Peak Nasal Inspiratory Flow Is a Useful Measure of Nasal Airflow in Functional Septorhinoplasty

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Objective: To evaluate the utility of peak nasal inspiratory flow (PNIF) as a measure of nasal airflow and functional septorhinoplasty (FSRP) outcomes.

Methods: Patients with nasal obstruction were administered Nasal Obstruction Symptom Evaluation (NOSE) questionnaire and PNIF testing between January 2015 and 2018. Surgical patients repeated these tests at 2, 4, 6, 12, and 24 months postoperatively. Patient demographics and operative techniques were recorded.

Results: A total of 610 patients were evaluated for nasal obstruction with mean (standard deviation [SD]) NOSE score of 61.5 (23.2) and PNIF of 74.1 (35.4) liters per minute (L/min); correlation $r = -0.16$ ($P < 0.001$). Predictors of lower PNIF were female gender ($\beta = -13.3$, 95% confidence interval [CI] 7.7 to 18.2, $P < .001$) and higher NOSE scores ($\beta = -0.43$, 95% CI 0.19 to 0.68, $P < 0.001$). A total of 281 patients underwent FSRP with statistically and clinically significant improvements in both mean NOSE and PNIF scores that were stable out to 2 years. NOSE scores changed $-41.0$ (25.5) points, and PNIF improved $20.7$ (35.5) L/min at last follow-up. Grafting material did not affect outcomes, whereas spreader grafts improved PNIF values ($\beta = 25.46$, 95% CI 5.5 to 45.4, $P = 0.013$). Clinically significant changes between NOSE and PNIF were concordant, although the correlation was weak ($r = -0.26$, $P = 0.02$).

Conclusion: Peak nasal inspiratory flow is a rapid, cheap, and easily performed test that detects nasal obstruction and clinically significant improvements in airflow following FSRP. Although PNIF does not correlate well enough with the patient experience of nasal obstruction to be used as a diagnostic tool, it does provide unique and complementary information useful for evaluating, understanding, and improving the effects of surgical techniques.

Key Words: Peak nasal inspiratory flow, septorhinoplasty.

Level of Evidence: 2C

INTRODUCTION

Structural abnormalities causing nasal obstruction are refractory to medical management and can only be managed with surgery. Understanding the efficacy of these interventions is critical to improving surgical outcomes. Unfortunately, a widely used and accepted direct measure of nasal airflow does not currently exist. Prior attempts to directly quantify nasal airflow, for example, using nasal rhinomanometry and acoustic rhinometry, have failed to gain widespread use due to expense, test burden, and a lack of correlation with patient-reported outcomes measures.\(^1\)\(^2\)\(^3\)\(^4\)\(^5\)\(^6\) Because the goal of nasal surgery is to increase quality of life, improvement in patient-reported outcome measures (PROMs) is essential; however, understanding how the surgeries we perform alter nasal function is also critical to continued surgical advancement.

Over the years, PROMs have improved from nonvalidated visual analogue scales and questionnaires to standardized, validated, and reliable measures such as the disease-specific Nasal Obstruction Symptom Evaluation (NOSE) scale and the global health related EuroQol-5 Dimension quality-of-life questionnaires.\(^8\)\(^9\)\(^10\)\(^11\)\(^12\) The NOSE scale is currently the most widely used validated and reliable PROM for nasal obstruction.\(^13\) Despite improvements in available PROMs, the search for a direct measure of nasal airflow that could complement the information obtained from patient report continues.

Peak nasal inspiratory flow (PNIF) has the potential to fill this need because it is an inexpensive, rapid, and easy-to-use tool that directly measures nasal airflow during maximal inspiration. It has demonstrated good reproducibility and correlation with rhinomanometry, and acoustic rhinometry and recent studies have found a correlation between PNIF and patient report when the validated NOSE scale was used, although some disagreement remains.\(^14\)\(^15\)\(^16\)\(^17\)\(^18\)\(^19\) Contemporary allergy literature recommends PNIF as a measure that should be used in daily practice, and minimal clinically important differences in PNIF values have been established.\(^20\)\(^21\) An early investigation by our group into the utility of PNIF for functional septorhinoplasty outcomes demonstrated clinically significant improvements in airflow following functional septorhinoplasty.\(^22\)
In this study, we seek to further investigate the utility of PNIF as both a diagnostic tool for nasal obstruction and as an outcome measure of functional septorhinoplasty while also assessing its relationship with NOSE scores and the effect of patient demographics and surgical techniques on these measures. To our knowledge, the current study is the largest study to date, with the longest follow-up period that evaluates both NOSE and PNIF scores in patients presenting for evaluation of nasal obstruction and undergoing functional septorhinoplasty.

MATERIALS AND METHODS

Participants

This study was performed at a single tertiary care medical center between January 2015 and 2018 with institutional review board approval from the Human Subjects Research Committee. Patients who presented for evaluation and treatment of nasal obstruction refractory to medical therapy by the senior author (R.W.L.) who had both PNIF and NOSE scores were included. A full description of the surgical technique used for each location of obstruction has been previously published.10 Exclusion criteria included inability to give informed consent, unwillingness to participate, and lack of fluency with English. Additionally, patients with severe pulmonary disease (e.g., chronic obstructive pulmonary disorder, emphysema, restrictive lung diseases, cystic fibrosis), patients with chronic rhinosinusitis with or without nasal polypsis, and/or a history of acute sinus infection within 1 month of surgery were excluded. No patients had active sinus or nasal infections at the time of assessment.

Measures of Nasal Obstruction

Patient-reported symptoms of nasal obstruction were measured using the validated disease-specific quality-of-life outcomes measure, the NOSE questionnaire. This measure contains five questions related to nasal obstruction along a five-point Likert scale, and responses are then converted to a total score from 0 (no nasal obstruction) to 100 (severe nasal obstruction).9 Patients were administered the NOSE scale preoperatively and at 2, 4, 6, 12, and 24 months postoperatively in a Health Insurance Portability and Accountability Act-compliant manner in an electronic format at their scheduled clinic appointment or electronically via email through REDcap (research electronic data capture)21–23.

Direct measurement of nasal airflow was performed using an In-Check portable inspiratory flow meter (Clement Clarke International Ltd., Harlow, UK) to measure PNIF preoperatively and postoperatively. Peak nasal inspiratory flow was measured using a tight-fitting anesthetic mask that did not alter the shape of the nose. Patients were instructed to inhale as hard and fast as possible through the mask while keeping their mouth closed and were allowed to practice with the device prior to formal testing. At formal testing, the patients performed three trials at maximal effort while sitting. The highest flow rate (liters per minute [L/min]) of these three measurements was recorded, as has been previously described.24,25 Following measurement of PNIF, a standardized nasal exam was performed that evaluated both the static and dynamic external and internal nasal anatomy by anterior rhinoscopy using a standardized nasal exam.24

Patient demographics, comorbidities, and operative interventions were recorded.

Statistical Analysis

Statistical analyses were conducted using Excel (Microsoft Corp., Redmond, WA, Version 15.28) and STATA 12.0 (StataCorp LP, College Station, TX). For all tests, P values of <0.05 were considered significant. The minimal clinically important difference (MCID) for NOSE scores was set at 30 points and the MCID for PNIF values was set at 20 L/min, as previously described.10,21 A one-way analysis of variance (ANOVA) analysis with post-hoc Tukey test was performed to determine statistically significant differences between pre- and postoperative mean PNIF and NOSE scores at the various time points. Pre- and postoperative NOSE and PNIF scores were compared using paired and unpaired t tests, as appropriate. Correlations were calculated using Spearman correlation coefficients, and the N-1 two-proportion test was used to determine significance between binary variables. Multivariate linear regressions were performed using STATA 12.0 (StataCorp LP). A Fisher r to z transformation was used to test differences between correlation coefficients.

RESULTS

A total of 610 patients (54.1% women) with mean age (standard deviation [SD]) of 36.2 (18.6) years presented for evaluation of nasal obstruction and had both NOSE and PNIF scores recorded. Among these patients, 345 (56.6%) reported a history of allergies; 307 (50.3%) had a history of nasal fracture; and 240 (39.4%) had previously undergone a nasal surgery (septoplasty or septorhinoplasty). Among these patients, the average (SD) NOSE score was 61.5 (23.2) and average PNIF was 74.1 (35.4) L/min. Multivariate linear regression demonstrated that significant predictors of decreased PNIF included female gender (β = −13.3, 95% CI 7.7 to 18.2, P < 0.001) and higher NOSE scores (β = −0.43, 95% CI 0.19 to 0.68, P < 0.001), whereas allergies, history of fracture, age, and surgical history were not significant predictors. Mean baseline PNIF (SD) for males and females was 80.7 (39.7) and 68.5 (30.3) L/min, respectively (P < 0.001). Significant predictors of higher baseline NOSE scores were history of allergies (β = 3.9, 95% CI 0.2 to 7.6, P = 0.039), history of prior nasal surgery (β = 4.23, 95% CI 0.47 to 8.0, P = 0.028), increased age (β = 0.11, 95% CI 0.015 to 0.21, P = 0.023), and lower PNIF (β = −0.13, 95% CI −0.18 to −0.08, P < 0.001). There was no correlation between NOSE and PNIF scores in this group with correlation coefficient of −0.16 (P < 0.001). For women, the correlation was −0.19 (P < 0.001), and for men it was −0.15 (P = 0.01) (Figure 1).

A total of 281 of these patients subsequently underwent functional septorhinoplasty and had both pre-and postoperative NOSE and PNIF scores recorded. There were no significant differences in patient gender; age; preoperative NOSE score; or patient history of allergies, fractures, or prior surgery between those who underwent surgery and those who did not. However, baseline PNIF was higher in the surgical group (77.7 [35.8] vs. 71.0 [35.6] L/min, P = 0.021). The mean preoperative NOSE score was 61.8 (22.9).

The surgical patient demographics and the operative techniques used are demonstrated in Table I. Among this cohort of patients, multivariate linear regression again found that predictors of decreased baseline PNIF were...
female gender ($\beta = -15.75$, 95% CI 7.5 to 24.0, $P < 0.001$) and increased NOSE scores ($\beta = -0.28$, 95% CI 0.09 to 0.46, $P = 0.003$). The only significant predictor of higher baseline NOSE scores was lower PNIF ($\beta = -0.116$, 95% CI −0.19 to −0.039, $P < 0.001$); allergies, age, and prior nasal surgery were no longer significant in this group. Among the surgical patients, there again was no correlation between baseline NOSE and PNIF with a correlation coefficient of $-0.13$ ($P = 0.02$); among males, it was $-0.23$ ($P = 0.01$); and among females, it was not significant $-0.08$ ($P = 0.32$).

The mean postoperative follow-up time was 7.3 months (SD 5.4, range 2–24 months). Preoperative, last postoperative, and change in both NOSE and PNIF values by gender, age, and history of environmental allergies, nasal fracture, and prior nasal surgery are demonstrated in Table II. Mean pre- and postoperative NOSE and PNIF scores across all time points are shown in Figure 2A. ANOVA with post hoc Tukey test demonstrates that all postoperative NOSE and PNIF values, except the 24-month PNIF value, had a statistically significant improvement from baseline, and there was no statistical difference between postoperative time points. In addition, all postoperative NOSE and PNIF scores, except for the 2-month PNIF value, demonstrated a clinically significant improvement from baseline (decrease of $\geq 30$ points for NOSE scores and increase of $\geq 20$ L/min for PNIF). Figures 2B and 2C show box plots of the NOSE and PNIF scores at each time point to demonstrate the variance within the scores.

Multivariate linear regression found that the graft/implant material used had no significant impact on postoperative NOSE and PNIF values. Similarly, there was no significant impact of the intraoperative techniques used on postoperative NOSE scores; however, spreader grafts were found to be a positive predictor of postoperative PNIF ($\beta = 25.46$, 95% CI 5.5 to 45.4, $P = 0.013$).

Surgical patient demographics, medical history, and the surgical techniques used are listed.

**TABLE I.** Patient Demographics and Operative Techniques

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>122 (43.4%)</td>
</tr>
<tr>
<td>Female</td>
<td>159 (56.6%)</td>
</tr>
<tr>
<td>Age (years, SD)</td>
<td>36.3 (15.5)</td>
</tr>
<tr>
<td>Prior nasal surgery</td>
<td>106 (37.7%)</td>
</tr>
<tr>
<td>Seasonal allergies</td>
<td>161 (57.3%)</td>
</tr>
<tr>
<td>Nasal fracture</td>
<td>142 (50.5%)</td>
</tr>
<tr>
<td>OSA</td>
<td>11 (4.2%)</td>
</tr>
<tr>
<td>Graft/implant</td>
<td></td>
</tr>
<tr>
<td>Septal cartilage</td>
<td>217 (77.2%)</td>
</tr>
<tr>
<td>Autologous rib</td>
<td>37 (13.2%)</td>
</tr>
<tr>
<td>Cadaveric rib</td>
<td>22 (7.8%)</td>
</tr>
<tr>
<td>PDS plate</td>
<td>68 (24.2%)</td>
</tr>
<tr>
<td>Procedure</td>
<td></td>
</tr>
<tr>
<td>Spreader graft</td>
<td>257 (91.5%)</td>
</tr>
<tr>
<td>Columellar strut graft</td>
<td>72 (25.6%)</td>
</tr>
<tr>
<td>Lateral crural strut graft</td>
<td>50 (17.8%)</td>
</tr>
<tr>
<td>Alar rim graft</td>
<td>40 (14.23%)</td>
</tr>
<tr>
<td>Lateral crural replacement</td>
<td>9 (3.2%)</td>
</tr>
</tbody>
</table>

OSA = obstructive sleep apnea; SD = standard deviation. PDS = polydioxanone.
Interestingly, the correlation between postoperative NOSE and PNIF values increased with time from surgery, with a correlation of \(0.05\) at 2 months \((P = 0.41)\), \(-0.18\) at 4 months \((P = 0.03)\), \(-0.30\) at 6 months \((P = 0.002)\), and \(-0.42\) at 12 months \((P < 0.001)\). The correlation between the change in NOSE and PNIF scores at a year or more postoperative was \(-0.27\) \((P = 0.02)\).

NOSE and PNIF scores organized by change in NOSE score are shown in Table III and demonstrate concordance in reaching the MCID such that when the MCID in NOSE score is reached, the MCID in PNIF is also attained. We find that among all patients with a preoperative NOSE score greater than or equal to 30 (making attaining the NOSE MCID achievable), attaining the MCID for PNIF has a positive-predictive value of 79% for also reaching the NOSE MCID (sensitivity 53.6% and specificity 61.8%). Receiver operator characteristic (ROC) curves were generated to evaluate if preoperative NOSE and PNIF values could accurately predict who would achieve a clinically significant change in that measure following surgery (Figure 3). The preoperative NOSE ROC curve had an area under the curve (AUC) of 0.81 \((95\% \text{ CI 0.77 to 0.85})\) with the high sensitivity and specificity cutoff at 60 and with a sensitivity of 74.8% and specificity of 71.7%. By contrast, the PNIF was a less robust model with an AUC of 0.59 \((95\% \text{ CI 0.54 to 0.63})\) and the high sensitivity and specificity cutoff at 90 L/min with a sensitivity of 46% and specificity of 68%).

**DISCUSSION**

Peak nasal inspiratory flow is positioned to be a valuable measure of nasal airflow because it is rapid, inexpensive, easy to use, and directly measures nasal airflow. In this study, we evaluated its utility in the setting of functional septorhinoplasty and assessed its relationship to the NOSE questionnaire, a widely used PROM.

In this study, the mean baseline NOSE scores in both groups were significantly different \((P < 0.001)\). The NOSE MCID for this population is a change of \(-30\) with a sensitivity of 53.6% and specificity of 61.8%. Receiver operator characteristic (ROC) curves were generated to evaluate if preoperative NOSE and PNIF values could accurately predict who would achieve a clinically significant change in that measure following surgery (Figure 3). The preoperative NOSE ROC curve had an area under the curve (AUC) of 0.81 \((95\% \text{ CI 0.77 to 0.85})\) with the high sensitivity and specificity cutoff at 60 and with a sensitivity of 74.8% and specificity of 71.7%. By contrast, the PNIF was a less robust model with an AUC of 0.59 \((95\% \text{ CI 0.54 to 0.63})\) and the high sensitivity and specificity cutoff at 90 L/min with a sensitivity of 46% and specificity of 68%).
females in our study demonstrated significantly lower PNIF values than their male counterparts, which is consistent with prior studies.19,26,27 The baseline PNIF values for our patients were similar to those reported by others looking at patients with nasal obstruction, although some variation in the literature exists.2,6,21

The lower PNIF values in our patients and those of other studies with nasal obstruction compared with healthy individuals indicate that PNIF may be useful for detection of nasal obstruction. However, although PNIF and NOSE scores were significant predictors of one another in multivariate linear regression analysis, there was no overall correlation between baseline NOSE scores and PNIF values (r = −0.18, \( P < 0.001 \)). The negative correlation indicates that, as NOSE scores increased (worse obstruction), nasal airflow decreased. This correlation coefficient is similar to but slightly lower than that reported in other studies of patients with nasal obstruction.4,19,22,28 The lack of a strong correlation between PNIF and NOSE scores may be multifactorial. First, our

![Fig. 2. (A) Mean NOSE and PNIF values, with 95% confidence intervals, at each time point are shown. Dashed lines represent the minimal clinically important differences from baseline. One-way analysis of variance with post-hoc Tukey test demonstrates preoperative scores are significantly different from all postoperative scores, except 24-month PNIF. There is no significant difference between postoperative time points. (B) Box plot of NOSE scores at each time point. (C) Box plot of PNIF scores at each time point. L/min = liters per minute; MCID = minimal clinically important difference; NOSE = Nasal Obstruction Symptom Evaluation; PNIF = peak nasal inspiratory flow. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

![TABLE III. NOSE and PNIF Values by Change in NOSE Score at Last Follow-up](https://www.laryngoscope.com/content/129/3/598.long)

<table>
<thead>
<tr>
<th>Change in NOSE</th>
<th>N</th>
<th>Baseline NOSE</th>
<th>Baseline PNIF</th>
<th>Postoperative NOSE</th>
<th>Postoperative PNIF (L/min)</th>
<th>Change in NOSE</th>
<th>Change in PNIF (L/min)</th>
<th>Clinically Significant (NOSE/PNIF)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 0</td>
<td>26</td>
<td>47.1 (± 10.0)</td>
<td>77.3 (± 17.3)</td>
<td>53.8 (± 9.7)</td>
<td>83.5 (± 18.1)</td>
<td>6.7 (± 3.2)</td>
<td>6.2 (± 14.7)</td>
<td>no/no</td>
</tr>
<tr>
<td>−5 to −25</td>
<td>66</td>
<td>45.2 (± 45.2)</td>
<td>83.0 (± 9.0)</td>
<td>27.3 (± 5.2)</td>
<td>97.5 (± 9.5)</td>
<td>−18.0 (± 1.6)</td>
<td>14.5 (± 9.4)</td>
<td>no/no</td>
</tr>
<tr>
<td>−30 to −55</td>
<td>109</td>
<td>61.6 (± 3.1)</td>
<td>76.1 (± 6.3)</td>
<td>16.9 (± 3.0)</td>
<td>100.7 (± 8.0)</td>
<td>−44.7 (± 1.7)</td>
<td>24.6 (± 6.7)</td>
<td>yes/yes</td>
</tr>
<tr>
<td>−60 to −100</td>
<td>80</td>
<td>80.6 (± 2.6)</td>
<td>75.4 (± 7.4)</td>
<td>10.7 (± 2.3)</td>
<td>98.8 (± 9.7)</td>
<td>−69.9 (± 2.1)</td>
<td>23.3 (± 7.4)</td>
<td>yes/yes</td>
</tr>
</tbody>
</table>

Mean values and 95% confidence intervals are shown. Clinical significance determined by established minimal clinically important differences of 20 L/min for PNIF and 30 for NOSE.

L/min = liters per minute; NOSE = Nasal Obstruction Symptom Evaluation; PNIF = peak nasal inspiratory flow.
population only includes patients presenting for evaluation of nasal obstruction and does not include a normal, healthy population. Second, the patient experience of nasal obstruction may be vastly different between patients with similar nasal anatomy and function. Finally, these two measures do not account for whether the obstruction is unilateral or bilateral. For example, a patient with severe unilateral obstruction may experience severe obstruction while maintaining normal flow through the contralateral nasal passage. Due to the wide variation of PNIF scores in patients with symptomatic nasal obstruction and the lack of correlation between PNIF values and NOSE scores, we feel that the PNIF value should not be used a diagnostic measure for clinically symptomatic nasal obstruction. Furthermore, the ROC curves for PNIF demonstrate that preoperative PNIF scores are poor predictors of clinically significant improvements following surgery (Figure 3).

Next, we looked at the utility of PNIF in the assessment of functional septorhinoplasty outcomes. When looking at our surgical outcomes, our pre- and postoperative NOSE values are consistent with prior studies, providing external validity to our results. The minimal clinically important difference for PNIF suggested by Timperley et al. is 20 L/min by anchor-based assessment and 18 L/min by distributional assessment. The MCID by distributional assessment is estimated as 0.5 times the baseline standard deviation, and in the present study this value would be 17 L/min. By taking the MCID at 20 L/min, we provide a conservative assessment of clinically significant improvements.

We find that both NOSE and PNIF scores had statistically and clinically significant improvements from baseline following functional septorhinoplasty, and these remained stable over time (Figure 1). An exception to this was the 2-month PNIF value, which was statistically but not clinically different from baseline, likely owing to the impact of residual surgical edema at 2 months. The small sample size at 24 months (n = 13) likely resulted in the nonstatistically significant difference in PNIF scores at that time point, although the value remained clinically significant. The lack of significance at 24 months could also be related to a change in the patient’s health status over the 2 years that could affect PNIF values. Further, we found that reaching the MCID in the NOSE score is concordant with reaching the PNIF MCID (Table III) and that reaching the PNIF MCID had a 79% positive predictive value for also reaching the NOSE MCID. These findings indicate that PNIF is capable of detecting significant changes in nasal airflow following surgery.

Interestingly, the grafting/implant material used (septal cartilage, polydioxanone (PDS) plate, cadaveric rib, autologous rib) had no significant impact on the postoperative NOSE or PNIF values. The limitation of this is that our study only followed patients out to a maximum of 2 years, and differences from warping or absorption over a longer period may not be observed. Additionally, multivariate linear regression demonstrates that the grafting technique used (Table I) is not predictive of NOSE scores but does find that spreader graft placement is a significant positive predictor of postoperative PNIF values ($\beta = 25.46$, 95% CI 5.5 to 45.4, $P = 0.013$). This latter finding may be reflective of our patient population in which nasal valve dysfunction is common and is often a reason for referral of patients to our clinic. Spreader grafts are a known treatment for nasal valve dysfunction, although interestingly, other techniques affecting nasal valve function did not significantly impact PNIF. Although the surgical treatments performed were heterogeneous, they are reflective of what is seen/done in clinical practice. There are many causes of nasal obstruction, and the patients in this study underwent site-appropriate treatment for their specific anatomic findings.

Despite the significant improvements in both PNIF and NOSE scores following surgery, the correlation between the two measures and the changes in them remained weak. Interestingly, the correlation between postoperative NOSE scores and PNIF values increased with time from surgery, perhaps due to resolving surgical edema or changes in sensation from surgical manipulation. The correlation between changes in NOSE and PNIF values ($r = -0.26, P = 0.02$) was slightly lower than that reported by Lodder and Leong ($r = -0.39$). This weak correlation may be related to differences in patient perception or experience of similar nasal function, differences in airflow turbulence, mucosal or neurosensory
differences, the impact of nasal obstruction laterality, or other currently unknown factors. 

Despite the weak correlations with patient-reported outcomes, our group does feel that PNIF has an important clinical utility. Peak nasal inspiratory flow is inexpensive and is very simple to add to the clinical work flow because medical assistants can easily learn to administer this exam. Furthermore, patients very rarely refuse to do PNIF testing and in fact are often very interested in learning about the value of their PNIF scores. Although PNIF may not be able to diagnose the presence and or degree of nasal obstruction experience by the patient, it can help to inform the provider about the total nasal air flow for an individual patient and changes in it that result from surgical intervention. In the preoperative setting, if a patient presents with a high PNIF value (greater than 120 L/min) but reports severe symptoms of nasal obstruction, we suggest that surgical decision making be based on the clinical exam and identification of surgically correctable anatomic defects (septal deviation and/or nasal valve compromise). If the patient has no obvious anatomic defects, the high PNIF helps inform the provider and patient that air is passing through the nasal cavity and a possible nonstructural or intermittent cause should be explored. In this setting the PNIF score can be helpful in educating patients about their symptoms.

In the postoperative setting, PNIF values can also be very useful. First, they can show significant improvements in nasal airflow; if they do not, critical examination for residual structural defects should be explored. This can also help inform the surgeon about the efficacy of their surgical interventions when PNIF values are tracked in all surgical patients. Furthermore, patients may continue to report symptoms of nasal obstruction without an anatomic finding to support the continued symptoms. If the PNIF value is high, it demonstrates to the provider and to the patient that air is going through the nose but that they are not perceiving this increase in nasal air flow and additional surgery will likely not improve their symptoms. Interestingly, the senior author (R.W.L.) has seen clinically that these patients, will often have symptomatic improvement over the next 6 to 12 months.

Peak nasal inspiratory flow provides complimentary information to patient-reported symptoms that can be useful for both surgical decision making and patient education. We believe that obtaining both PROMs as well as direct measures of nasal airflow are critical to understanding nasal obstruction, surgical outcomes, helping to counsel patients pre- and postoperatively, and working to further improve our surgical interventions. Despite this, we acknowledge that it is not a perfect measure, and further investigation and improvements are necessary. Additionally, a better understanding of other factors affecting the sensation of nasal obstruction, such as nasal sensory feedback and mucosal cooling, is needed.

CONCLUSION

Peak nasal inspiratory flow is a rapid, cheap, and easily performed test with good reproducibility that provides a direct measure of bulk nasal airflow and provides important complementary information to patient-reported measures of nasal obstruction. Peak nasal inspiratory flow can detect differences in nasal airflow and demonstrates both clinically and statistically significant improvements in nasal airflow following functional septorhinoplasty that is concordant with and predictive of clinically significant changes in NOSE scores. Despite this, we find only very weak correlations between the two measures, likely owing to individual differences in the experience of their nasal airflow. Nonetheless, PNIF provides unique and complementary information to that obtained with PROMs and is critical for evaluating, understanding, and improving the effects of our surgical techniques and helping to counsel patients both pre- and postoperatively.

Acknowledgments

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