Airflow and Patient-Perceived Improvement Following Rhinoplastic Correction of External Nasal Valve Dysfunction

Tom Palesy, BSc(Med)Hons; Eleanor Pratt, BA, BSc; Nadine Mrad, MAppSc(MBT); George N. Marcells, MD; Richard J. Harvey, MD

IMPORTANCE External nasal valve dysfunction (ENVD) is a common cause of nasal obstruction. Although many techniques are described to help correct ENVD, evidence of the objective changes in the airway achieved by these interventions is mainly unknown.

OBJECTIVE To document the airway changes in patients with ENVD by comparing subjective and objective measures obtained before and after rhinoplasty.

DESIGN, SETTING, AND PARTICIPANTS Prospective case series with validated subjective and objective outcomes at a tertiary rhinologic center in Sydney, Australia. We included 19 patients with nasal obstruction and clinically diagnosed ENVD from January 2012 to May 2013.

INTERVENTIONS Functional reconstructive rhinoplasty involving lateral crural underlay strut grafts using costal cartilage or lateral crural cephalic turn-in maneuvers performed to correct ENVD.

MAIN OUTCOMES AND MEASURES Objective assessment included nasal peak inspiratory flow, nasal airway resistance, and minimum cross-sectional area. Subjective assessment included a visual analog scale for nasal obstruction, the 22-item Sinonasal Outcome Test, the Nasal Obstruction Symptom Evaluation Scale, and the 36-Item Short Form Health Survey, version 2. A 13-point Likert scale was also used to assess overall function and cosmesis. Objective data and visual analog scale scores were obtained before and after decongestion at baseline and 6 months after surgery.

RESULTS Mean (SD) age of the patients undergoing assessment was 33.3 (12.4) years; 13 patients (68%) were female. Significant improvement was observed in scores for the Sinonasal Outcome Test (mean [SD] change, 0.85 [0.96]), Nasal Obstruction Symptom Evaluation Scale (mean [SD] change, 30.53 [26.14]), and overall function (median [25th-75th percentiles] change, −6.5 [−7.0 to 1.0]) and cosmesis (median [25th-75th percentiles] change, −4.0 [−8.0 to 1.0]) (P < .01). The mean (SD) nasal peak inspiratory flow increased from 102.6 (45.6) to 124.0 (52.9) L/min (P < .01). Median (25th-75th percentiles) nasal airway resistance showed no significant change (from 0.296 [0.237-0.414] to 0.292 [0.267-0.371] Pa/cm³/s; P = .92). The minimum cross-sectional area also showed no significant change (mean [SD], from 1.188 [0.407] to 1.229 [0.336] cm²; P = .69).

CONCLUSIONS AND RELEVANCE Contrary to common belief, successful rhinoplasty had little effect on structural shape or resistance in ENVD, but symptoms improved with changes in collapsibility as defined by the nasal peak inspiratory flow. The need to reconstruct lateral wall support is reinforced by the data presented.

LEVEL OF EVIDENCE 4.
The nasal valve was identified in 1903 by Mink and is described as the narrowest point for airflow. The nasal valve can be divided anatomically into an internal nasal valve (INV) and an external nasal valve (ENV). The ENV, anterior to the INV, normally has a more lateral boundary than the INV. On the medial side, the ENV is bound by the caudal nasal septum and medial crus of the lower lateral cartilage; on the lateral side, it is bound by the lateral crus of the lower lateral cartilage and the fibrofatty tissue of the alar rim. The floor consists of the nasal sill and medial footplate of the lower lateral cartilage. In the normal physiological state, the INV is the site of greatest resistance in a healthy nasal airway. The diameter of the nasal passage is the most important variable in determining nasal airflow. Nasal airflow can be explained by Poiseuille's law ($Q = \frac{\pi Pr^4}{8\eta l}$), which states that small decreases in the radius can have a large effect on flow. In addition, acceleration of air through the ENV results in a decrease in intranasal pressure; this phenomenon, named the Bernoulli principle, has been previously discussed in the literature. The inward force generated by this pressure gradient is balanced by the supporting cartilaginous and fibrous components, maintaining patency of the ENV and allowing normal air entry into the nose. This process is especially true when the ENV becomes the restriction point because patency is not the normal state, and the lateral structures are held only by the strength of the cartilage and indirectly by ligamentous attachments to the piriform aperture. This process is not true for the INV, in which the upper lateral cartilages have direct, firm chondro-osseous attachment and bear the narrowest point for most patients with normal structures. External nasal valve dysfunction (ENVD) results when the ENV is narrower and obstructs normal breathing. This obstruction leads to symptoms of reduced airflow, such as dyspnea, pressure, and fullness in the nose. External nasal valve dysfunction may be classified as static or dynamic. Static ENV stenosis causes a constant obstruction that results from a greater intranasal pressure required to facilitate airflow. Dynamic ENV collapse causes more noticeable obstructive symptoms on inspiration at lower transmural pressures. Both types of dysfunction are not mutually exclusive; the narrower ENV in stenosis produces a greater Bernoulli effect, which may result in ENV collapse. Thus, separating patients into either group exclusively is not practical or relevant, and the clinical concept of ENVD to define this interrelation is used within our practice. Surgery to correct ENVD aims to overcome the intranasal pressure changes and prevent nasal obstruction. Techniques focus on the lower lateral cartilages by adding support with grafts or using sutures to achieve elevation and external rotation.

Rhee and Kimbell questioned whether increasing the diameter of the ENV or improving the rigidity contributed the most to improvements after nasal valve surgery. The aim of this study was to document the airway changes in patients before and after ENVD surgery using subjective and objective outcomes. It was hypothesized that functional rhinoplasty to correct ENVD changes the objective findings and improves symptoms. An attempt to define the changes in the physiological features of airflow following successful ENVD surgical interventions might better guide future surgical interventions.

Methods

This study was approved by the Human Research Ethics Committee of St Vincent’s Hospital. Data were collected as reidentifiable data (for follow-up reasons). The study data were part of an audit of prospectively collected data performed as part of routine care for patients undergoing surgery from January 2012 to May 2013. We recruited patients with nasal obstruction and clinically diagnosed ENVD undergoing functional reconstructive rhinoplasty at a tertiary rhinologic center in Sydney, Australia. Patients underwent a lateral crural cephalic turn-in alone if they underwent a primary intervention (Figure 1) or a lateral crural underlay strut graft using costal cartilage if they underwent a revision procedure (Figure 2).

Patient-Reported Outcome Measures

A visual analog scale (VAS) asked patients to rate their ease of breathing on each side on a scale of 0 to 100 mm, where 0 mm indicates not blocked and 100 mm indicates totally blocked. A number was then obtained from 0 to 100 for severity of nasal obstruction on each side. Patients also completed the validated Nasal Obstruction Symptom Evaluation (NOSE) Scale, 22-item Sinonasal Outcome Test (SNOT-22),7 and 36-Item Short Form Health Survey, version 2 (SF-36v2). A sinonasal obstruc-
tion score was isolated from the SNOT-22 based on the component of the questionnaire that asked specifically about symptoms of nasal obstruction. Functional and cosmetic anchor scores were obtained by asking patients to rate the overall nasal function and external appearance of their nose, respectively, on a 13-point Likert scale from −6 (terrible) to 0 (neither good nor bad) to +6 (excellent).

Objective Assessment of Airflow
Nasal peak inspiratory flow (NPIF) was measured with the patient seated and using a nasal inspiratory flow meter (In-Check; Clement Clarke International) with an attached anesthetic mask. A tight seal was ensured without compressing the external nares, and the patient was instructed to take a maximal forced inspiratory effort through the nose with the mouth closed. The best recorded result of 3 attempts was used according to previous studies.9-11 Nasal airway resistance (NAR) was measured by active anterior rhinomanometry with a fixed reference level of 150 Pa (NR6; GM Instruments) as per the international standardization of rhinomanometry.12 The patient was seated and allowed to rest for 15 minutes before testing, which was performed in a climate-controlled room. An airtight anesthetic mask was held by the patient over the nose with the nostril opposite the testing side sealed. The patient was instructed to breathe smoothly and consistently through the nose with the mouth closed while the measurements were recorded. The other side was then tested using the same method. Once both sides were tested, the entire process was repeated until 2 consistent baseline total NAR measurements were produced.13 The minimum cross-sectional area (MCA) was measured with an acoustic rhinometer (A1; GM Instruments). Patients were seated upright, and the sound tube was applied to the caudal end of the nostril with the appropriately sized nose piece. Once an airtight seal was established, the patient was instructed to breathe in and hold the breath. This process was repeated at least 3 times until 2 consistent MCA results were obtained.14 The process was then repeated for the other side. Baseline VAS scores and objective data were collected, followed by application of a nasal decongestant (500 μg of oxymetazoline hydrochloride per nostril). Patients were asked to rest for 15 minutes while completing the NOSE, SNOT-22, and SF-36v2 questionnaires. After 15 minutes, postdecongestion VAS and objective data were collected. Decongestion allowed separation of the mucosal and structural determinants of breathing. Decongestant application reduces the effects of mucosal tissue in the nose. Postdecongestion data therefore best represented the effect of structural components on nasal function. All the subjective and objective data measured before and after decongestion formed the complete nasal airway assessment, which was conducted before and after surgery.

Statistical Analysis
Commercially available software (SPSS, version 21; SPSS, Inc) was used to perform the statistical analysis. A 2-tailed paired-sample t test was used to analyze preoperative and postoperative values for VAS, NOSE, SNOT-22, and SF-36v2 scores and NPIF and MCA values. A Wilcoxon signed rank test was used to analyze anchor scores for function and cosmesis, sinonasal obstruction score, and NAR values. Results are expressed as mean (SD) for parametric data and median (25th-75th percentiles) for nonparametric data.

Results
Nineteen patients were included for assessment. Mean age was 33.3 (12.4) years (range, 16.4-60.9 years), and 13 patients (68%) were female. The mean body mass index (calculated as weight in kilograms divided by height in meters squared) was 22.9 (3.3); height, 166.5 (10.8) cm; and weight, 64.1 (14.9) kg.

Baseline Patient-Reported Outcome Measures
Patients with ENVD rated an elevated sensation of obstruction on the VAS for the left and right sides (mean scores, 46.2 [23.8] and 48.4 [23.5], respectively) (Table 1). After decongestant application, they rated less obstruction, but the VAS for the left and right sides remained above the reference range (30.3 [24.0] and 35.3 [25.2], respectively). Other symptoms of nasal obstruction were also present as indicated by an elevated mean NOSE score (60.53 [21.60]). Sinonasal quality of life was also worse, with elevated mean SNOT-22 scores (1.59 [0.78]). General findings for quality of life were within the reference range.
Median anchor scores for overall function and cosmesis were poor (−3.0 [−4.0 to −2.0] and −2.0 [−4.0 to 0.3]). The median sinonasal obstruction score from the SNOT-22 indicated increased obstruction among the patients with ENVD (3.0 [2.0–4.0]) (Table 1).

### Baseline Objective Measures

Baseline mean NPIF was low in the patients with ENVD (94.2 [41.8] L/min). Following decongestion, mean NPIF remained below reference values (102.6 [45.6] L/min) (Table 2). Total median NAR was elevated before decongestion (0.363 [0.306–0.519] Pa/cm3/s) and improved after decongestion (0.296 [0.237–0.414] Pa/cm3/s) (Table 3). The median NAR on the left side was above the reference value before (0.763 [0.598–1.097] Pa/cm3/s) and after (0.595 [0.447–0.785] Pa/cm3/s) decongestion. Similar baseline median NAR results were found on the right side (0.713 [0.505–0.992] and 0.616 [0.478–0.845] Pa/cm3/s, respectively). Total mean MCA was below the expected value before (1.065 [0.365] cm2) and after (1.188 [0.407] cm2) decongestion. Unilateral mean MCA improved following decongestion but remained below the reference values on the left (0.548 [0.198] to 0.601 [0.212] cm2, respectively) and right (0.517 [0.256] to 0.587 [0.268] cm2, respectively) sides (Table 4).

### Postoperative Changes

A significant improvement in the patient-related outcome measures following rhinoplasty to correct ENVD (Table 1) was found. General quality of life improved but did not show a significant change. The VAS score on the left side showed less change compared with the VAS score on the right side. Similar results were found when comparing mean postdecongestion VAS changes on the left side (from 30.3 [24.0] to 25.0 [23.1]; P = .14) with those on the right side (from 35.3 [25.2] to 16.2 [7.4]; P < .01). Mean pre-decongestion NPIF improved significantly by more than the minimal clinically important difference (94.2 [41.8] vs 116.6 [44.4] L/min; change, −22.4 L/min), whereas total NAR and total MCA showed no significant changes (Table 2). Change in overall postdecongestion values demonstrated similar results.
Moore and Eccles reviewed the studies incorporated objective measures in assessment. Most looked at 44 studies of nasal obstruction found that only 27% of studies incorporated objective measures in assessment. Most looked at MCA changes. Haavisto and Sipilä showed that dynamic ENVD maybe underestimated because narrowing of the nasal airway resistance was measured in this study during apnea; the true extent of preoperative stenosis in a patient with ENVD alone were identified, and none used objective outcomes. In 2010, Rhee et al. achieved a consensus that patient-reported outcome measures were more important than objective outcome measures, and the general use of objective measures has been discouraged in clinical settings owing to poor correlation with subjective outcomes. A review by Rhee et al. that looked at 44 studies of nasal obstruction found that only 27% of studies incorporated objective measures in assessment. Most studies of objective outcomes following rhinoplasty have focused on a single measurement. Moore and Eccles reviewed the objective evidence of the efficacy of septal surgery. Seven studies showed improvement in NAR and 6 studies showed improvement in MCA. Only 1 study reported an improvement in NPIF, but this report potentially reflects a poor choice of outcome because NPIF is very sensitive to collapse and not to airway symmetry. A study by Pirilä and Tikanto was one of only two that used NAR and MCA to assess patient outcomes. In contrast to the present study, those authors found that both measurements improved significantly but for correction of septal deformities.

Although the concept of widening the nasal passage may improve patency, it may also lead to undesirable cosmesis. Minimum cross-sectional area was measured in this study during apnea; the true extent of preoperative stenosis in a patient with dynamic ENVD may be underestimated because narrowing occurs during inspiration. Varying results in past studies have looked at MCA changes. Haavisto and Sipilä showed that the MCA increased following surgery to correct septal deviation. In contrast to ENVD, septal deviation causes narrowing of the nasal passage whether the patient is breathing or apneic, so these results for MCA are expected. Zoumalan and Constantinides looked at the changes in subjective outcomes and MCA in 31 patients undergoing septrhinoplasty. They found that the MCA did not significantly change with subjective improvement, but the location of the MCA and the volume of the nasal cavity did change. Grymer also found that cosmetic rhinoplasty decreased the MCA. The extra cartilage that is embedded in the lateral nasal wall to reinforce the ENV could result in the nasal passage becoming stiffer but narrower.

A relationship between NAR and MCA may exist. Haavisto and Sipilä found that the NAR increased postoperatively in their patients. They proposed that the shape of the MCA may be just as important as the MCA value because the shape has consequences for airflow and NAR, similar to the findings by André et al. The values for rhinomanometry that did not significantly change may also be explained by the surgical technique. Rhinomanometry measures the NAR of the entire nasal passage. When making the structural components of the ENV more rigid, other components of the lateral nasal wall, such as the INV, may be affected. The effects of the interventions described cannot be isolated, and the surgical maneuvers likely affect components of both the INV and ENV. Apaydin described the lateral crural turn-in flap technique and addressed the effect of lower lateral cartilage surgery on the angle of the ENV. Apaydin also emphasized the need to combine the technique with others, such as spreader grafts. Patients undergoing rhinoplasty often present with a number of problems, and more than 1 surgical technique is applied. Improvements are difficult to assess in isolation with a single technique, which is an aspect of rhinoplasty research that is often acknowledged. In addition, a compromise must be made between improving nasal function and preserving or improving cosmesis during ENVD surgery. In this study, the improvements in subjective results show that rhinoplasty can improve function and cosmesis in patients with ENVD; however, not all constructs of breathing demonstrate objectively measured change.

### Discussion

Spielmann et al. conducted a systematic review in 2009 of outcomes following surgical management of ENVD. Only 7 studies of ENVD alone were identified, and none used objective outcomes. In 2010, Rhee et al. achieved a consensus that patient-reported outcome measures were more important than objective outcome measures, and the general use of objective measures has been discouraged in clinical settings owing to poor correlation with subjective outcomes. A review by Rhee et al. that looked at 44 studies of nasal obstruction found that only 27% of studies incorporated objective measures in assessment. Most studies of objective outcomes following rhinoplasty have focused on a single measurement. Moore and Eccles reviewed the objective evidence of the efficacy of septal surgery. Seven studies showed improvement in NAR and 6 studies showed improvement in MCA. Only 1 study reported an improvement in NPIF, but this report potentially reflects a poor choice of outcome because NPIF is very sensitive to collapse and not to airway symmetry. A study by Pirilä and Tikanto was one of only two that used NAR and MCA to assess patient outcomes. In contrast to the present study, those authors found that both measurements improved significantly but for correction of septal deformities.

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### Table 4. Unilateral Objective Changes After Rhinoplasty

<table>
<thead>
<tr>
<th>Predecongestion</th>
<th>Baseline</th>
<th>Postoperative</th>
<th>Change</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left NAR, median (25th-75th percentiles), Pa/cm²/s</td>
<td>0.763 (0.598 to 1.097)</td>
<td>0.710 (0.572 to 0.789)</td>
<td>0.068 (−0.114 to 0.304)</td>
<td>.30</td>
</tr>
<tr>
<td>Right MCA, mean (SD), cm²</td>
<td>0.548 (0.198)</td>
<td>0.547 (0.181)</td>
<td>0.001 (0.197)</td>
<td>.99</td>
</tr>
</tbody>
</table>

### Postdecongestion

<table>
<thead>
<tr>
<th>Predecongestion</th>
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<th>Change</th>
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<tbody>
<tr>
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<td>0.572 (0.502 to 0.822)</td>
<td>0.056 (−0.077 to 0.206)</td>
<td>.40</td>
</tr>
<tr>
<td>Right MCA, mean (SD), cm²</td>
<td>0.517 (0.256)</td>
<td>0.630 (0.191)</td>
<td>−0.113 (0.274)</td>
<td>.09</td>
</tr>
</tbody>
</table>

Abbreviations: MCA, minimum cross-sectional area; NAR, nasal airway resistance.
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Author Contributions: Dr Palesy had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Pratt, Harvey.
Acquisition, analysis, or interpretation of data: Palesy, Mrad, Marcells, Harvey.
Drafting of the manuscript: Palesy, Harvey.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Palesy, Harvey.
Obtained funding: Harvey.
Administrative, technical, or material support: Palesy, Pratt, Mrad, Harvey.
Study supervision: Marcells, Harvey.

Conflict of Interest Disclosures: Dr Harvey has served on an advisory board for GlaxoSmithKline and Schering Plough; has served as a consultant with Medtronic, Olympus, and Stallergenes; has served on speakers bureaus for Arthrocare and Merek Sharp Dolme; and has received grant support from NeillMed. No other disclosures were reported.

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