

Airflow Obstruction and Peak Nasal Inspiratory Flow (PNIF)

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Summary

Peak nasal inspiratory flow rate is a simple, cost-effective, reliable and objective measure of airflow obstruction. Data has shown the sensitivity of this test and the close correlation with patients' symptoms of blockage and other objective measures of nasal airway function. Peak nasal inspiratory flow rate has been used to evaluate medical and non-medical therapies and has also been used as an outcome measure in nasal challenge testing. Nasal/oral flow ratios have also been used in order to account for the influence of lower airway function on peak nasal inspiratory flow.

Importance of nasal disease

Allergic rhinitis is an inflammatory condition of the upper airways, which has an increasing incidence throughout the western world^(1,2), occurring in up to 20% of the population⁽³⁾. Although it does not have an associated mortality, it causes distress and impaired quality of life to sufferers⁽⁴⁾. This results in decreased productivity and potentially absenteeism from work or schooling⁽⁵⁾. Structural causes of nasal airflow obstruction are also of interest due to the availability of minimal access nasal surgery.

Subjective versus objective

The assessment of treatment response in any condition can either be by subjective or objective measures. Subjective assessment has the advantage of reporting treatment response from the patient's point of view and therefore can be considered to be the most important endpoint, at least in the short term. However, they tend to be qualitative in nature and therefore standardised symptom scoring systems have been developed and validated⁽⁶⁾. Objective measures have the advantage of being quantitative and are devoid of emotional influence. An optimal objective measure is repeatable, simple to perform, non-invasive, inexpensive, and the results obtained reflect treatment response or disease activity.

Measures of nasal obstruction

Nasal airflow obstruction is an important component of the allergic rhinitis syndrome⁽⁷⁾, and of structural nasal abnormalities. Nasal blockage causes distress to patients, exacerbation of lower airways disease due to mouth breathing, and facial pain or headaches from sinusitis if the sinus ostia are involved. In a clinical evaluation of the different components of rhinitis symptoms, it was nasal blockage which was the most troublesome in the majority of patients⁽⁸⁾.

Both acoustic rhinometry and rhinomanometry are recognised to be sensitive and reliable methods in assessment of nasal obstruction⁽⁹⁻¹¹⁾. Acoustic rhinometry has been validated using high resolution computerised tomography scanning and magnetic resonance imaging^(11,12). However both acoustic rhinometry and rhinomanometry measurements require trained personnel and technical difficulties have been acknowledged. For example, with acoustic rhinometry artifacts may arise from positioning the probe and from acoustic leaks at the nostril⁽¹³⁾. Measurements made beyond the posterior end of the nasal septum are less reliable^(11,14). Anterior rhinomanometry is easy to perform, although it involves making a seal around one nostril at a time. Posterior rhinomanometry, although having the advantage of assessing total nasal resistance, is also technically difficult to perform, often requires intensive patient training and may be impossible in some patients.

Just as peak expiratory flow has been used as a measure of disease control in asthma⁽¹⁵⁾, investigators have used nasal flow to assess upper airways function. Peak nasal inspiratory and expiratory flow^(16,17) as well as peak nasal inspiratory and expiratory volume in 1 second have been used to evaluate nasal function⁽¹⁸⁾. More recently inspection of the inspiratory flow volume curve has also been utilised to assess nasal obstruction⁽¹⁹⁾. Although both peak nasal inspiratory flow (PNIF) and peak nasal expiratory flow are closely related⁽¹⁶⁾, the former is considered to be the better measure, as it correlates better with rhinomanometry⁽²⁰⁾ and avoids expelling nasal secretions. In 1980, Youlten⁽²¹⁾ developed a peak nasal inspiratory flow meter which was non-invasive and had the advantages of simplicity, portability and economy.

The repeatability of PNIF has been shown to be sufficiently good to be used in epidemiological studies⁽²²⁾. The coefficient of variation has been calculated at 8%. This equates to a change of 19 l/min being adequate to detect a clinically relevant alteration in response in the laboratory setting⁽²³⁾. More recently, Hara et al⁽²⁴⁾ evaluated different methods of assessing nasal function and demonstrated that PNIF was the most reproducible measure. However, Enberg and Ownby⁽²⁵⁾ showed that coefficients of variation with PNIF were greater than with peak expiratory flow in healthy volunteers and suggest that PNIF is more dependant on adequate technique than peak expiratory flow. They demonstrated significant improvements in symptom scores and PNIF in 10 patients with nasal obstruction following nasal oxymetazoline therapy but no correlation between subjective and objective measures of change. Assuming adequate co-operation, PNIF can be used in children as well as adults⁽²⁶⁾, and studies with children have shown a linear increase in PNIF with age, height and weight⁽²⁷⁾.

Relation to rhinomanometry

Studies have shown good correlation between PNIF and rhinomanometry when altering nasal patency with allergen or histamine nasal challenge in the laboratory^(16,28,29). Jones et al⁽³⁰⁾ compared anterior and posterior rhinomanometry with different indices of nasal and oral flow (including PNIF, oral PEF, nasal FEV₁, and oral FEV₁) and showed that anterior rhinomanometry had the closest correlation with PNIF ($r=0.678$ $p=0.000$).

However it is considered that changes with rhinomanometry are greater than those of PNIF^(31,32), and that flow measured by rhinomanometry during quiet respiration was more sensitive to physiologically induced changes in nasal resistance than peak flow⁽²⁰⁾. As the disease severity in seasonal allergic rhinitis varies over a short-term basis, it has been suggested, more recently, that the use of domiciliary PNIF may be more informative than one-off clinic measurements of rhinomanometry^(33,34). In a study evaluating the effect of intra-nasal mometasone or oral cetirizine plus montelukast in patients with seasonal allergic rhinitis, a significant treatment effect could be demonstrated with either treatment regimen, compared to placebo, with domiciliary measurement of PNIF but not with laboratory measurement of rhinomanometry or acoustic rhinometry⁽³⁴⁾. This can be considered similar to the use of daily peak expiratory flow rate when monitoring asthma control.

Relation to symptoms

Clinical examination and anterior rhinometry have been shown to correlate poorly with patients subjective sensation of upper airway patency^(35,36). Gleeson however showed that PNIF ($r=0.54$) had a closer correlation with the sensation of nasal blockage, after increasing and decreasing resistance with histamine and cocaine respectively, compared to anterior ($r=0.47$) and posterior rhinomanometry ($r=0.45$)⁽²⁸⁾. Significant correlations were also seen in a longitudinal study in healthy volunteers⁽³⁷⁾, and in terms of morning and evening results in patients with seasonal allergic rhinitis⁽³⁸⁻⁴⁰⁾.

Diagnosis of occupational rhinitis

The diagnosis of rhinitis is usually made based on a patient's symptoms or ear nose and throat examination and rarely requires assessment of nasal function⁽⁴¹⁾. However, nasal peak inspiratory flow has been used in the assessment of occupational induced rhinitis. Hellgren et al⁽⁴²⁾ compared workers exposed and non-exposed to paper dust and documented evidence of increased nasal blockage and crusting but no significant difference was demonstrated in PNIF, spirometry or measures of nasal inflammation. In two separate studies Miralles et al^(43,44) used PNIF in specific nasal challenge testing to successfully demonstrate occupational rhinitis due to artichoke and chemicals from a pharmaceutical plant.

Evaluation of medical therapy

Anderson et al⁽⁴⁵⁾ evaluated intra-nasal budesonide delivered from a dry powder inhaler in 60 patients with rhinitis due to birch pollen and showed a significant improvement in PNIF after 1 week of therapy as well as improvement in symptoms and anti-histamine usage. Other authors have examined the effect of PNIF used on a twice-daily basis and detected significant improvements following therapy with intra-nasal corticosteroids. Fokkens et al⁽⁴⁶⁾ showed a onset of action of 12 hours with intra-nasal budesonide in children with perennial allergic rhinitis, Jordana et al⁽³⁹⁾ demonstrated improvements in clinical efficacy and PNIF in adolescents with ragweed allergy and Wilson et al showed objective improvements in grass pollen rhinitis with PNIF in adults receiving budesonide⁽⁴⁷⁾ or mometasone⁽³⁴⁾. Pedersen et al⁽⁴⁸⁾ and Pedersen et al⁽⁴⁹⁾ showed improvements in both PNIF and peak expiratory flow in adults and children respectively, after inhaling corticosteroid nasally from a spacer device. When subjects

with seasonal allergic rhinitis were subjected to pollen in an allergen chamber and asked to record their symptoms and PNIF hourly, the onset of action of budesonide was shown to be 3 hours with the PNIF and 7 hours in terms of symptoms⁽⁵⁰⁾. Bende et al⁽⁵¹⁾ were able to detect a difference between budesonide 256 µg per day and mometasone 128µg per day in terms of PNIF but not with symptoms.

Several studies have assessed the efficacy of intranasal corticosteroids in patients with nasal polyposis using PNIF⁽⁵²⁻⁵⁵⁾. Each showed a significant increase in PNIF which was accompanied by subjective improvement of nasal blockage, and in most cases an associated reduction of nasal polyp size. In an evaluation of once daily versus twice daily 400µg fluticasone propionate nasal drops in patients with polyposis, there were significant dose related improvements in laboratory measurement of PNIF but no difference between doses in terms of polyp size or symptoms⁽⁵⁶⁾. A similar trend was seen with laboratory assessment of PNIF when comparing once versus twice daily 128µg with budesonide⁽⁵⁷⁾.

Evaluation of non-medical therapy

Lund and Scadding⁽⁵⁸⁾ performed a study evaluating objective measures of endoscopic sinus surgery which showed that neither PNIF or rhinomanometry significantly improved following the operation, despite subjective improvements in nasal blockage. However Marias et al⁽⁵⁹⁾ showed improvements in PNIF after septoplasty, as did Cook et al⁽⁶⁰⁾ after laser therapy for rhinitis. PNIF has also been utilised to evaluate the effectiveness of nasal splints when used in the management of alar collapse during high inspiratory maneuvers⁽⁶¹⁾ and during intensive⁽⁶²⁾ or prolonged exercise⁽⁶³⁾. More recently Bjornsdottir et al⁽⁶⁴⁾ examined the effect of allergen avoidance in cat allergic subjects, and demonstrated significant improvement in PNIF and better symptoms scores, when compared to a control group.

Other uses of PNIF

In a similar manner to the usefulness of assessing oral inspiratory flow rate through inhaler devices in order to maximise lung delivery of inhaler devices, PNIF through a nasal Turbuhaler has also been used to demonstrate that children could use this device to deliver corticosteroid intranasally from the age of 6 years⁽⁶⁵⁾. Other investigators have used PNIF to examine the nasal valve⁽⁶⁶⁾ and the effect of nasal flow at high altitude⁽⁶⁷⁾.

Outcome measure in nasal challenge testing

PNIF has been used to determine the reaction threshold or cutoff value to determine the endpoint in nasal challenge testing. Terrien et al⁽⁶⁸⁾ used an algorithm to combine the change in PNIF or acoustic rhinometry, the number of sneezes and the volume of nasal secretions, in order to determine the reaction threshold during a nasal allergen challenge, and showed that fexofenadine was significantly more effective than terfenadine. In another study the reaction threshold for acoustic rhinometry and PNIF were calculated as 29% and 26% respectively from data on the variability of these measures⁽⁶⁹⁾. When applying these criteria the authors reported that all patients with rhinitis had a positive response with PNIF and all but one with acoustic rhinometry⁽⁶⁹⁾. With nasal allergen challenge, Scadding et al⁽⁷⁰⁾ found a significant reduction in PNIF, worsening of

symptom scores and increase in nasal lavage histamine and prostaglandins. Intranasal fluticasone propionate has been shown to exhibit a 37% and 96% reduction in PNIF in the early and late phase response respectively in nasal allergen challenge⁽⁷¹⁾.

Although guidelines on nasal provocation challenges suggested that PNIF is less accurate than rhinomanometry⁽⁷²⁾, other reports have contradicted this. Hellegren et al⁽⁷³⁾ compared objective methods of assessing nasal reactivity to histamine challenge and showed that PNIF was more sensitive at detecting a response than acoustic rhinometry or rhinomanometry. These findings were confirmed by another study, which evaluated treatment response with intra-nasal mometasone furoate in patients with perennial allergic rhinitis using nasal histamine challenge testing. The authors were able to detect a treatment response using PNIF, but not with acoustic rhinometry or rhinomanometry, as the outcome measure during the challenge⁽⁷⁴⁾.

More recently, PNIF has been used as an outcome measure in both nasal mannitol and adenosine monophosphate challenge. Koskela et al⁽⁷⁵⁾ performed a mannitol challenge in patients as well as control subjects and demonstrated a fall in PNIF in patients, but no change with control subjects. A subsequent study showed that this fall in PNIF could be inhibited by both leukotriene receptor antagonists and anti-histamines⁽⁷⁶⁾. Nasal adenosine monophosphate challenge has been compared to nasal histamine challenge as a method of assessing short term (2 weeks) response to 200µg once daily mometasone furoate in patients with perennial allergic rhinitis⁽⁷⁷⁾. No significant difference could be detected using the histamine challenge test, but the intra-nasal corticosteroid had a significant effect compared to placebo with nasal AMP challenge. PNIF has also been used during nasal aspirin⁽⁷⁸⁾, hexahydrophthalic anhydride challenge⁽⁷⁹⁾ and artichoke challenge⁽⁴⁴⁾.

Nasal oral index

Peak nasal inspiratory flow rate is determined by nasal obstruction and by the maximum negative pressure generated from the lower respiratory tract. Changes in either inspiratory effort or lower airways resistance will alter the peak nasal inspiratory flow independently of nasal obstruction. Phagoo et al⁽³¹⁾ increased intra thoracic airways resistance with histamine challenge and showed misleading results with PNIF during nasal challenge especially if patients had high baseline nasal conductance. For this reason, methods of correcting for respiratory function have been developed. Taylor et al⁽¹⁷⁾ suggested a blockage index (peak oral flow minus peak nasal flow divided by peak oral flow) and showed this to compare well with rhinometry. This index has been used by other authors⁽²²⁾. Larsen et al⁽⁸⁰⁻⁸²⁾ developed peak expiratory and inspiratory nasal patency indices (the ratio of nasal to oral flow rate) which correlated with subjective response to septoplasty. Also in surgical patients, the ratio of forced inspiratory volume in one second through the nose and mouth has been shown to correlate better to symptoms of nasal blockage than nasal forced inspiratory volume in 1 second alone⁽⁸³⁾. A recent study suggests that using a patency index caused greater variability in results and was detrimental to reproducibility⁽²⁴⁾.

Limitations

There are several limitations of peak nasal inspiratory flow rate. It does not seem as sensitive as, for example, rhinomanometry⁽³¹⁾. In a study with histamine challenge, small changes in airway resistance with low dose histamine were detected with rhinomanometry but not by PNIF⁽⁸⁴⁾. At very low flow rates (<30 l/min) PNIF may not be possible and assessment should be made with rhinomanometry. Furthermore, no information is obtained regarding the structure of the nose or the location of nasal obstruction with PNIF, as is the case with acoustic rhinometry. PNIF is also patient dependant, like spirometry, and requires a maximal effort by the patient. However, PNIF seems to be an inexpensive, simple, portable test which is reproducible and sensitive, correlates well with symptoms and enables the clinician to determine changes in response to medical and surgical intervention.

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