Functional Nasal Surgery

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Learning Objectives: After studying this article, the participant should be able to: (1) understand the functional significance of nasal anatomy as it relates to rhinoplasty and perform a comprehensive functional nasal assessment. (2) Identify the anatomical level of obstruction based on the authors' algorithmic approach and understand the current evidence supporting operative techniques for correcting nasal airway obstruction from septal deformity, inferior turbinate hypertrophy, internal nasal valve collapse, external nasal valve collapse. (3) Understand the current evidence supporting operative techniques for correcting nasal airway obstruction from septal deformity, inferior turbinate hypertrophy, internal nasal valve collapse, and external nasal valve collapse. (4) Appreciate the objective assessment tools for functional nasal surgery from a clinical and research perspective.

Summary: The intent of functional rhinoplasty is to improve nasal airflow (and the perception thereof) by surgically correcting the anatomical sources of obstruction in the nasal airway. Cosmetic and functional rhinoplasty are not mutually exclusive entities, and the techniques that address one area, inevitably may affect the another. The rate of functional problems after cosmetic rhinoplasty range from 15 to 68 percent with nasal airway obstruction found to be the most common indication for secondary surgery. The objective of this CME article is to provide readers with an understanding of the (1) functional components of nasal anatomy, (2) clinical functional assessment, and (3) the current evidence supporting corrective maneuvers for each component. (*Plast. Reconstr. Surg.* 150: 439e, 2022.)

FUNCTONAL ANATOMY

Prior publications have described nasal anatomy that is encountered during rhinoplasty.[1–6] A recent contribution to the body of literature was provided by Daniel and Palhazi.[7] "Form follows function," and in no area of plastic surgery is this more accurate than in rhinoplasty. The two specific anatomical structures that most commonly contribute to nasal airflow dysfunction are the septum and inferior turbinates. Characteristics of the septum, turbinate, and other structures have causative effects on airflow limitations by their influence on regional cross-sectional area within the nose (Fig. 1). The two most important regional cross-sections of potential airflow restriction are the internal nasal valve and external nasal valve.[1,5,6,8–12] These two regions are important because they normally and consistently represent the narrowest cross-sections of the nasal airway. Patients experiencing the perception of nasal obstruction often have more than one contributing anatomical factor; if only the most obvious factor is addressed, the outcome may be unsatisfactory.

Although several classification systems for septal deformities have been described, most encompass three basic categories: caudal septal deviation, concave dorsal deformity (C-shaped), and concave/convex dorsal deformities (S-shaped) (Fig. 2).[13–15] Intrinsic forces on the septum can affect its morphology; an example is the buckling effect and deviation that can occur when septal growth exceeds the limitations of the soft-tissue envelope of the nose. Extrinsic forces can lead to septal deformities as well. In these settings, the osseous articulations with

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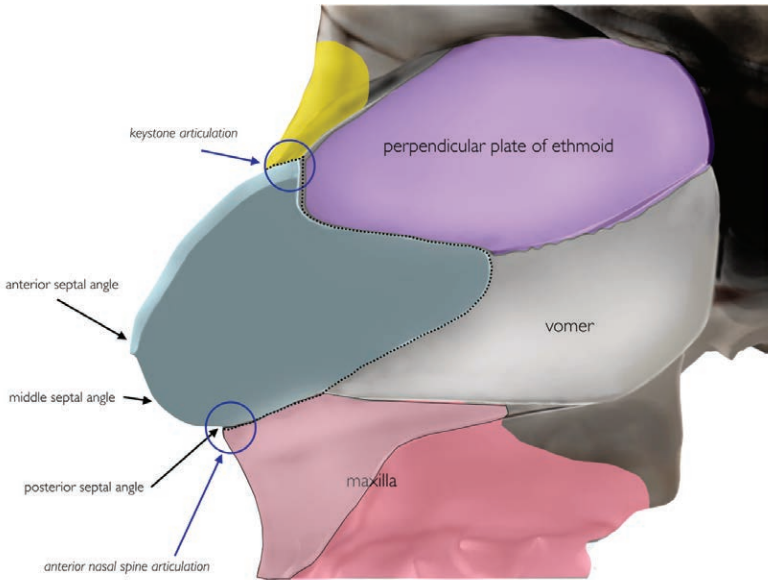

Fig. 1. Septal anatomy. The cartilaginous septum ("quadrangular cartilage") is a planar midline structure that separates the right and left nasal airways and promotes laminar airflow under normal conditions (Friedman O, Koch CA, Smith WR. Functional support of the nasal tip. *Facial Plast Surg*. 2012;28:225–230). The septum is lined by nasal mucoperichondrium. Its free border is located caudally, and it is contiguous on all remaining sides with other midline structures. Posteriorly, it is contiguous with the perpendicular plate of the ethmoid; inferiorly with the maxillary crest and vomer, and dorsally with the upper lateral cartilages and the nasal bones. The two key points of stability for the cartilaginous septum are located at the confluence with the nasal bones at the keystone region and at the anterior nasal spine where the posterior septal angle of the caudal septum is secured in the skeletal midline. The dorsal and caudal septum contribute structural support for the shape of the overlying nasal soft-tissue envelope and nasal aperture (Howard BK, Rohrich RJ. Understanding the nasal airway: Principles and practice. *Plast Reconstr Surg*. 2002;109:1128–1146, quiz 1145–1146; Ahmad J, Rohrich RJ, Lee MR. *Surgical Management of the Nasal Airway*. 3rd ed. St. Louis: Quality Medical; 2014).

the septum themselves are deformed or lateral to the facial midline and are causative of cartilaginous septal deviations (Fig. 3). Examples include the complex maxillary deformity in unilateral cleft lip, nasal pyramid angulation as seen in craniosynostosis, traumatic septal dislocations or fractures, and iatrogenic septal deformities.[16–18]

The nasal cavity contains three pairs of turbinates: superior, middle, and inferior.[19] All three turbinates are responsible for warmth, humidification, and filtration. The inferior turbinate is the largest and has immune functions because it is the first to come in contact with outside air; the immune response leads to transient and/or long-term enlargement. Enlargement of the inferior turbinate occupies space, and because the anterior head of the inferior turbinate is the inferolateral border of the internal nasal valve, it has a significant role in regulating airflow (Fig. 4).

The internal nasal valve is normally the site of minimal cross-sectional area in the nose along what is termed the "acoustic axis" (Figs. 5 and 6). The internal nasal valve angle, which is not synonymous with "internal valve" but represents the angle between the upper lateral cartilage and septum, should measure between 15 and 20 degrees. The external nasal valve is the area in the nasal vestibule formed by the alar rim, nasal sill, caudal septum, and lower lateral cartilage medial crus. The primary structural support of the external nasal valve is the upper lateral cartilage, and especially the lateral crus. Lower lateral cartilages are not as rigid as septal cartilage, as demonstrated by their pliable character, and they vary significantly among individuals in terms of their dimensions

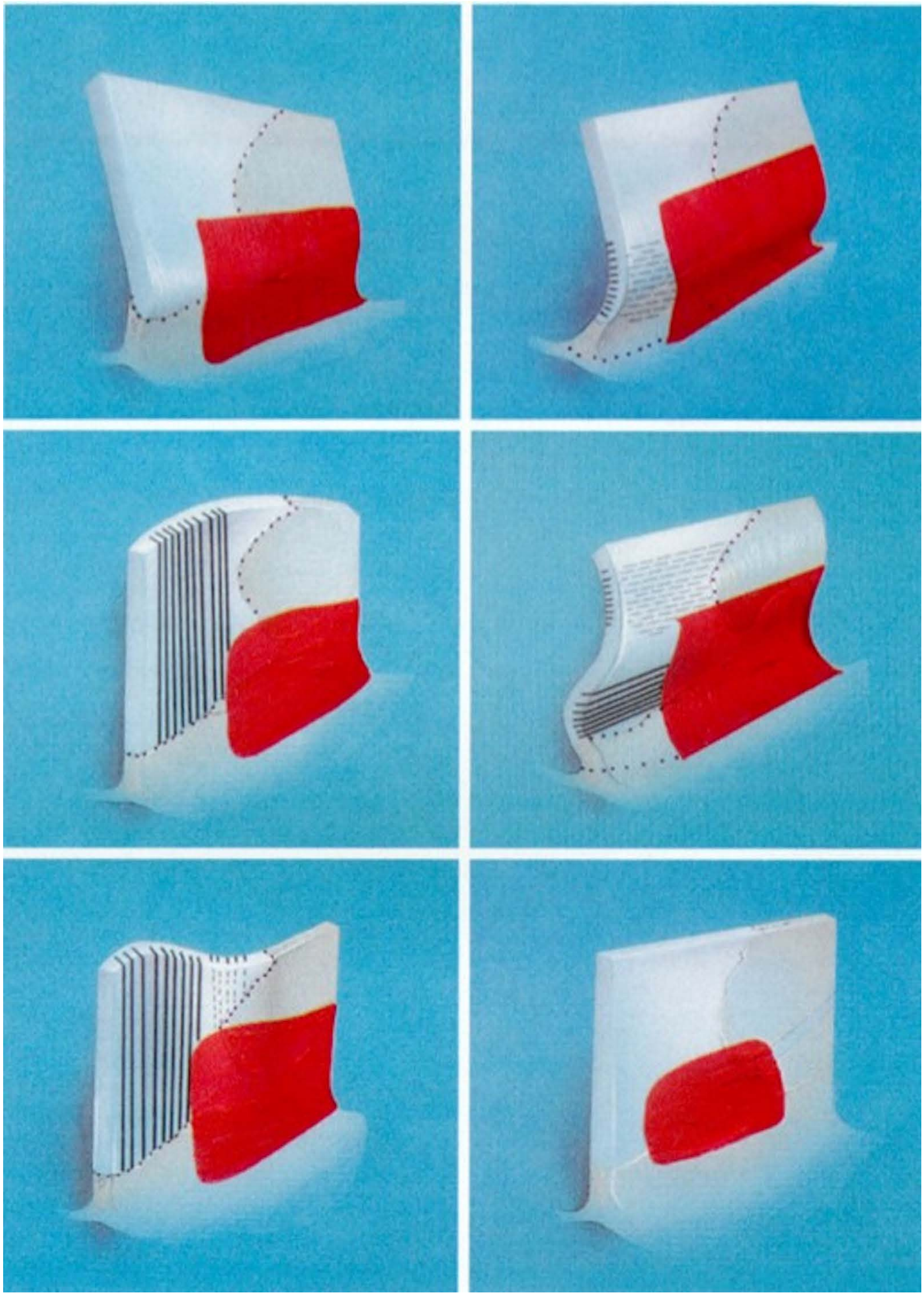

Fig. 2. Septal deformity. (Original artwork published by Guyuron B, Uzzo CD, Scull H. A practical classification of septonasal deviation and an effective guide to septal surgery. *Plast Reconstr Surg*. 1999;104:2202–2209; discussion 2210–2212. Published with permission.)

and rigidity (Fig. 7). As an anatomical component of the external nasal valve, caudal septal deviation and medial crura flaring also affect the nasal aperture by narrowing the nostril.[20] When describing these nasal valves, insufficiency refers to baseline aperture stenosis requiring greater intranasal pressure to facilitate airflow.[21,22] Alternatively, collapse refers to a structural weakness allowing the physical collapse of the valve encountered during inspiration at lower transmural pressures.[22–24] The

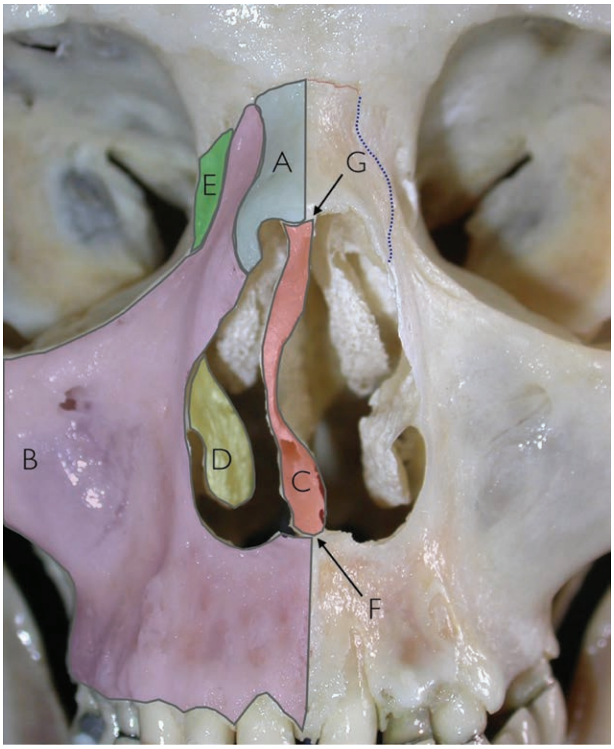

Fig. 3. Cross-sectional osseous anatomy. Regional osseous anatomy as related to the nose is shown. (*A*) Nasal bone (*light blue*). (*B*) Maxilla with frontal process of the maxilla (*purple*). (*C*) Osseous septum, which includes the vomer inferiorly and the posterior plate of the ethmoid superiorly (*red*). (*D*) Inferior turbinate bony process (*yellow*). (*E*) Lacrimal bone (*green*).

former is sometimes referred to as "static" valvular dysfunction; the latter, "dynamic."

FUNCTIONAL NASAL ASSESSMENT

The goal in functional assessment of a rhinoplasty patient is to first determine whether the patient has nasal airway obstruction and to then identify its underlying cause(s). The tools available are (1) thorough history, (2) patient-reported outcome measurement instruments, (3) physical examination, and (4) adjunct imaging. A systematic approach using these tools will help identify both nonanatomical and anatomical causes of airway obstruction.

A thorough history should include an initial understanding of the obstructive symptoms. This includes the duration and frequency of symptoms, unilateral versus bilateral obstruction, perennial versus seasonal obstruction, obstruction at rest or forced inspiration, and exacerbating or alleviating factors. The presence of sinus headaches or sinus infections requiring antibiotics may suggest a medical approach for management. Frequent nose bleeds are a valuable detail that suggest underlying abnormality or chronic dry mucosa. Frequency and efficacy of previously used medications may indicate obstructive cause. Rhinitis is a common medical cause for nasal obstruction (Table 1). Patients with chronic runny nose

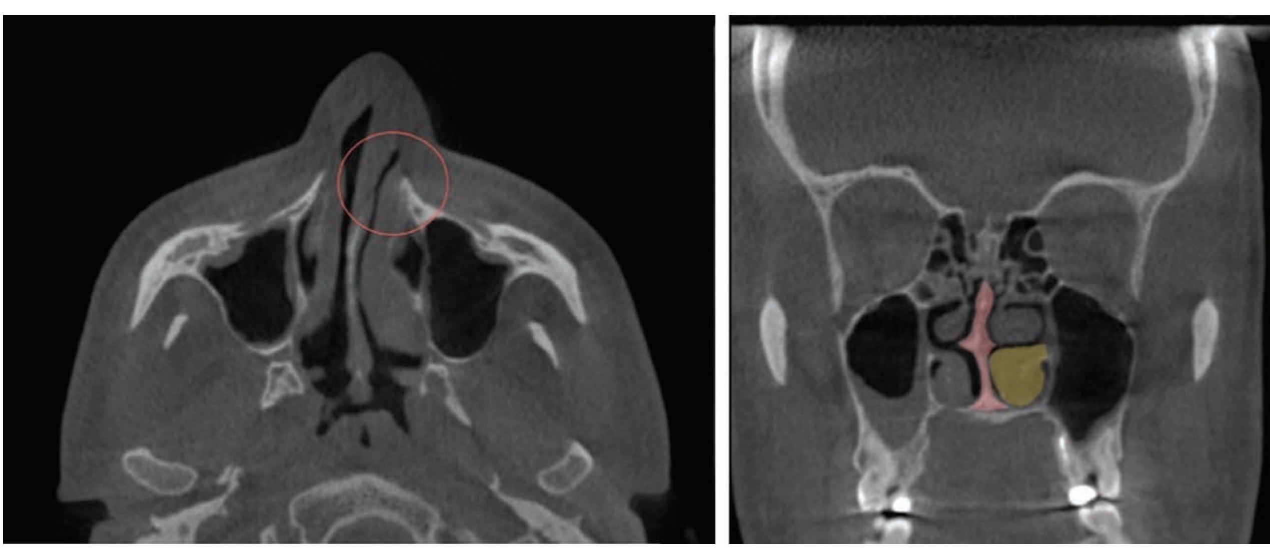

Fig. 4. Inferior turbinate hypertrophy. The inferior turbinate made up of long, thin, curled bone that attaches to the lateral nasal wall and extends medially into the nasal cavity. It is covered by a mucosal layer made up of pseudostratified columnar ciliated respiratory epithelium. Between mucosa and concha bone is erectile tissue composed of venous sinusoids that drain the capillary system of the nasal mucosa. The nasal cycle, along with different environmental triggers, promotes the cavernous sinusoids to engorge with blood. Chronic hypertrophy can lead to nasal airway obstruction by decreasing the cross-sectional area of the internal nasal valve (Batra PS, Seiden AM, Smith TL. Surgical management of adult inferior turbinate hypertrophy: A systematic review of the evidence. *Laryngoscope* 2009;119:1819–1827; Friedman O, Cekic E, Gunel C. Functional rhinoplasty. *Facial Plast Surg Clin North Am*. 2017;25:195–199).

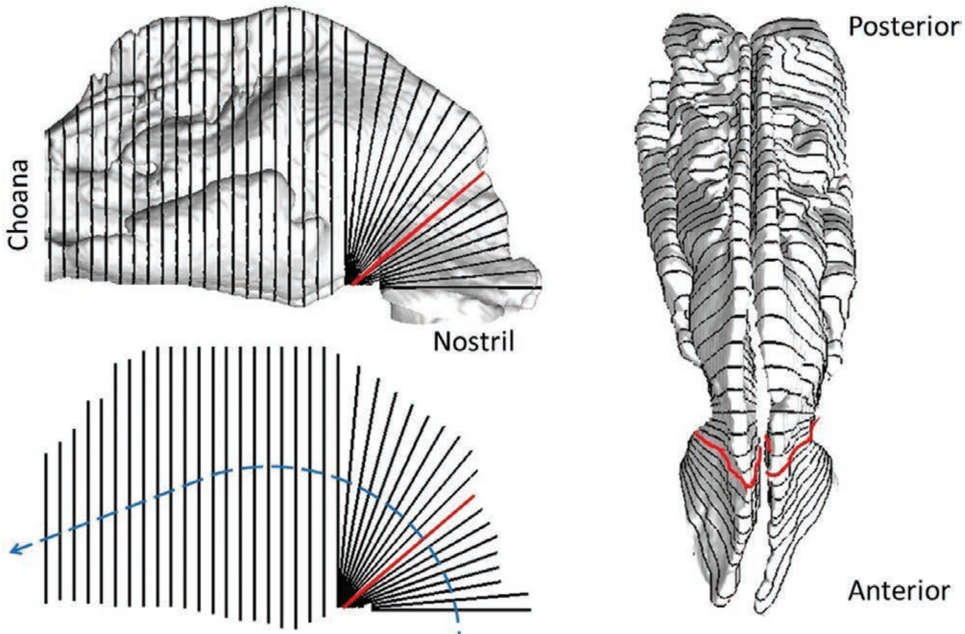

Fig. 5. Nasal physiology. Physiologic airflow in the nasal airway is related to resistance. The internal nasal valve contributes 50 percent of the total airway resistance (Howard BK, Rohrich RJ. Understanding the nasal airway: Principles and practice. *Plast Reconstr Surg*. 2002;109:1128–1146). Because resistance is inversely proportional to the fourth power of the radius of nasal passage, small changes in the size of the valve secondary to septal deviation, nasal valve collapse, and/or inferior turbinate hypertrophy can have significant effects on airflow resistance. Bernoulli's principle states that as air flows across a narrowed nasal valve, its velocity increases and pressure decreases. This results in a negative pressure in valve area and an increased transmural pressure difference, causing nasal valve collapse resistance (Howard and Rohrich). This figure is a three-dimensional rendering of the nasal airway demonstrating the internal nasal valve (*red*) as the narrowest cross-sectional area along the acoustic axis (*blue*). (*Above*, *left*) Three-dimensional sagittal view. (*Below*, *left*) Wire representation of sagittal view. (*Right*) Three-dimensional axial view. (Figure previously published by Coan BS, Neff E, Mukundan S Jr, Marcus JR. Validation of a cadaveric model for comprehensive physiologic and anatomic evaluation of rhinoplastic techniques. *Plast Reconstr Surg*. 2009;124:2107–2117. Published with permission.)

symptoms, which are generally attributable to environmental exposures, may incorrectly expect that rhinoplasty will improve these symptoms.

There are two validated patient-reported outcome measures that provide a disease-specific assessment of a patient's subjective nasal patency: the Nasal Obstruction Symptom Evaluation and the Standardized Cosmesis and Health Nasal Outcomes Survey (Table 2). The Nasal Obstruction Symptom Evaluation score is a disease-specific quality-of-life instrument developed for the assessment of nasal obstruction shown to be valid, reliable, and sensitive in evaluation of nasal obstruction.[4] It was validated originally with patients undergoing septoplasty, and has been used in many subsequent studies for functional rhinoplasty as well. It has greater than 90 percent sensitivity and specificity in evaluation of patients with nasal airway obstruction. Expanding on this measurement tool, the Standardized Cosmesis and Health Nasal Outcomes Survey was developed to include both cosmetic and functional rhinoplasty outcome measures.

The functional nasal physical examination is divided into an external nasal examination and an internal nasal examination (Table 3). The external nasal examination analyzes surface anatomy from three primary views (i.e., frontal, lateral, and basal) to identify anatomy that predisposes patients to airway obstruction. Functionally relevant anatomy includes nasal bone length and width, middle vault length and width, dorsal septal deviation, lower lateral cartilage strength and orientation, nasolabial angle, columella and medial crura flare, and caudal septal deformity. The internal nasal examination is obtained using

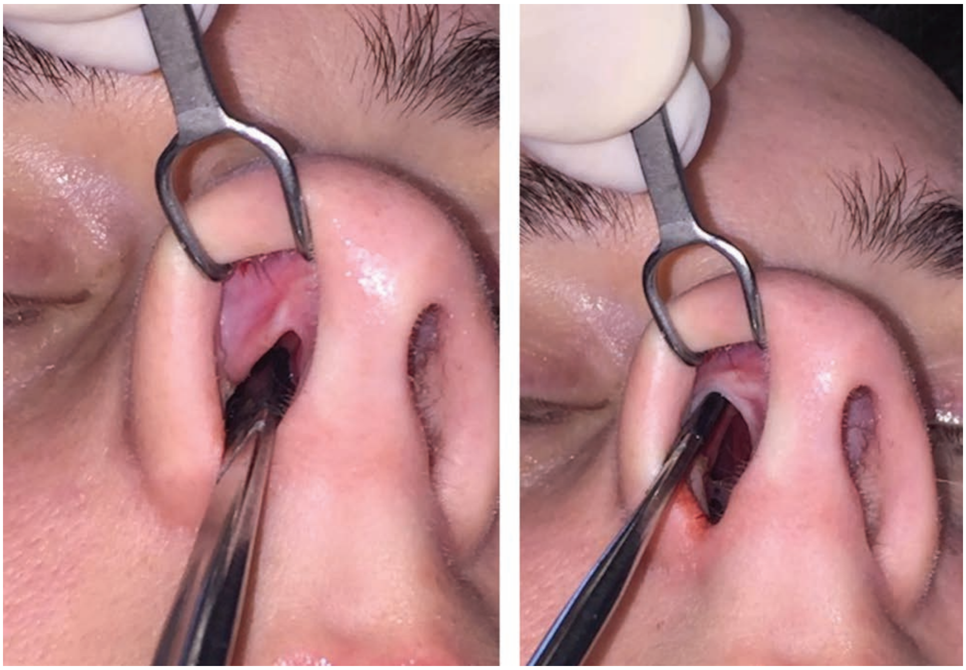

Fig. 6. Internal nasal valve. The internal nasal valve is located at the caudal edge of the upper lateral cartilage and bounded medially by the septum, laterally by the upper lateral cartilage and the anterior head of inferior turbinate, and inferiorly by the nasal sill. (*Left*) Endonasal view of internal nasal valve exposing the caudal edge of the upper lateral cartilage. (*Right*) Analogous to the modified Cottle test, this demonstrates manual support of the upper lateral cartilage caudal edge helps to widen the internal nasal valve angle and support the internal nasal valve during respiration.

a nasal speculum for anterior rhinoscopy. Septal abnormality, inferior turbinate, and internal nasal valve can be visualized.

A critical component of the functional nasal examination is identifying valvular insufficiency or collapse (Fig. 8). Gruber et al. described the use of nasal strips placed either at the level of caudal nasal bone or lower lateral cartilage/ala to determine internal nasal valve and external nasal valve abnormality.[25,26] The BreatheRight (GlaxoSmithKline, Brentford, United Kingdom) nasal strip challenge has been used by the authors as a provocative maneuver to determine the role of the internal valve in the obstructive condition and the need for surgical support.[27] In a cadaveric model, the nasal strip was shown to result in objective physiologic improvements similar to spreader grafts. Patients are asked to rate their side-specific improvement on a scale of 0 to 3 following application. A vasoconstrictor challenge is also used with a similar 0-to-3 scale of improvement before and after intranasal treatment with oxymetazoline. The turbinates are examined by anterior rhinoscopy before and after testing. Significant reduction in turbinate size coinciding with subjective improvement suggest that soft-tissue reduction is warranted.

Flexible nasendoscopy is a routine component of the functional workup for those skilled in the technique to visualize the nasal airway posterior to that which is visible by anterior rhinoscopy. Imaging for the posterior airway can be used as a surrogate for direct visualization and also provides information on the sinuses and other structures. The authors recommend imaging in the following circumstances: failed prior functional surgery, significant obstructive symptoms in the setting of minimal visible abnormality, suspected posterior obstruction, prior orthognathic surgery, history of major craniomaxillofacial trauma, or history of chronic sinusitis. In the latter, sinus treatment before functional rhinoplasty may be the safest consideration.

SURGICAL MANAGEMENT OF NASAL AIRWAY OBSTRUCTION

Septal Deformity

Prior reports have described both closed endonasal and open approaches to treating

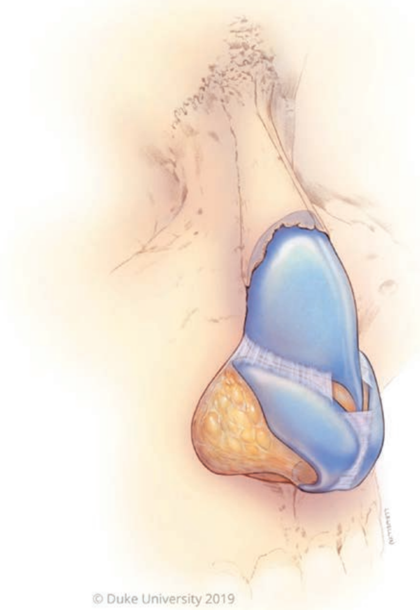

Fig. 7. Lower lateral cartilage orientation. The orientation of the long axis of the lateral crus should be toward the lateral canthus at 45 degrees to be supportive of the alar soft tissue. A more vertical or cephalic orientation (long axis toward the medial canthus) is associated with dynamic external nasal valve collapse, as the lateral crus then fails to provide adequate structural support to the ala (Constantian MB. The incompetent external nasal valve: Pathophysiology and treatment in primary and secondary rhinoplasty. *Plast Reconstr Surg*. 1994;93:919–931, discussion 932–933; Hamilton GS III. The external nasal valve. *Facial Plast Surg Clin North Am*. 2017;25:179–194). (Figure previously published by Avashia YJ, Marshall AP, Allori AC, Rohrich RJ, Marcus JR. Decision-making in middle vault reconstruction following dorsal hump reduction in primary rhinoplasty. *Plast Reconstr Surg*. 2020;145:1389–1401. Figure used with permission.)

septal deformities, as they serve to address both cosmetic and functional concerns.[13,27–33] In the past 15 years, there have been several articles regarding septoplasty with success rates from 27 to 84 percent, 6 months to 11 years after surgery.[34,35] Constantian and Clardy demonstrated the concept that septoplasty alone without valvular support does not objectively improve nasal airway obstruction on rhinomanometry (**Level II Evidence**).[36] In contrast, the Nasal Obstruction Septoplasty Effectiveness study demonstrated a significant improvement in subjective nasal obstruction at both 3 months and 6 months postoperatively through the validated Nasal Obstruction Septoplasty Effectiveness scale (**Level II Evidence**).[37] In the authors' opinion, these findings are not mutually exclusive. As alluded to previously, the anatomical cause for nasal airway obstruction is often multifaceted.[28,30,32,33,38–40] When multiple contributing sources exist, one would expect to provide a graduated degree of relative relief as more contributing factors are eliminated. From the work of Constantian, however, one may infer that the physiologic effects of spreader grafting are powerful.

Septal surgery must be thorough and complete, correcting all areas of stenosis. The most common areas of neglect resulting in secondary septal surgery are persistent caudal septal deviation, residual maxillary crest spur (particularly anteriorly), and posterior septal spur. A systematic approach to correcting septal deformities can be performed by means of open or endonasal techniques. Endonasal septorhinoplasty may be performed, but the decision to proceed open versus closed is surgeon dependent. For combined functional/aesthetic surgery and/or when structural modifications to the lower lateral cartilages are planned, the authors prefer an open approach with anterior

Table 1. Rhinitis Cause and Treatment

Type	Cause	Treatment
Infectious	Viral upper respiratory; acute bacterial sinusitis (Gram-positive)	Viral Self-limiting; oral or topical decongestant (no greater than 3 times per day) Bacterial Saline nasal lavage, mucolytic agents, decongestant, antibiotic course (2 wk)
Allergic	Antigen-antibody mediated	Avoidance behavior Nasal saline lavage Decongestant Oral antihistamine Nasal topical steroids
Vasomotor	Sympathetic/parasympathetic imbalance	Nasal decongestant; transnasal neurectomy
Atrophic	Iatrogenic (aggressive turbinectomy)	Nasal saline lavage
Rhinitis medicamentosa	Prolonged sympathomimetic use (e.g., Afrin, Dristan, Neo-Synephrine)	Complete cessation (requires weeks for improvement)

Table 2. Nasal Obstructive Symptom Evaluation*

1.	Nasal congestion or stuffiness
2.	Nasal blockage or obstruction
3.	Trouble breathing while sleeping
4.	Unable to get enough air through nose during exercise or exertion
5.	Trouble breathing through nose

*All questions are rated on a severity scale from 0–4, with the raw score multiplied by 5.

visualization of the septum. [**See Video 1 (online)**, which displays the septoplasty procedure.]

In an open approach, following exposure, the first step is to approach the anterior septal angle.[41] Working from the anterior septal angle, the caudal edge of the septum is exposed, and submucoperichondrial elevation is performed on one or both sides of the septum to provide the necessary exposure to identify and treat all obstructive sites.[13,30,32,33,38] When submucous resection is performed, the deviated portion of septum is removed, leaving a cartilaginous dorsal L-strut. Structural integrity of this L-strut is maintained by leaving no less than 10 mm of caudal and dorsal septal cartilage; most current thought leaders advocate for 12 to 15 mm, wherein the portion removed constitutes only that which is necessary to remove obstructive anatomy and create supportive grafts. Any linear spurs along the length of the maxillary crest and/or posterior spurs of the septum's cartilaginous interface with the perpendicular plate are resected. In cases of caudal deviation from the midline, centralization is necessary following release (Figs. 9 and 10). Persistent dorsal concavities or angulations can be addressed by several maneuvers. [**See Video 2 (online)**, which displays the adjunct septal techniques.]

For minor focal concavities, cartilage scoring on the concave side perpendicular to the axis of deviation may be used often in conjunction with supportive grafts such as spreader grafts or thin pieces of perforated, harvested perpendicular plate. Severe concavities and angulations are treated most commonly with bilateral or asymmetric spreader grafts.[38,42–44] Guyuron further described midvault closure with differentially tied "clocking" sutures to correct dorsal deviation.[32,34]

Extracorporeal septoplasty may be reserved for select cases of severe septal deformity, defined as those with prior septal surgery, removal of portions of septum, and/or remaining deviated framework.[45–47] The technique as described by Gubisch involves complete removal of the osseocartilaginous septum and a combination of options to straighten the septum by way of cartilage scoring, reconstructing remaining fragments into a composite L-strut, reinforcing with bony or cartilaginous septal fragments, and reinforcing with spreader grafts (**Level IV Evidence**).[46] Critical to extracorporeal septoplasty is the stable fixation of the neoseptum construct at the keystone and at the anterior nasal spine to prevent the potential later complications of saddling and instability.[48] Most and Surowitz et al. have described the anterior septal reconstruction, which is a variant of extracorporeal septoplasty that preserves a dorsal septal strut to the nasal bones. This modification helps reduce the potential risks of saddling and dorsal instability that lead to recurrent deviation and secondary revisions.[49,50] A

Table 3. Systematic Functional Nasal Assessment

Component	Endpoint
History of present illness and subjective questionnaire (PROM)	Determine anatomical vs. physiologic obstruction; determine degree of subjective nasal patency
External nasal examination (i.e., frontal, lateral, and basal views) • Nasal bone length • Dorsal septal deviation • LLC orientation • Nasolabial angle • Medial crural flare • Caudal septal deformity	Short nasal bones, long middle vault, narrow nasal bones predisposes for INV dysfunction; cephalically oriented LLC, acute NL angle, caudal septal deviation, or medial crural flare predisposes for ENV dysfunction
Internal nasal examination • Anterior rhinoscopy (nasal speculum) • Nasoendoscopy (endoscope)	Determine presence and type of septal deformity; determine inferior turbinate hypertrophy
Valvular assessment • Cottle/modified Cottle maneuver • Nasal strip test (BreatheRight)	Determine INV insufficiency and/or collapse; determine ENV insufficiency and/or collapse
Inferior turbinate hypertrophy • Decongestant challenge (Afrin)	Determine bony vs. mucosal hypertrophy
Imaging • CT scan	Determine chronic sinusitis if history indicate; determine anatomy in posttraumatic cases

PROM, patient-reported outcome measure; LLC, lower lateral cartilage; INV, internal nasal valve; NL, nasolabial; ENV, external nasal valve; CT, computed tomographic.

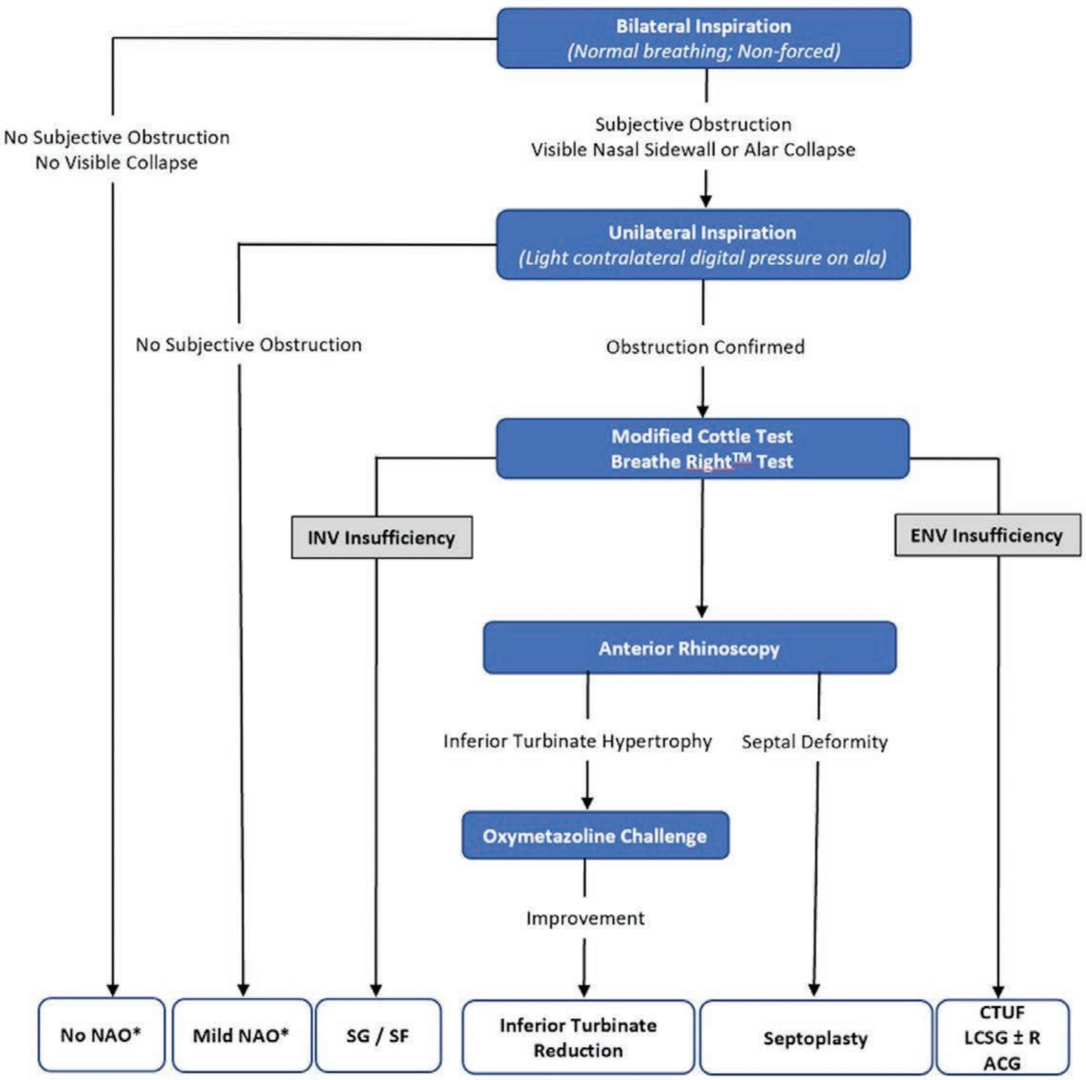

Fig. 8. Functional nasal examination and diagnosing valvular dysfunction. Diagnosing the presence, type, and cause of valvular dysfunction is the goal of the functional nasal examination. Subjective obstruction or visible collapse of the nasal sidewall and/or ala during normal breathing (bilateral inspiration) indicated nasal airway obstruction (*NAO*). To further isolate nasal passage with anatomical obstruction, unilateral inspiration is examined by placing soft pressure on one ala and occluding that nasal passage. Baseline difficulty with normal inspiration indicates contralateral valvular insufficiency to the side occluded. If physical collapse is observed, this would constitute valvular collapse, indicating not only insufficiency but also structural weakness. By supporting the internal or external nasal valve, one can diagnose the level of obstruction. The Cottle maneuver facilitates a nonspecific opening of both the external and internal nasal valves by digitally supporting the internal valve during inspiration. The modified Cottle maneuver involves insertion of a cotton-tipped applicator inside the nose to elevate the lateral nasal wall at the level of either the caudal upper lateral cartilages or the ala to isolate either the internal or external nasal valve. In the BreatheRight test, a nasal strip is placed at the level of the internal or external nasal valve. Patients are asked to rate their side-specific improvement. These maneuvers help define the type of valvular abnormality: internal nasal valve insufficiency or external nasal valve insufficiency. Specific techniques can be applied, depending on the type of valvular insufficiency. *INV*, internal nasal valve; *ENV*, external nasal valve; *SF*, spreader flap; *SG*, spreader graft; *CTUF*, cephalic turn-under flap; *LCSF±R*, lateral crural strut graft with or without repositioning; *ACG*, alar contour graft. Anterior rhinoscopy allows one to identify septal deformities and the presence of inferior turbinate hypertrophy. In cases of inferior turbinate hypertrophy, a vasoconstrictor challenge with oxymetazoline is given to determine the value of soft-tissue reduction. (Figure previously published by Avashia YJ, Marshall AP, Allori AC, Rohrich RJ, Marcus JR. Decision-making in middle vault reconstruction following dorsal hump reduction in primary rhinoplasty. *Plast Reconstr Surg*. 2020;145:1389–1401. Figure used with permission.)

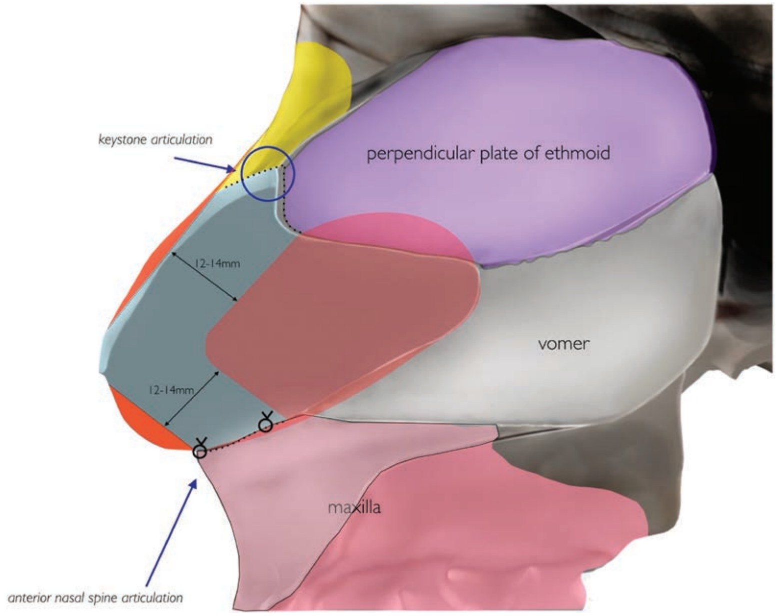

Fig. 9. Caudal septal deviation. Caudal septal deviations are functionally significant because small shifts from the midline at the caudal aspect of the septum can cause disproportionate reductions in cross-sectional area at the external nasal valve. Failure to correct caudal septal deviation is one of the most common causes of unsuccessful functional nasal surgery. The most common form of caudal septal deviation is the septal tilt, in which the base of an otherwise straight caudal septum lies lateral to the anterior nasal spine and anterior maxillary crest. C-shaped and S-shaped septal deformities can have either an anteroposterior or craniocaudal orientation of their deformity. Inferior excesses are resected to allow the caudal support to move as a "swinging door" to the midline. The caudal septum is secured to the anterior nasal spine and premaxilla. This can be done through drill holes in the bone or secure bites of periosteum.

retrospective review of functional outcomes over a 28-month period after anterior septal reconstruction showed statistically significant improvement in Nasal Obstruction Septoplasty Effectiveness score by a factor of 9 ($p < 0.05$)[50] (**Level III Evidence**). Postoperative follow-up revealed an improvement in dorsal asymmetry and nostril asymmetry on basal view, without dorsal saddling.

Inferior Turbinate Hypertrophy

Surgical options for inferior turbinate hypertrophy share the common aim of expansion of the nasal airway cross-sections through reduction of space-occupying structures. Reducing turbinate size improves airflow through the nose by decreasing intranasal resistance.[51] In recent decades, the treatment options for inferior turbinate hypertrophy have expanded from total and subtotal turbinectomy to partial turbinectomy, submucosal resection, radiofrequency ablation, microdébrider submucous resection, electrocautery, laser cautery, cryotherapy, and turbinate outfracture.[52] Complications of turbinate overreduction include crusting, bleeding, atrophy, rhinorrhea, postnasal drip, infection, and synechiae formation.[1,9,10,53,54]

Although sufficient literature exists describing the efficacy of each technique, prior comparative studies have been most useful in identifying the techniques that will provide either short-term and/or long-term improvement.[55–58] Passali et al. performed a prospective randomized trial of 382 patients with 6-year follow-up for six surgical techniques including turbinectomy, laser cautery, electrocautery, cryotherapy, submucous resection, and submucous resection plus lateral displacement of the turbinate.[55] Their results demonstrated submucosal resection with lateral displacement provided the best long-term outcomes in nasal patency at 6 years (**Level I Evidence**). In two prospective randomized studies studying microdébrider-assisted and radiofrequency ablation, inferior turbinoplasty demonstrated similar

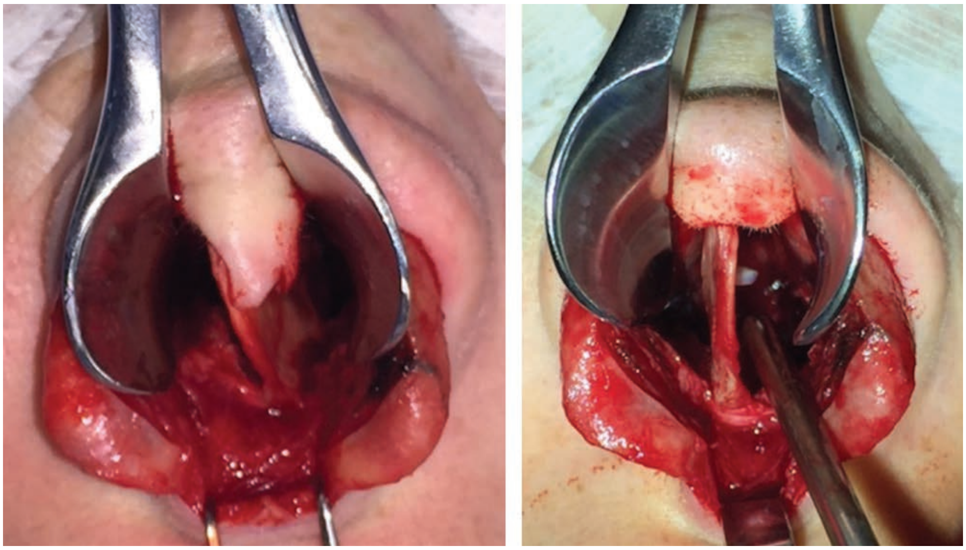

Fig. 10. Caudal septal centralization. During caudal septal centralization, it is advisable to place one suture at the anterior nasal spine and a second posterior to this site to prevent pivoting of the caudal septum along the axis of the anterior fixation point. It should also be noted that inherent anterior nasal spine deviation from the midline should be identified, in which case the caudal septum is secured to the true midline (Guyuron B, Behmand RA. Caudal nasal deviation. *Plast Reconstr Surg*. 2003;111:2449–2457). (*Left*) Caudal septal deviation. (*Right*) Corrected deviation with caudal septal centralization.

short-term improvements at 3 years 6 months, with the microdébrider providing better long-term relief of nasal obstructive symptoms (**Level I Evidence**).[56–58] Gindros et al. published a prospective randomized trial comparing ultrasound turbinate reduction, radiofrequency ablation, and traditional submucosal cauterization.[59] The most dramatic results were seen with the ultrasound procedure, followed by the radiofrequency ablation (**Level I Evidence**).

A recent systematic review studying treatment options and outcomes for inferior turbinate hypertrophy showed that submucous resection with microdébrider had the highest percentage (91.2 percent) of patient improvement, which was also confirmed by the visual analogue scale (**Level III Evidence**).[52] Tanna et al. administered a survey to members of American Society of Plastic Surgeons revealing that 49.1 percent perform outfracture alone for inferior turbinate hypertrophy.[60] The largest series evaluated 500 patients who all underwent closed micro-outfracture technique for inferior turbinate hypertrophy, with no cases of recurrent hypertrophy[61] (**Level IV Evidence**). No objective outcomes were reported. Evidence shows tissue reduction techniques (radiofrequency ablation and submucous resection with microdébrider) provide long-lasting results, preservation of turbinate function, and low complication rates.[56] [**See Video 3 (online)**, which displays the inferior turbinate reduction and outfracture.] Turbinate outfracture may be used in combination with these techniques for optimal results, but its role in independently treating inferior turbinate hypertrophy has not been substantiated with higher level evidence.

Internal Nasal Valve Dysfunction

Internal nasal valve dysfunction comprises a large proportion of patients with functional airway obstruction and encompasses both insufficiency and collapse. Sheen coined the term "narrow nose syndrome" as a combination of anatomical predispositions leaving patients at risk for internal nasal valve insufficiency, particularly following dorsal hump reduction.[62] These anatomical findings include short nasal bones, long and weak upper lateral cartilage, and thin skin (Fig. 11). Sheen introduced the concept of spreader grafts to correct the narrow midvault and resultant insufficiency created by dorsal hump reduction (inverted-V deformity), which at the time was typically performed in composite fashion, leaving an open roof. The open roof deformity is a cosmetic palpability of a bony vault that has not been repaired. The medial borders of the nasal bones and caudal septum are individually palpable under the soft-tissue envelope.

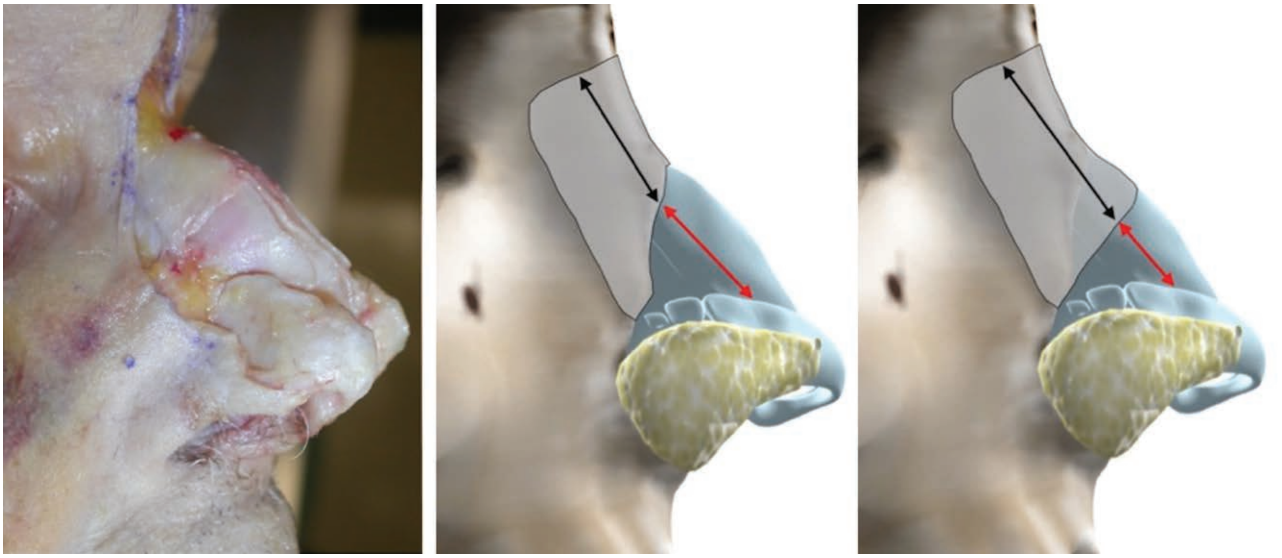

Fig. 11. Internal nasal valve dysfunction predisposing anatomical factors. This figure demonstrates the interplay between the bony vault and middle vault. Short nasal bones (*black arrow*) are associated with longer middle vault counterparts (*red arrow*). The reverse relationship also holds true. The upper lateral cartilages of the middle vault are supported by their attachments to the undersurface of the nasal bones at the keystone. This is the basis of "narrow nose syndrome," which is a combination of anatomical predispositions leaving patients at risk for internal nasal valve insufficiency that include short nasal bones, long and weak upper lateral cartilage (long middle vault), and thin skin. (*Left*) Cadaver dissection demonstrating the lower lateral cartilage, upper lateral cartilage, and nasal bones. (*Center*) Long nasal bones and short middle vault. (*Right*) Short nasal bones and long middle vault.

In addition to treating septal deviations when they exist, techniques for treating the internal nasal valve insufficiency involve increasing the cross-sectional area of the nose by supporting and stabilizing the position of the nasal sidewalls (upper lateral cartilages) relative to the septum in the midvault.[63] These techniques include placement of spreader grafts or spreader flaps, and/or the use of flaring sutures.[23,30,42,44,62,64–68] Spreader grafts serve to widen the midvault and buttress the lateral walls from the septum (Fig. 12). This increases the internal valve angle and prevents inward lateral wall movement under the negative pressure of inspiration. [**See Video 4 (online)**, which displays the spreader graft.]

Spreader grafts can be performed unilaterally, bilaterally, or asymmetrically (two grafts of different thicknesses).[69,70] Unilateral or asymmetric spreader graft placement can aid in correcting or camouflaging nasal dorsal angulation.[13,28,38,44]

In the 1990s, several authors described an alternative technique to the spreader graft.[67,71,72] Oneal and Berkowitz coined the term spreader flap to describe this technique, and described restoration of the normal T-shape of the midvault (Fig. 13).[65,67] Various modifications of the spreader flap have been described, including suture techniques to further narrow the nasal dorsum, those to widen the dorsum, and those to correct asymmetries.[72–75] The primary advantage of spreader flaps is their ability to reconstitute the midvault with a focus on maintaining the smooth, flowing contours of the dorsal aesthetic lines.[44,74,76] [**See Video 5 (online)**, which displays the spreader flap.]

The flaring stitch was later described by Park as an adjunct to the spreader graft as a method for improving the internal valve angle by moving the upper lateral cartilage in a lateral and externally rotated position.[68] It has now been described for use either with spreader grafts or spreader flaps.[74,76] [**See Video 6 (online)**, which displays the flare stitch.]

A recent cadaveric study using computational fluid dynamics to measure airway resistance and airflow velocity showed the flaring suture to be a powerful adjunctive technique for internal nasal valve insufficiency and collapse. Although spreader grafts have served as the standard for treating internal nasal valve insufficiency, spreader flaps have received criticism regarding their efficacy in improving nasal airway obstruction. Limited comparative studies exist in the literature to aid in decision-making for spreader grafts or spreader flaps.[23,44,63,77] Through an organized communication method, a panel of internationally recognized rhinoplasty surgeons defined patient-specific and anatomical indications for spreader grafts and spreader flaps.[78] The authors performed a cadaveric study comparing the

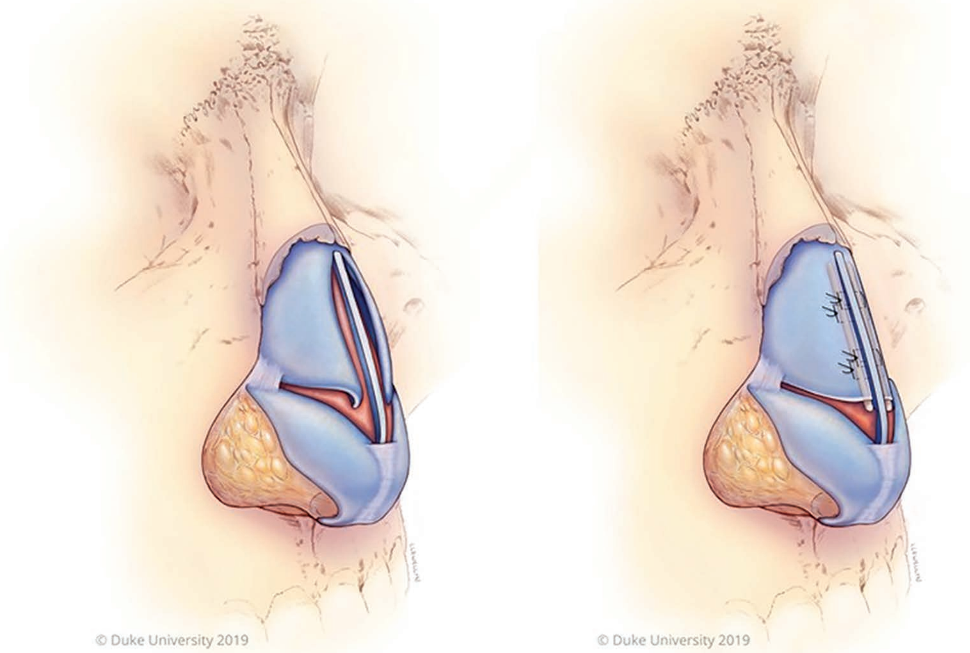

Fig. 12. Spreader grafts are one of the two techniques used to support the internal nasal valve. The upper lateral cartilages are detached longitudinally from the dorsal aspect of the septum before dorsal hump reduction, and spreader grafts are placed between them flush with the dorsal line. Spreader grafts can also be placed recessed to the dorsal line to avoid a sharp dorsal aesthetic line, or above the dorsal line to augment the dorsal height if desired. (*Left*) Release of upper lateral cartilage from the dorsal septum. (*Right*) Middle vault repair with spreader grafts. (Figure previously published by Avashia YJ, Marshall AP, Allori AC, Rohrich RJ, Marcus JR. Decision-making in middle vault reconstruction following dorsal hump reduction in primary rhinoplasty. *Plast Reconstr Surg*. 2020;145:1389–1401. Figure used with permission.)

physiologic changes after midvault closure using spreader flaps with spreader grafts. Computer-generated simulation models using computational fluid dynamics demonstrated spreader flaps to improve airflow and reduce airway resistance similarly with spreader grafts.

External Nasal Valve Dysfunction

It is important to distinguish external from internal nasal valve pathology because of distinct anatomy despite adjacent anatomical regions.[79] Analogous to the internal nasal valve, the goals for treating external nasal valve insufficiency and collapse include increasing the cross-sectional area and reinforcing the lateral wall. Techniques that focus on opening the external nasal valve cross-sectional area include addressing caudal septal deviations, columellar deformities from medial crural flaring, and nasal tip ptosis and nasal deprojection, both of which influence the airway aperture. The use of nonanatomical alar rim grafts, alar batten grafts, lateral crural repositioning with lateral crural strut grafts, along with lower lateral cephalic turn-under or turn-over flaps serve to restore a structurally reinforced external nasal valve in varying degrees.

The lateral crural strut graft is a powerful tool to address the weak, misshapen, or malpositioned lower lateral cartilage. The graft is secured on the deep surface of the lateral crus in a pocket created between the vestibular skin and cartilage with the lateral end placed on the piriform, caudal to the alar groove. [**See Video 7 (online)**, which displays the lateral crural repositioning.]

Gunter and Antrobus described the lateral crural strut graft for reshaping and repositioning the lower lateral cartilage lateral crura in 118 patients with clinical indications varying from alar rim retraction and collapse to boxy tip and vertically malpositioned lower lateral cartilage.[80] Janis et al. described the lateral crural turnover flap, a modification of McCollough and Fedok's turnover graft, in which the anterior perichondrium is kept intact when

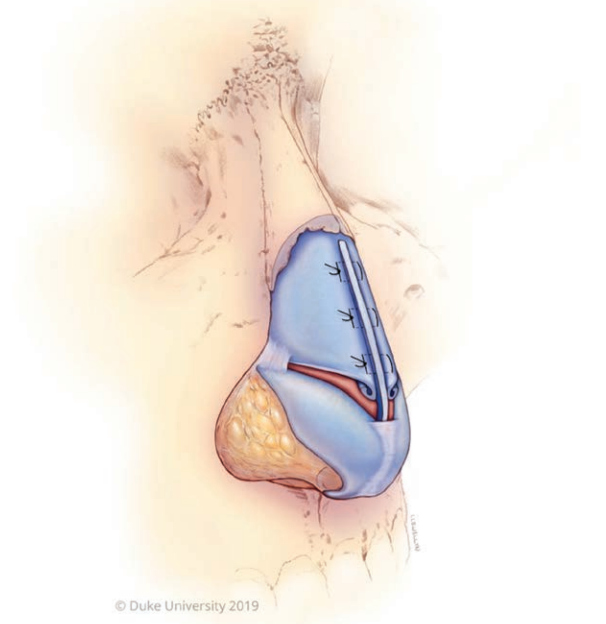

Fig. 13. Spreader flaps are another one of the two techniques used to support the internal nasal valve. Horizontal flaps from excess upper lateral cartilage height are folded downward and inward along the dorsal septum as a means by which to reconstruct the midvault (Gruber RP, Park E, Newman J, Berkowitz L, Oneal R. The spreader flap in primary rhinoplasty. *Plast Reconstr Surg*. 2007;119:1903–1910.). (Figure previously published by Avashia YJ, Marshall AP, Allori AC, Rohrich RJ, Marcus JR. Decision-making in middle vault reconstruction following dorsal hump reduction in primary rhinoplasty. *Plast Reconstr Surg*. 2020;145:1389–1401. Figure used with permission.)

turning over the cephalic portion of the lateral crus. The cephalic turn-under flap follows an analogous concept as the turnover flap, in which concave/convex pairing of the cephalic and caudal halves of the lateral crus counteract lateral crural concavity and provide reinforcement. [**See Video 8 (online)**, which displays the cephalic turn-under flap.]

Recent studies have demonstrated that cephalic crural turn-under and costal cartilage crural strut grafts provide rigidity to the external nasal valve, and are functionally and cosmetically acceptable options for correction of external valve dysfunction.[81] A recent prospective case series demonstrated improvements in both subjective and objective outcome measurements for patients who had either costal cartilage lateral crural strut grafts or cephalic turn-under flaps.[82] Although the minimal cross-sectional area was not significantly improved, peak nasal inspiratory flow was improved, correlating with improvements in 22-item Sinonasal Outcome Test and Nasal Obstruction Septoplasty Effectiveness scores (**Level IV Evidence**). Barham et al. performed a prospective cohort study with the same study groups and showed improvements in visual analogue scale, 22-item Sinonasal Outcome Test, and Nasal Obstruction Septoplasty Effectiveness scores, in addition to patient-reported function (**Level II Evidence**).[83] Furthermore, they demonstrated a reduced collapsibility of the airway along with an increase in airway size with costal cartilage strut grafts.

Placement of the batten grafts should be over the area of the internal nasal valve to strengthen the lateral crura of lower lateral cartilage. Toriumi et al. reported use of alar batten grafts for correction of external and internal nasal valve collapse.[84] Their patient-reported subjective outcome survey demonstrated improvement in nasal airway obstruction in 98 percent of patients. Cervelli et al. demonstrated significant improvements in peak airflow velocity with alar batten grafts for external nasal valve collapse.[85] Rohrich et al. described the use of nonanatomical infracartilaginous alar contour graft to correct rim deformity.[86] From a total of 123 patients, 91 percent of patients undergoing primary rhinoplasty and 73 percent of patients undergoing secondary rhinoplasty reported improvement in alar notching and collapse (**Level IV Evidence**).

CONCLUSIONS

It is an accepted concept that any rhinoplasty patient who breathes better will be more satisfied with their result, regardless of the cosmetic outcome. Performing a systematic functional nasal assessment is a prerequisite to developing a complete surgical plan. The authors have provided evidence-based support for the current techniques used in treating nasal airway obstruction for the anatomical structures encountered throughout the airway conduit: septum, inferior turbinate, internal nasal valve, and external nasal valve. These surgical techniques will help restore or maintain the functional integrity in functional and/or cosmetic rhinoplasty patients.

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