NOSE scale. Because this study intended to investigate the clinical value of PNIF, POIF, and the NPI in relation to the patient's real experience about nasal patency, the use of the NOSE scale and the NP-VAS rather than rhinomanometry or acoustic rhinometry as baseline measurements was more suitable.

MATERIALS AND METHODS

Participants

This study was performed between November 2012 and January 2013 at a tertiary academic center in the Netherlands. Eligible subjects were adults aged 18 years or older and both male and female. The patients were referred to the ear, nose and throat (ENT) department for evaluation of nasal patency or for nonrhinologic symptoms. We also recruited students and members of the staff into the study. As a result, subjects with and without nasal complaints were recruited (N = 131). Exclusion criteria for the study included subjects younger than 18 years, inability to give informed consent, unwillingness to complete the study protocol, or lack of fluency in verbal and written Dutch. No participant was initially recruited in a control group. Our intention was not to distinguish normal from pathologic rates, but rather to monitor the fluctuation of the objective measurements on subjects with and without nasal complaints, in correlation to each other, as well as to the subjective individual assessment of nasal patency.

Subjective Score and Objective Measurements

Before participating in the study, a general medical and ENT history as well as information regarding age, height, weight, gender, and ethnicity were obtained from each individual.

Subjective symptoms in nasal obstruction were measured with the validated NOSE scale.[5] The NOSE scale is based on five questions, each rated on an ordinal scale from 0 to 4. The NOSE scale is scaled from 0 to 100 by multiplying the raw score by 5, with higher scores indicating more severe nasal obstruction. All patients also completed the NP-VAS. All subjects were asked to grade their present degree of nasal obstruction on a 100-mm line without a scale. The left side of the line indicated no complaints of nasal obstruction, whereas the right side of the line indicated very serious symptoms of nasal obstruction.

An In-Check Nasal portable handheld inspiratory flow meter was used for the measurement of both PNIF and POIF (Clement Clarke International Ltd., Harlow, UK). PNIF was measured using the mask, which was tightly fitted onto the face without altering the shape of the nose. To measure PNIF, every individual was tested while sitting and was encouraged to inhale as hard and as fast as possible through the mask while keeping the mouth closed. The same procedure was performed for the measurement of POIF, but the measured inhalation was performed through the oral part of the device keeping the nose tightly closed. For both measurements, the residual volume method was used. Therefore, the forced maximal inspiratory maneuver was initiated from the end of a maximal expiration. For each test, three satisfactory maximal inspirations with an interval of at least 30 seconds were obtained. All assessments were performed by two assessors (M.T., D.J.M.).

Statistical Analysis

All analyses were conducted using the SPSS (IBM, Armonk, NY) statistics program version 20 for Windows (Microsoft Corp., Redmond, WA). For all tests, P values $<.05$ were accepted as significant. Spearman rank correlation coefficients were calculated to document associations between PNIF, POIF, NPI, NOSE scale, and NP-VAS. To examine possible relationships between the measurements further, multivariable linear regression analyses were performed with the NOSE scale as the dependent and the other tests as the independent variables in separate models. Adjustments were made for potential confounders (age, gender, inhalation allergies [yes/no], previous nasal surgery [yes/no and type], nasal medication [yes/no and type], lung diseases [yes/no], lung medication [yes/no and type], smoking, height, and weight). Assumptions for linear regression were checked and not violated.

RESULTS

In total, 131 subjects were studied. The sample was 52% male (N = 68), 48% female (N = 63) and average age was 38.7 years (standard deviation [SD] = 13.9 years; range, 18–79 years; median, 40.0 years). The average height of the participants was 174.5 cm (SD = 10.1 cm; range, 151–202 cm; median, 175.0 cm), their average weight was 74.4 kg (SD = 14.7 kg; range, 50–120 kg; median, 73.0 kg), and their average BMI was 24.4 (SD = 4.2; range, 17.4–39.8; median, 23.3).

In terms of ethnic origin, 77.9% (N = 102) of the participants were Caucasians, 14.5% (N = 19) were from the Middle East, 3.8% (N = 5) were South Americans, 3.1% (N = 4) were Africans, and 0.8% (N = 1) were Asians.

Overall, 60.3% (N = 79) of the subjects had undergone nasal surgery in the past. More specifically, 21.4% (N = 28) had undergone septoplasty, 0.8% (N = 1) inferior turbinate reduction, and 2.3% (N = 3) the combination of the two above-mentioned procedures. Moreover, 16% (N = 21) had undergone rhinoplasty, whereas 20.6% (N = 27) had undergone functional endoscopic sinus surgery.

Of the participants, 24.4% (N = 32) reported the presence of inhalation allergy and 26.7% (N = 35) had to use a steroid nasal spray to control their symptoms of

TABLE I.
Mean Values, Median Values, SD, and Ranges of Measured Data.

Variable	Mean	Median	SD	Range
PNIF	115.3	110	10.1	10–200
POIF	281.4	280	62.2	150–370
NPI	0.42	0.40	0.14	0.04–0.88
NOSE	35.0	30.0	29.8	0–100
NP-VAS	38.1	38.2	29.9	0–100

NOSE = Nasal Obstruction Symptom Evaluation; NPI = nasal patency index; NP-VAS = nasal patency visual analog scale; PNIF = peak nasal inspiratory flow; POIF = peak oral inspiratory flow; SD = standard deviation.

nasal obstruction. With respect to the lower airways, 23.7% (N = 31) of the participants reported the presence of some kind of pulmonary disease, and consequently 16.8% (N = 22) had to use a corticosteroid inhaler, whereas 3.8% (N = 5) had to use a bronchodilator. Finally, 24.4% (N = 32) of the participants were smokers.

The measured mean values of PNIF, POIF, NPI, and NOSE scale are illustrated in Table I, along with median, SD, and range values. Subjects were divided into two groups depending on the scores that each individual obtained in both the NOSE scale and NP-VAS. Those who obtained a score $\leq$15 in the NOSE scale combined with a score $\leq$21 in the NP-VAS were regarded as nonsymptomatic, whereas all the rest were regarded as symptomatic.[24] As a result, 28% (N = 37) of the participants were normal and 72% (N = 194) of them were pathologic. Table II shows the mean values of the measurable data of all the tests used against the most important clinical and demographic characteristics of the population that was studied.

Spearman correlations were computed because the NOSE scale did not show a normal distribution. Table III shows the correlation coefficients between POIF, PNIF, NPI, the NOSE scale, and NP-VAS. POIF was only significantly correlated to PNIF. PNIF alternatively was significantly correlated to NPI, the NOSE scale, and NP-VAS. NPI showed significant correlations with the NOSE scale and NP-VAS; however, these correlations were not more significant compared to the results of PNIF (Fig. 1).

Possible relationships between the subjective and objective measurements were analyzed using multiple linear regression analysis with the NOSE scale as the dependent variable. PNIF, NPI, and NP-VAS were significantly associated with the NOSE scale, after adjustment for the confounders (PNIF: regression coefficient B = −0.29, 95% confidence interval [CI] = 95% [−0.42 to −0.16], $P < .01$; NPI: B = −72.12, 95% CI = −107.30 to −36.93, $P < .01$; and NP-VAS: B = 8.27, 95% CI = 7.28 to 9.26, $P < .01$). POIF, however, was not significantly associated with the NOSE scale (B = −0.05, 95% CI = −0.15 to 0.05, $P = .32$).

TABLE II.
Mean Values of Measured Data Against Clinical and Demographic Characteristics.

Characteristics	No.	PNIF	POIF	NPI	NOSE	NP-VAS
Status						
Normal	37	125.5	285.6	0.445	4.4	4.32
Pathologic	94	111.2	279.7	0.404	47.07	51.27
Sex						
Male	68	128.1*	304.4*	0.432	35.14	40.15
Female	63	101.4	256.6	0.399	34.92	35.71
Age group						
<40 years	68	122.4*	282.6	0.441*	33.23	36.03
>40 years	63	107.5	280.1	0.390	36.98	40.16
Ethnicity						
Caucasian	102	114.5	284.6	0.408	33.77	36.17
African	4	112.5	277.5	0.392	35.00	42.50
Asian	1	140.0	370.0	0.378	0.00	0.00
Middle East	19	111.6	268.4	0.424	45.79	48.95
South American	5	142.0	250.0	0.572	27.00	38.02
Nasal surgery						
Yes	79	113.1	279.6	0.415	37.65	37.08
No	52	118.5	284.0	0.417	31.05	39.42
Inhalation allergy						
Yes	32	112.5	273.3*	0.415	35.65	39.29
No	99	123.7	306.2	0.416	33.12	34.06
Lung problems						
Yes	31	111.6	276.1	0.378	44.67*	43.87
No	100	116.4	298.3	0.428	32.05	36.19
Smoking						
Yes	32	109.2	264.6	0.417	41.56	40.93
No	99	117.2	286.8	0.416	32.92	37.07
BMI group						
<23.3	65	113.1	276.1	0.4163	36.85	39.23
>23.3	66	117.3	286.6	0.416	33.26	36.81

*The difference is significant at the .05 level (two-tailed).
BMI = body mass index; NOSE = Nasal Obstruction Symptom Evaluation; NPI = nasal patency index; NP-VAS = nasal patency visual analog scale; PNIF = peak nasal inspiratory flow; POIF = peak oral inspiratory flow.

DISCUSSION

Our study showed that PNIF, NPI, and NP-VAS correlate with the NOSE scale or the subjective perception of nasal passage. POIF did not show this correlation; POIF does not measure subjective complaints of nasal passage. Spirometric peak flow measurements represent relatively simple methods to estimate the patency of the nasal airway. Oral and nasal peak inspiratory flows can be expressed in an NPI, which up to now has been used in a few studies.[19,20] In three of them, a significant correlation between this index and self-assessment scores of nasal function in each patient were shown.[21–23] More specifically, in a study published by Larsen and Kristensen in 1990,[21] 20 adult patients, who had undergone septoplasty with or without partial submucous resection of the middle turbinate, were studied. NPI rates were obtained with a Mini-Wright peak flow meter (Clement Clarke Int Ltd, Harlow, UK) and were found to have a significant correlation with self-assessment scores. The self-assessment form graded nasal obstruction from 0 (no obstruction) to 5 (complete

TABLE III.
Spearman Correlations of the Objective and Subjective Parameters.

		POIF	PNIF	NPI	NOSE	NP-VAS
POIF	Spearman correlation	1				
	Significance					
PNIF	Spearman correlation	.43	1			
	Significance	<.01*				
NPI	Spearman correlation	−.16	.79	1		
	Significance	.61	<.01*			
NOSE	Spearman correlation	−.06	−.34	−.33	1	
	Significance	.52	<.01*	<.01*		
NP-VAS	Spearman correlation	−.08	−.39	−.32	.84	1
	Significance	.34	<.01*	<.01*	<.01*	

*The correlation is significant at the .05 level (two-tailed).
NOSE = Nasal Obstruction Symptom Evaluation; NPI = nasal patency index; NP-VAS = nasal patency visual analog scale; PNIF = peak nasal inspiratory flow; POIF = peak oral inspiratory flow.

obstruction), whereas postoperatively, the patients made the overall assessment on the operative result by grading the patency of the total nasal airway as "improved," "unchanged," or "worsened." In the second study, NPI was measured in 26 patients undergoing surgery for nasal obstruction, preoperatively and 1 month postoperatively. The patients' subjective assessment of their nasal patency was classified again as "improved," "unchanged," or "worsened." Good correlation between the subjective improvement of nasal patency and the increase in NPI was observed. The latter study involved 24 patients who were studied prior to septoplasty and 1 month postoperatively. Each patient's self-assessment was expressed by a score from 0, indicating an open nasal airway, to 5, indicating complete occlusion. In this case, a high score was correlated to a low peak flow NPI, reflecting a poor nasal patency. All subjects recruited in these studies underwent surgery for nasal obstruction, the number of individuals was relatively small, the questionnaires were not validated, and mucosal decongestion was applied before testing. Moreover, the Mini-Wright peak flow meter, which was used in all three studies, was designed to measure expiratory flow rates. Therefore, inspiratory measurements were performed with the device placed inversely in an air tight translucent plastic tube. Moreover, peak flow values <60 L/min could not be recorded on these standard instruments, and therefore were registered as 0.

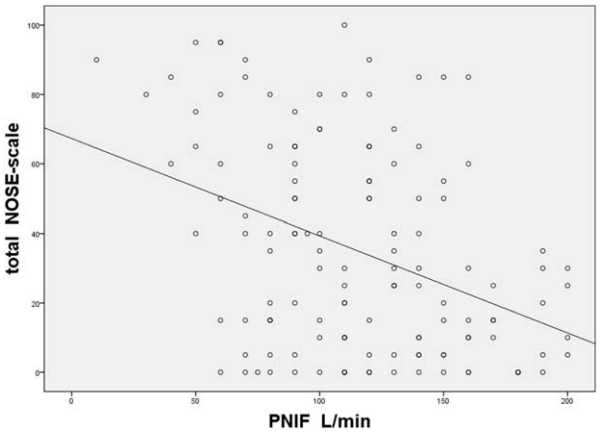

Fig. 1. Scatter plot showing the relation between the NOSE-scale and PNIF. NOSE = Nasal Obstruction Symptom Evaluation; PNIF = peak nasal inspiratory flow.

In our study, NPI was measured with the In-Check Nasal portable handheld inspiratory flow meter without the use of a nasal decongestant. POIF only had a significant correlation with PNIF but not with the other subjective and objective measurements. Moreover, POIF did not show a significant association with the NOSE scale. NPI, on the other hand, showed highly significant correlations with the NOSE scale and NP-VAS. PNIF showed significant correlations with the NOSE scale, NP-VAS, and the objective tests POIF and NPI, but was also significantly associated with the NOSE scale in multiple linear regression analysis. For that reason, there is no clinical need to measure POIF or to calculate the NPI. Moreover, NP-VAS showed a highly significant correlation and association with the NOSE scale. This finding suggests that an NP-VAS might be an alternative for the NOSE scale as a subjective measurement of nasal patency.

The measurement of inspiratory flow through the mouth has been used in patients with chronic obstructive pulmonary disease (COPD) and in asthmatic patients to determine their inhalation rate in dry powder inhalers (DPIs).[25–28] These studies have highlighted the potential of In-Check DIAL (Clement Clarke International Ltd., Harlow, UK), a low-range inspiratory flow meter, to identify the inspiratory efforts of all types of patients including children and patients with COPD, using a selection of DPIs.[29–32] The measurement of peak inspiratory mouth flow through a stenosed In-Check DIAL device, which simulated the internal resistance of the Turbuhaler (Astra Zeneca, Lund, Sweden), has also been used to measure the effects of bronchodilators,[33] whereas POIF has served as an indicator of breathing effort changes after exercise.[34] We observed a strong relation between POIF and PNIF, thus confirming that PNIF strongly depends on pulmonary function.

The main limitation of the measurement of PNIF and POIF is the fact that the full cooperation of the tested subject is crucial for the validity of the measurement. The patient can obtain an unreliably poor result by not strongly inhaling the air through the nose or mouth. As suggested in previous studies,[9] PNIF increases with practice, particularly after the first attempt. Because our aim was to measure the maximum inspiratory flow, the highest of the three results of both PNIF[9] and POIF was taken as valid measurement.

CONCLUSION

Although nasal airflow and PNIF depend on pulmonary function, POIF does not correlate with the subjective feeling of nasal patency. As expected, PNIF and NPI showed significant correlations with the NOSE scale and NP-VAS. PNIF and NPI also showed a significant association with the NOSE scale after adjustment for confounders. For that reason, there is no clinical need to measure POIF or to calculate the NPI in the evaluation of nasal patency. PNIF is a reliable method for the assessment of nasal patency. It is quick, inexpensive, and easy to perform and correlates significantly with the subjective feeling of nasal obstruction. Moreover, NP-VAS was shown to have a highly significant correlation and association with the NOSE scale. This finding suggests that a NP-VAS might be an alternative for the NOSE-scale as a subjective measurement of nasal patency.

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