PROBLEM/OVERVIEW

Nasal obstruction is a complaint frequently encountered in otolaryngology. This obstruction can occur as a result of underlying inflammatory or anatomic pathologic conditions. Inflammatory pathologic conditions include allergic rhinitis, nasal polyps, and chronic rhinosinusitis. Among the anatomic causes are septal deviation, turbinate hypertrophy, and nasal valve compromise (NVC). The nasal valve was first described by Mink in the early twentieth century but has received increasing attention recently. It is the narrowest portion of the nasal airway and, therefore, where the most resistance to airflow occurs. It can be divided into external and internal portions (Fig. 1). The external nasal valve is the area in the nasal vestibule formed by the alar rim, nasal sill, caudal septum, and medial crus of the lower lateral cartilage. The
The internal nasal valve is the area bound by the caudal edge of the upper lateral cartilage, nasal septum, head of the inferior turbinate, and nasal sill (Fig. 2) and is located approximately 1.3 cm from the nares.² It is proposed that the nasal valve serves as a regulator to prevent airflow from exceeding the capacity of the nose to warm and humidify inspired air.⁴,⁵

Problems with nasal airflow occurring at the nasal valve exhibit both static and dynamic properties. There can be fixed anatomic obstruction caused by abnormalities of any of the structures that contribute to the makeup of the nasal valve, including the septum, turbinates, and nasal cartilages. These abnormalities can exist as a result of traumatic, congenital, or iatrogenic causes.⁶ There can also be a dynamic component to NVC. Bernoulli’s principle states that air flowing into narrowed segments accelerates, leading to a decrease in intraluminal pressure. This phenomenon can contribute to dynamic collapse of the lateral nasal wall during inspiration, leading to further compromise of the nasal valve region resulting in obstruction of nasal airflow.²,⁷ The difficulty in evaluating patients with NVC is determining whether the problem is the small diameter of the nasal valve causing fixed obstruction or whether the lack of rigidity of the lateral nasal wall leading to dynamic collapse is the issue because the surgical approach may differ depending on the underlying problem.
Functional rhinoplasty has emerged in the literature as a collective term for procedures that address nasal obstruction occurring at the nasal valve. This term serves to differentiate procedures directed at correcting nasal obstruction from those that address the cosmetic appearance of the nose and includes techniques that target the nasal septum (dorsal and caudal portions), lateral nasal wall, and the soft tissue nasal vestibule. However, in reality, the structure and function of the nose are intimately related. Therefore, procedures performed with the intent to change the cosmetic appearance of the nose can also affect its function and vice versa. One must be cognizant of this relationship when counseling patients and undertaking nasal surgery for either cosmetic or functional purposes. Functional rhinoplasty and nasal valve repair are commonly used as synonymous terms and, thus, are used interchangeably for the purposes of this article.

EVIDENCE-BASED CLINICAL ASSESSMENT

History and Physical Examination

The main symptom of NVC is decreased nasal airflow. However, there are a myriad of conditions that can present with nasal obstruction. These conditions include infectious, inflammatory, and neoplastic conditions, and the treatment varies depending on the underlying cause. Therefore, a detailed history should include the timing, onset, seasonal variation, laterality, prior history of nasal trauma or surgery, and exacerbating or alleviating factors of nasal obstruction. It is also important to determine the presence or absence of associated symptoms, such as epistaxis, anosmia, rhinorrhea, or postnasal drainage. This differentiation can help identify or rule out causes of nasal obstruction that are not attributable to pathologic conditions of the nasal valve.

There is currently no gold standard objective test to diagnose NVC; it remains a clinical diagnosis. A general assessment of the external appearance of the nose can identify problems with the potential to cause nasal obstruction, such as nasal tip ptosis, a narrow midvault, an inverted-V deformity, or narrowed nostrils. Additional physical examination techniques can identify abnormalities of the lateral nasal wall related to weak or malformed upper and/or lower lateral cartilages. Specifically, findings on physical examination suggestive of NVC include visible inspiratory collapse of the lateral nasal wall or alar rim. Also, subjective and audible improvement in nasal airflow during a Cottle maneuver (lateral retraction of the cheek) or modified Cottle maneuver (intranasal lateralization of the lateral nasal wall) is consistent with NVC.

Anterior rhinoscopy is an adequate intranasal evaluation of the nasal valve region and will provide information about the position of the septum and size of the turbinates. Nasal endoscopy can be useful to rule out other causes of nasal obstruction not attributable to NVC if the diagnosis is uncertain but is not routinely indicated. If surgery is being planned or considered, preoperative photography can be helpful for patient counseling, preoperative planning, and documentation, even in cases when the surgical intent is purely functional, but this is especially true if surgery is being undertaken for both functional and cosmetic purposes.

In patients with NVC, it can be difficult to determine which components of the nasal valve to address because there are several anatomic structures that contribute. However, identifying the problematic area can help guide the surgeon in deciding which procedure is likely to provide the most benefit. In general, functional rhinoplasty techniques target a specific area or component of the nasal valve. Also, determining whether obstruction is resulting more from fixed or dynamic obstruction can help the surgeon decide between a procedure intended to increase the actual diameter of the nasal valve or one that aims to strengthen a weak lateral wall or alar rim.
Subjective Measures of Nasal Obstruction

Traditionally, a common method of assessing nasal obstruction and reporting outcomes of functional nasal surgery is subjective patient-reported measures. For assessing the efficacy of a surgical intervention, a comparison of preoperative and postoperative results is often used. In addition, there has been a trend in medicine toward evaluating quality of life (QOL) in the assessment of disease processes and the efficacy of treatment.\textsuperscript{12} Generic health-related QOL can be measured using scales, such as the Medical Outcomes Study Short Forms (SF-12 and SF-36).\textsuperscript{13–15} However, disease-specific QOL measures can be superior to generic QOL instruments because they may be more sensitive for the detection and quantification of small changes.\textsuperscript{16} There are validated QOL instruments specific for rhinologic disease, such as the Rhinosinusitis Disability Index,\textsuperscript{17,18} Rhinoconjunctivitis Quality of Life Questionnaire,\textsuperscript{19,20} and the Sinonasal Outcomes Test,\textsuperscript{21} each of which has been used in the past for evaluating septal or nasal valve pathologic conditions. These instruments all include nasal obstruction in their evaluation; however, their primary purpose is the evaluation of inflammatory nasal disease, which may secondarily result in nasal obstructive symptoms.

Nasal obstruction symptom evaluation scale

The QOL measure most relevant to structurally based nasal valve pathologic conditions is the Nasal Obstruction Symptom Evaluation scale, a disease-specific quality-of-life instrument developed for the assessment of nasal obstruction with evidence in support of its validity, reliability, and sensitivity.\textsuperscript{22} With this instrument, patients are asked to rate the severity of several nasal symptoms and the results are summed and scaled. Its original use was in patients undergoing septoplasty who demonstrated an improvement in disease-specific QOL after surgery.\textsuperscript{23} Subsequent studies using the NOSE scale in patients undergoing surgery for NVC also demonstrated statistically significant improvements in disease-specific QOL.\textsuperscript{24,25}

Visual analog scales

Visual analog scales (VAS) are a common method of subjectively measuring symptoms in various conditions that have also been used as an evaluation method and outcome measure in nasal obstruction. In VAS, patients are asked to rate their experience of symptoms on a linear scale ranging from no obstruction to complete obstruction.\textsuperscript{26} Multiple studies have shown improvement in VAS for nasal obstruction after nasal valve repair.\textsuperscript{4,27} One potential advantage of VAS over other objective tests is that, for patients with unilateral symptoms, VAS for each side of the nasal cavity can be assessed separately. Several studies show better correlation between VAS for nasal obstruction and objective measurement techniques when unilateral VAS is used.\textsuperscript{28–30}

Objective Measures of Nasal Obstruction

Aside from subjective measures, there is also interest in the development and implementation of validated objective measures to assist in preoperative evaluation and to better assess surgical outcomes. Several techniques have been developed and validated to date. Of these, rhinomanometry and acoustic rhinometry (AR) have been used most frequently.\textsuperscript{4,27} Rhinomanometry allows the determination of nasal airway resistance by simultaneously measuring transnasal pressure drop and nasal airflow.\textsuperscript{31} This technique has been used to objectively document changes in nasal resistance after nasal valve surgery. However, it is not in widespread use because of several limitations. These drawbacks include the inability to precisely locate the area of obstruction and the need for specialized equipment and a well-trained operator.\textsuperscript{32}
AR for nasal obstruction
AR is a technique that uses the measurement of deflected sound waves to provide an estimate of the cross-sectional area (CSA) of the nasal cavity as a function of the distance from the nostrils. AR is relatively easy to perform and is quick and noninvasive. It too has limitations, however. Similar to rhinomanometry, it does require specialized equipment and an experienced operator. Also, the results obtained are sensitive to variations in technique and testing conditions. Another known limitation of AR is that it overestimates CSA in areas beyond 5 cm from the nostrils or after constricted regions or areas of drastic changes in nasal anatomy. The advantages of AR make it one of the most common objective methods used to evaluate nasal patency. However, it has not achieved widespread clinical use because of the limitations noted previously.

Imaging studies for nasal obstruction
Imaging studies, such as computed tomography (CT) or magnetic resonance imaging (MRI) scans, can have a role in the evaluation of nasal obstruction, with utility in evaluating infectious, inflammatory, or neoplastic disease, but have a limited role in the evaluation of nasal valve pathologic conditions specifically. CT imaging can be used as a method of measuring the nasal valve angle (between the septum and upper lateral cartilage). When used for this purpose, the most accurate measures are obtained from views other than the traditional coronal view, which may underestimate the true nasal valve angle. Specifically, a modified view known as the nasal base view, which uses slices oriented perpendicular to the approximated acoustic axis of the nose, provides the most accurate information about the nasal valve angle. This technique has not been adopted for widespread use because there is subjectivity in the selection of the acoustic axis and the need to reformat CT images into a nonstandard view. There is also a lack of evidence in regard to its reproducibility, although studies comparing this method with AR-derived data show good correlation in the measurement of the nasal valve area.

Computational fluid dynamics for nasal obstruction
Computational fluid dynamics (CFD) is emerging as a new method to evaluate nasal airflow and resistance as well as other physiologic parameters important to the function of the nose, including particle deposition and air conditioning. CFD is a technology used widely in engineering as a way to model the motion of fluids. For this technique, anatomically accurate 3-dimensional computational models of patients’ nasal cavities are generated from imaging data captured by CT or MRI (Fig. 3). CFD software programs can then be used to obtain computed measures of airflow, resistance, heat transfer, and air humidification.

The ability to study multiple parameters of interest under different simulated conditions with minimal cost or inconvenience to patients makes CFD an attractive method to investigate nasal function. A further benefit of CFD over other objective measures of nasal function is the ability to determine airflow and other factors of interest at precise anatomic locations rather than in the nasal cavity as a whole as is done with other methods. Another exciting extension of CFD technology is the ability to do simulated surgery on the digital models. The computed nasal geometry can be virtually modified in a manner reflecting surgical techniques, and, subsequently, new patterns of airflow and heat and water vapor transport can be calculated.

There are also limitations with current CFD technology. There is additional cost to obtain the necessary imaging studies. Also, at present, the process of producing the digital models is time and labor intensive, although as technology has advanced,
the cost and time to build models has declined and is expected to continue to do so. Further, although models can be built from either CT or MRI scans, the models based on CT imaging give better results because of better resolution, thus subjecting patients to radiation exposure that they would otherwise not receive. CFD also makes assumptions that are reasonable in many cases but may not always hold true, such as laminar flow of air within the nasal cavity, fixed and rigid nasal cavity walls, and steady-state airflow.31

CFD analysis with respect to nasal function is still in its early stages and most studies are limited in scope and number. Further studies are needed to fully validate the method and elucidate the correlation between CFD-derived parameters and actual clinical and patient-reported data. However, this exciting technology holds great promise and may prove to be a valuable resource in objective preoperative evaluation, surgical planning, and analysis of surgical outcomes for surgeons performing functional rhinoplasty.

Controversy in Outcome Measures

An area of conflict in many medical conditions is the relationship between what patients subjectively report and what is objectively observed by physicians or measured by objective tests.26 This point is especially true in the area of nasal obstruction. This issue is complex and is not explained by nasal resistance and airflow alone. Nasal sensation also plays a large role, as demonstrated by studies whereby nasal sensation has been blocked with local anesthetics in the nasal cavity or vestibule, with studies reporting both increases and decreases in perceived nasal airflow without any measured effect on nasal resistance.41 This finding suggests that the sensation of nasal airflow may, under certain circumstances, be independent of any objectively measurable change in nasal resistance. Therefore, some investigators have made the argument that subjective patient-reported measures are the most important factor when evaluating nasal obstruction.2,41,42

Ideally, a gold standard objective test would be quantifiable, reproducible, and have a strong correlation with subjective measures of nasal airflow.26,31 As described

Fig. 3. Digital nasal airway model for use in CFD analysis.
earlier, such a test has not been reported to date. Independently, subjective and objective tests have shown validity and reproducibility but there is weak correlation when compared side by side.\textsuperscript{26,41,43} It has been proposed that the different methods of assessment are capturing different aspects of the nasal airway and, therefore, may be complementary.\textsuperscript{26} Although an ideal test of nasal patency remains elusive, it may prove to be the case in the future that a combination of testing methods with both subjective and objective components best approaches the conditions mentioned earlier. In the meantime, the debate is ongoing regarding the role of subjective and objective measures in the evaluation of nasal obstruction.

### EVIDENCE-BASED SURGICAL TECHNIQUE

With respect to evidence for the efficacy of functional rhinoplasty, there have been 3 important contributions to the literature in recent years: 2 systematic reviews and 1 clinical consensus statement.

In 2008, Rhee and colleagues\textsuperscript{27} conducted a systematic review of the existing literature on the efficacy of modern-day rhinoplasty techniques for the treatment of NVC. Their review spanned a 25-year period, from 1982 to 2007. Forty-four articles met their inclusion criteria and were each assigned a level of evidence.

- Only 2 of the studies, both cohort studies that compared one surgical technique to another, achieved level 2b evidence.
- The remaining 42 studies were all level 4 evidence and were of varying quality.
- Procedures performed in the reviewed studies included spreader grafts, butterfly onlay grafts, alar batten grafts, dorsal onlay grafts, alar cartilage relocation, alar rim grafts, suture suspension, flaring sutures, columellar struts, and onlay grafts.
- All of the included articles were in support of the efficacy of functional rhinoplasty techniques for the treatment of NVC, with reported effectiveness ranging from 65% to 100%.
- Of the articles, only 6 (14%) reported outcomes using validated patient-reported questionnaires and 12 (27%) used objective measures, the most common objective measurement being rhinomanometry.
- In 75% of the studies, adjunctive surgical procedures were performed in combination with nasal valve surgery, including septoplasty, turbinate reduction, functional endoscopic sinus surgery, and orthognathic surgery, which diluted the ability to measure the efficacy of the functional rhinoplasty component alone.
- In all, the investigators assigned the evidence an aggregate grade C recommendation in support of functional rhinoplasty as a treatment of NVC.

An additional corroborating systematic review conducted by Spielmann and colleagues\textsuperscript{4} was published in 2009.

- The authors noted that there seemed to be a move toward the use of stronger outcome measures because most of the articles that used validated objective or subjective measures were published after 2004.
- The investigators also noted that much of the published literature on functional rhinoplasty is more concerned with technical descriptions of surgical technique rather than establishing evidence of a long-term benefit.
- The investigators concluded, similarly to the Rhee and colleagues review aforementioned, that the evidence was generally in favor of the efficacy of functional rhinoplasty. Again, this finding would correlate to an overall grade C recommendation.
The American Academy of Otolaryngology-Head and Neck Surgery’s Consensus Statement

As a reflection of the lack of cohesiveness among clinicians regarding the diagnosis and management of pathologic conditions involving the nasal valve as well as the relative lack of strong evidence in the literature, the American Academy of Otolaryngology-Head and Neck Surgery, in 2010, endorsed a clinical consensus statement aimed at addressing the ambiguities and disparities that exist regarding NVC.² It was thought that a consensus statement was more appropriate as opposed to a clinical practice guideline based on the lack of strong evidence available. The panel members, all experts in functional nasal surgery, reviewed the existing literature on NVC, including the 2 reviews previously mentioned. With regard to the literature, the panel noted that much of the difficulty in analyzing the evidence for nasal valve repair lies in the wide variety of techniques that were reported as well as the additional procedures (ie, septoplasty, turbinate reduction, or endoscopic sinus surgery) that are often done in conjunction with rhinoplasty, making it difficult to determine how much of the benefit might be attributable to these other interventions. However, they did note a consistent finding of beneficial effects of nasal valve surgery in all reviewed studies. Regarding outcome measures, there was a near consensus regarding the relative importance of patient-reported outcome measures versus objective measures in measuring the success of an intervention. The general conclusion was that patient-oriented outcomes are more important than objective outcomes.

Nonsurgical Management

Patients who have NVC and coexisting allergic or inflammatory symptoms or findings on physical examination suggestive of rhinitis may benefit from treatment of these conditions or a trial of medical therapy, such as intranasal steroids, before considering surgical intervention. However, in absence of these symptoms or findings, there is no role for medical therapy.² There are additional nonsurgical options that may be considered, including nasal dilator strips or stents.⁴⁴–⁴⁷ The ability of patients to adhere to these treatments in the long term is unknown. However, these alternatives may be a good option for patients who do not wish to pursue surgery or are not good candidates for surgery because of medical comorbidities.

BOTTOM LINE: WHAT DOES THE EVIDENCE TELL US?

Although the gold standard in evidence-based medicine is the randomized controlled trial,⁴⁸ this is often not a possibility in surgical research because of the ethical and practical difficulties of randomizing patients to different surgical procedures in a blinded fashion. Therefore, surgical outcome studies often rely on retrospective and observational studies (ie, level 2b evidence) at best, with a preponderance of level 4 and 5 evidence.⁴⁹ To date, most functional rhinoplasty studies are uncontrolled studies (level 4 evidence) of varying quality. The heterogeneity of study designs and outcome measures does not allow pooling of studies to strengthen the existing evidence. Additionally, many of the studies include simultaneous procedures aimed to correct nasal obstruction (ie, septoplasty, turbinate reduction), adding another level of complexity in analyzing the evidence because it is impossible to determine how much benefit was a result of nasal valve repair itself.

However, it is important to make the distinction between weak evidence and lack of evidence for efficacy.² Although the existing evidence is relatively weak, it does show a consistent benefit of nasal valve repair (grade C recommendation). The reported efficacy ranges from 65% to 100%⁴,²⁷; there are no studies reporting that functional...
rhinoplasty is ineffective. Studies with improved design, including comparison cohorts and using validated outcome measures, would better establish the efficacy of functional rhinoplasty for the correction of NVC.\textsuperscript{27,42}

REFERENCES