Nasal Airway Evaluation

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Abstract

The nose has several important functions including inspiration, humidification of air, and filtering of allergens. The nose also has a major role in facial harmony as the central focal point. Patients will present to the rhinoplasty surgeon in an effort to fix the inability to breathe through the nose or correct a perceived nasal deformity in the shape of the nose. Choosing the optimal techniques to effectively change the nose requires a thorough understanding of nasal anatomy and nasal mechanics. Ultimately, a complete nasal evaluation is essential in identifying what corresponds to a patient's complaints and how those issues can be addressed surgically or perhaps nonsurgically. When the nose is divided into subunits, and a systematic nasal analysis is performed, one can be confident that all components of the nasal skeleton have been assessed.

Keywords
- nasal evaluation
- rhinoplasty
- outcome measures

Importance of Nasal Evaluation in the Clinical Encounter

The nasal airway has several functions that are essential to a patient's quality of life including humidifying the air and filtering allergens.[1] When there is nasal obstruction, these processes are interrupted and the patient can become symptomatic. Nasal obstruction can change the normal laminar airflow to turbulent airflow. These anatomical changes may lead to a symptomatic patient who will then seek consultation. The timeline and progression of nasal symptoms can provide valuable information when appropriately elicited. The clinician will obtain a detailed history of present illness, presence of allergies or sinus disease, past medical and surgical histories, past and current treatments, and any relevant social history. A thorough history can guide the physical examination, and when combined will lead to the proper medical or surgical treatment for the patient.

Understanding the Patient's Goals and whether They Are Reasonable

Assessing the feasibility of achieving the patient's expected goals is paramount to obtaining optimal surgical results. The patient's functional goals are taken into account as well as medical comorbidities that may affect the surgical outcome, such as obstructive sleep apnea, allergies, or comorbidities that may not allow the patient to tolerate anesthesia. Any aesthetic changes the patient desires to have should be ascertained, balancing how these aesthetic changes may impact the nasal airway so as not to sacrifice nasal function in pursuit of aesthetic alterations. It is the role of the clinician to have a comprehensive understanding of nasal mechanics and nasal physiology to properly conduct an evaluation prior to determining a surgical plan. In this article, we aim to provide an overview of the nasal anatomy and nasal mechanics to better equip the reader with effective tools and techniques in the nasal evaluation that can be added to their clinical practice.

Anatomy

The functional goals of the patient will often coincide with underlying nasal pathology. To properly assess the nasal anatomic pathology, one must first reference normal nasal anatomy and physiology. When evaluating the nose, we recommend that one assess the external and internal components of collapse separately. The external components of nasal evaluation can be divided into the upper, middle, and

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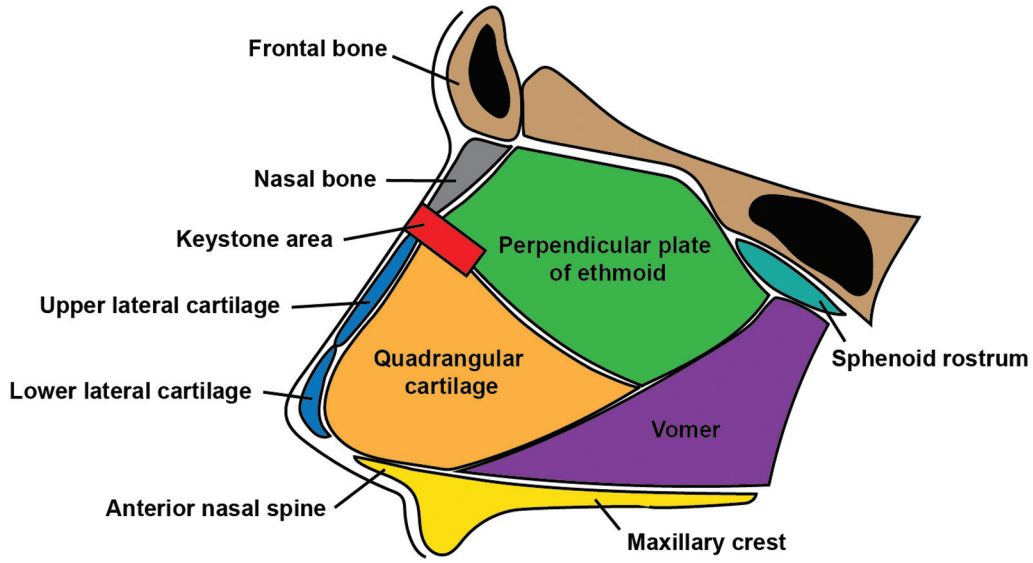

Fig. 1 Nasal septum and surrounding structures.

lower vaults. The internal components can also be divided into thirds for the corresponding points on the external nose, but these are also subdivided into bony, cartilaginous, and soft-tissue structures.

The bony structures include the frontal bone, nasal bones, the bony septum (perpendicular plate of the ethmoid and vomer) maxillary crest, anterior nasal spine, and sphenoid (►**Fig. 1**). The cartilaginous structures include the paired upper lateral cartilages, paired lower lateral cartilages, quadrangular cartilage, sesamoid cartilages, and accessory cartilages. The upper lateral cartilages articulate with the nasal bones superiorly, the septum medially, the lower lateral cartilages caudally, and connective tissue laterally.[1] The lower lateral cartilages can be subdivided into the medial, intermediate, and lateral crura (►**Fig. 2**).

There are also several areas of articulation that deserve mention as they have significant functional contributions. These include the keystone area, Pitanguy's ligament, and the nasal valves. The keystone area is the attachment of the cartilaginous septum, perpendicular plate of the ethmoid, and the nasal bone (►**Fig. 1**). Disarticulation of the septum from these areas can lead to destabilization of the L-strut and subsequent collapse, and should be carefully managed during surgery. Pitanguy's ligament is the point of attachment of the skin–soft-tissue envelope (SSTE) to the intermediate crura of the lower lateral cartilages. This ligament can be sutured together at the conclusion of the rhinoplasty to eliminate dead space between the SSTE and the underlying cartilages. The components of the internal and external nasal valves are shown in ►**Fig. 3**.

Briefly, the lower third of the nose has both major and minor tip supporting mechanisms (►**Table 1**). These support structures can be manipulated depending on the patient's needs and will affect the stability of the nose. While manipulating any of the major tip support mechanism can affect the stability of the nose, such as the medial crural attachment to the caudal septum, manipulating a minor tip support mechanism may not necessarily affect the stability of the nose unless several or all of the minor tip support mechanisms are surgically addressed. Nonetheless, the surgeon should be mindful of all support mechanisms that are being disrupted during the course of surgery to appropriately create a stable and aesthetically pleasing nasal structure.

Clinical Examination

Evaluation should begin with obtaining a detailed history to understand the timing, quality, and progression of any nasal symptoms. It is important to note whether the obstruction is unilateral or bilateral, alternation of laterality, and is there is nasal drainage, epistaxis, crusting, and seasonal changes. The history should also include the length of nasal obstruction, prior medications or treatments,

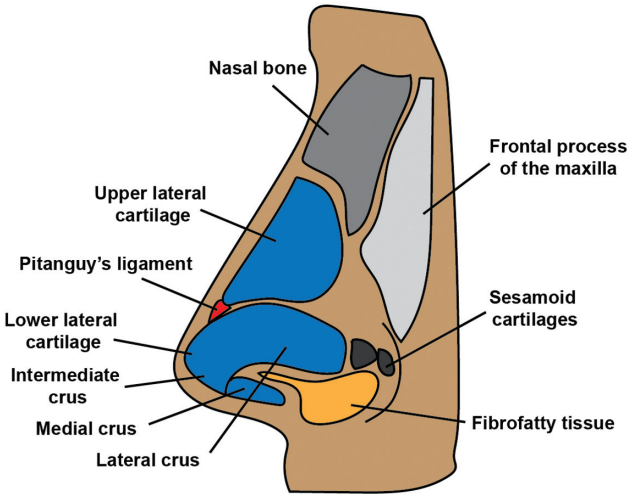

Fig. 2 Profile view of the bony, cartilaginous, and soft-tissue structures of the nose.

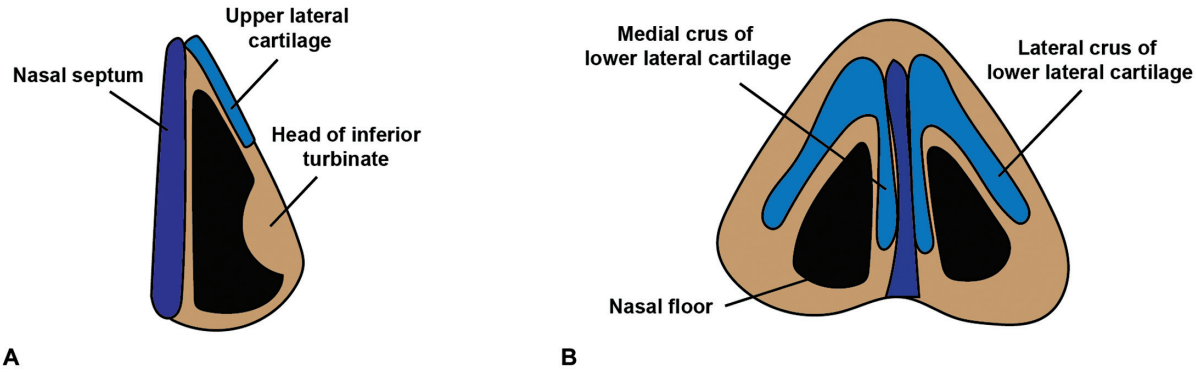

Fig. 3 (A) Internal nasal valve borders: septum, upper lateral cartilage, and head of inferior turbinate. (B) External nasal valve borders: medial and lateral crus of the lower lateral cartilage, and the nasal floor.

Table 1 Major and minor tip support mechanisms of the nose

Major tip support	Minor tip support
Strength, direction, resiliency of the lower lateral cartilages	Anterior nasal spine
Medial crural footplate attachment to the caudal septum	Membranous septum
Attachment of the upper lateral cartilage and lower lateral cartilage	Cartilaginous septum
	Sesamoid cartilages
	Interdomal ligament
	Skin soft-tissue envelope

history of allergies, history of trauma, history of nasal or sinus surgeries, and any relevant past medical history. Nasal pathology can be sectioned into mucosal and structural disease processes, but a full differential diagnosis should be elicited (►**Table 2**).

Mucosal Disease

There are various causes of nasal obstruction due to mucosal disease (►**Table 2**). It is also important to evaluate for any autoimmune diseases or vasculitides depending on what was elicited in the history. In this section, we will address the most common causes of mucosal diseases that contribute to nasal obstruction to include rhinitis, rhinosinusitis, and inferior turbinate hypertrophy.

Nasal rhinitis can be due to many reasons and can be classified as allergic rhinitis, nonallergic rhinitis, atrophic rhinitis, rhinitis medicamentosa, vasomotor rhinitis, or infectious rhinitis. The most common cause of nasal obstruction is rhinitis due to viral or bacterial causes.[2]

Prior treatment with oral allergy medications, nasal steroids, or nasal antihistamine should be elicited in the history of patients with suspicions for allergic or nonallergic rhinitis. Chronic use of nasal decongestants suggests that the nasal obstruction may be due to rhinitis medicamentosa. Nasal congestion and drainage associated with exercise,

Table 2 Differential diagnosis of chronic nasal obstruction

V: vascular	Hemangioma, juvenile nasopharyngeal angiofibroma, pyogenic granuloma
I: infectious/inflammatory	HIV, vestibulitis, syphilis, rhinosinusitis, nasal polyps, inferior turbinate hypertrophy, allergic or nonallergic rhinitis
T: trauma	Nasal bone fracture, synechiae, facial nerve paralysis
A: autoimmune	Polyangiitis with granulomatosis, eosinophilic polyangiitis with granulomatosis, sarcoidosis, lupus
M: metabolic	Cocaine use, rhinitis medicamentosa
I: iatrogenic	Nasal valve collapse, septal perforation, postnasal surgery valve collapse
N: neoplastic	Inverted papilloma, oncocytic papilloma, osteoma, neurofibroma, dermoid, squamous cell carcinoma, adenocarcinoma, esthesioneuroblastoma, lymphoma, mucosal melanoma, nasopharyngeal carcinoma, salivary gland neoplasms, lymphoma
C: congenital	Choanal atresia, pyriform stenosis, cleft lip, cystic fibrosis, primary ciliary dyskinesia, septal deviation
D: degenerative	Atrophic rhinitis
E: endocrine	Pregnancy, hypothyroidism

eating, or changes in temperature may be due to vasomotor rhinitis.[2] It is important to note any of the aforementioned items, especially if the patient has concurrent structural pathology as these mucosal causes of nasal obstruction will not resolve with surgery and require preoperative counseling for realistic patient expectations.

Structural Pathology

The majority of pathologies by which the facial plastic surgeon can surgically repair are structural in nature. It is precisely for this reason that a comprehensive understanding of the nasal anatomy is paramount. These structural areas include the internal nasal valves, external nasal valves, septum, turbinates, and nasal bones.[2] The associated pathologies and their clinical significance are discussed further in the subsequent sections in this article.

Patient-Reported Outcome Measures

It can be helpful to use a validated nasal survey to further assess symptoms. Commonly used surveys include the Nasal Obstruction Symptom Evaluation (NOSE), and the Standardized Cosmesis and Health Nasal Outcomes Survey (SCHNOS). The NOSE instrument consists of five functional nasal questions that are rated by the patient from 0 to 5. The raw score can then be multiplied by 5, with a maximum score of 100.[3] The SCHNOS survey was more recently developed and is useful when there is a cosmetic component that the patient wants to be addressed.[4] The SCHNOS consists of 10 questions, also rated from 0 to 5, that incorporates both functional questions of the nose and cosmetically related questions. The cosmetic-focused questions address how the patient feels about the shape of their nose, their self-esteem, and, overall, how they feel the nose fits their face. The NOSE and SCHNOS surveys have four questions each that overlap in terms of nasal functionality. The SCHNOS and the NOSE surveys have a strong correlation in scores when assessing the functional components.[4] Rhinoplasty surgeons should strongly consider utilizing patient-reported outcome measures (PROMs) in the pre- and postoperative assessment of their patients.

Other non-nasal specific PROMs include the EuroQol 5-Dimension (EQ-5D), 10-Item version of the Functional Outcomes of Sleep Questionnaire (FOSQ-10), and the FACE-Q. The EQ-5D has five different domains consisting of mobility, self-care, usual activity, pain/discomfort, and anxiety/depression and is graded on a Likert scale.[5] Improvement in the EQ-5D tends to correlate with improvement in the NOSE score.[5] The quality-of-life improvement patients experience based on the EQ-5D after septorhinoplasty due to improvement in nasal obstruction is significant when measured as a health utility value.[6,7]

The FOSQ-10 consists of five domains: general productivity, activity level, vigilance, social outcomes, and intimate and sexual relationships. Each domain has between one and three questions, with a total score ranging from 5 to 20.[8] The FACE-Q is directed more toward cosmetic procedures. This questionnaire has three different components: satisfaction with appearance, quality of life, and adverse effects.[9] The satisfaction with appearance section only needs the nasal-related questions answered. The raw score can be tabulated and then converted to a scale score.[9]

These surveys can be administered during the initial consultation and also after a period of recovery postsurgery to objectively assess the PROMs. The PROMs can provide meaningful information on a patient's subjective improvement in symptoms, as the changes and improvement in nasal structure do not always correlate with the patient's subjective experience.

Physical Examination

After a thorough history has been obtained, an equally thorough physical examination should be performed. Understanding the nasal anatomy is fundamental to being able to perform the physical examination and subsequently develop an appropriate surgical plan.

The status of the septum should be noted, with the presence of septal deviation, and the position of the dorsal and caudal septum. Any abnormalities in the septal mucosa should be noted with special attention to friability of the mucosa, septal perforations, prominent vasculature, or abnormal crusting. Any of these could indicate a vasculitis, inflammation, previous surgery, and/or autoimmune disorders. Use of endoscopy can be helpful in evaluating the posterior aspect of the nose if anterior rhinoscopy does not allow full examination, or to rule out other nasal pathologies such as inflammatory nasal disease.[10]

Turbinate hypertrophy should be noted as well as any obvious concha bullosa of the inferior or middle turbinates. The nasal valves should be evaluated and the presence of narrowing of the internal and/or external nasal valves, and/or lateral wall insufficiency (nasal valve collapse) should be noted. Dynamic valve collapse can be assessed by having the patient deeply inhale through the nose. Stabilization of the valve collapse can be performed with Cottle's maneuver, which pulls the cheek skin laterally to open the nasal valve, or with modified Cottle's maneuver in which the examiner places a small-caliber instrument in the area of the internal nasal valve as the patient inspires. Tip support and the position of the lower lateral cartilages should be noted to develop an appropriate plan for addressing any lateral wall insufficiency while factoring in resultant changes to the nasal tip.

It is imperative to note any asymmetries, deviations, or curvatures present externally. The changes seen externally are a direct reflection of the status of the internal structure of the nose. For example, convexities or concavities in the upper third can indicate nasal bone deviation; a pinched mid-vault could indicate lack of support of the upper lateral cartilage, and a bulbous nasal tip can indicate a domelike shape to the lower lateral cartilages. These will be described in further detail.

Physiologic Measurements

There are several ways to objectively measure the nasal airway. These include acoustic rhinometry, rhinomanometry, and

nasal peak inspiratory flow. These methods provide objective data regarding the patient's nasal obstruction in terms of airflow, airway resistance, and cross-sectional area of the nasal airway.[11–13] Computed tomography (CT) scans are obtained by some surgeons, particularly in the cases with a history of complex or uncertain surgeries, or possible implant placement, even though the authors of this study do not routinely obtain CT scans and rely instead on the physical examination findings.

Acoustic Rhinometry

The cross-sectional area and volume of the nasal airway can be measured with acoustic rhinometry.[11] Sound waves are transmitted through the nasal cavity and measured as the sound waves return.[11] The time between administering the sound wave and the reflection correlates with the nasal passage length.[11] The amplitude of the reflected sound wave and the distance the sound waves traveled through the nose can be used to calculate the approximate cross-sectional area of the nose.[11]

Rhinomanometry

Rhinomanometry measures airflow and airway resistance by recording the transnasal pressure.[1,11] There are both active and passive versions of this tool. In the active version, the patient is breathing through a single nasal cavity and the pressure is measured on the contralateral nasal cavity. In the passive method, a face mask is placed over the patient's nose and air is delivered.[1,11] This allows the clinician to assess the airflow and airway resistance. While this may not be necessary to assess surgical candidacy, it can be useful as a comparison postoperatively to calculate the amount of improvement of both of these measures.

Peak Nasal Inspiratory Flow

Peak nasal inspiratory flow (PNIF) measures the maximum airflow during a forced inspiration.[11] There are different meters that can be used to measure the PNIF; the result is read in liters per minute (L/min). The patient is asked to inspire maximally through the device while keeping their mouth closed. The highest of three maximal attempts is utilized.[12] A normal PNIF is around 138.4 L/min.[11] The changes can be assessed preoperatively and postoperatively to objectively measure the individual patient's improvement in nasal obstruction after surgery. Although it can be used on the individual patient, one should keep in mind that PNIF correlates only weakly with the NOSE scores, so its utility as a diagnostic tool is limited.[12]

Computational Fluid Dynamics Modeling

Computational fluid dynamic measures simulate the fluid patterns of liquids and gases within a defined space and the interaction of these fluids and gases with the boundaries of the defined space.[14] It can be applied to the nose using a three-dimensional recreated nasal geometry using CT or magnetic resonance imaging that allows for measurement of nasal airflow.[14] Specific software (Lexma Technology) can be used with the lattice Boltzmann method to determine the nasal airflow.[14] In patients with bilateral static nasal obstruction, there is a positive correlation between the airflow measurement and the NOSE survey.[14]

Nasal Analysis

Photography

It is imperative to take preoperative photographs for a more detailed analysis of the nasal structures. The following views should be taken: frontal, bilateral obliques, bilateral profiles, bird's-eye view, and basal view. Camera settings should be adjusted to avoid excess or inadequate exposure. Typical focal length will be between 90 and 105 mm.[15] The shutter speed should be between 1/1,000th and 1/60th of a second.[16] Finally, the aperture size is measured via f-stops. The f-stop is the ratio of the focal length to the aperture diameter. A larger f-stop correlates to a smaller aperture size.[16]

The nose should be fully in focus, and the lighting must be adequate to obtain high-quality photographs. The depth of field is the distance range where all aspects of a photograph are in focus. The depth of field can be altered by changing the focal distance, changing the distance of the photographer to the patient, or changing the aperture size. Aperture size tends to be the easiest to change.[16] It is important to keep in mind that if the aperture size is decreased, then there is risk of having an underexposed photograph, which can be controlled by decreasing the shutter speed to allow more time for light to pass through.[16]

Once the photographs are taken, a nasal analysis can be performed using the photographs. The photographs can be shown to the patient so that they understand the external issues that are related to their symptoms. This should be performed in a systematic fashion, so that all components of the nose are addressed every time. The external components can be described in detail with the photographs and taken into consideration with the intranasal findings.

Location of Pathology

Septum

Evaluation of the septum can be split into the caudal septum, dorsal septum, and remaining intermediate portion of the septum. One should describe the position of the caudal septum, the status of the posterior septum, and the presence of any bony spurs or deviations. There can be prominence of a swell body, which can also narrow the nasal airway, particularly at the internal nasal valve.

A weakened dorsal septum could lead to saddling. This would need correcting with spreader grafts and possible dorsal augmentation grafting. A weakened caudal septum could result from a variety of etiologies to include poor cartilage quality, trauma resulting in septal fracture, or over-resection from prior surgery. The result could present as poor tip support and/or tip ptosis.

The location of the deviation can help guide what type of surgical approach can be used. For example, a caudal septal

deviation or a high septal deflection could make a successful endonasal approach more difficult to achieve due to the access available and the different maneuvers needed to correct the abnormalities of the septum.

Turbinates

Any hypertrophy should be noted, along with any evidence of concha bullosa. If hypertrophy is noted during the examination, testing the mucosa for response to a topical nasal decongestant, such as oxymetazoline, can give insight into the effects of performing submucosal turbinoplasty. If there is a poor response to the nasal decongestant, but there continues to be turbinate hypertrophy present, the problem is likely excess or osteitic conchal bone.

Nasal Valves

Static Collapse

The external nasal valve and the internal nasal valve should be evaluated for any static narrowing. The external nasal valve can be narrowed by a displaced caudal septum, splaying of the medial crural footplates, recurvature of the lower lateral cartilages, concavities of the lower lateral cartilages, congenital weakness of the lower lateral cartilage, cephalic malpositioning of the lower lateral cartilages, loss of vestibular skin, a ptotic tip, postsurgical vestibular stenosis, deviation of the anterior nasal spine, or even facial paralysis.[2]

The internal nasal valve is the narrowest section in the nose, and contributes significantly to nasal airway resistance.[2] It can be narrowed by a deviated nasal septum, particularly if there is a dorsal septal deviation, enlarged turbinates, medialized upper lateral cartilages, medialization and depression of the nasal bone, and/or prominence of the swell body. Short nasal bones with long upper cartilages may increase suspicion for some level of internal valve collapse due to lack of rigid support for the cartilage.

Dynamic Collapse

Dynamic valve collapse can be elicited by having the patient inspire deeply through their nose. Poor cartilaginous support can cause collapse to occur at both the internal and external nasal valve. Supporting the valves in clinic and gauging the relative benefit to the patient is a useful way to determine whether there is utility in placing support grafts. When this is observed, one can anticipate needing to enhance the support in these regions surgically through cartilaginous grafts, suturing techniques, tensioning of the nose, or a combination of these.

External Nose

Upper Third

The position of the nasal bones and any asymmetry should be noted. The height, length, and width of the nasal bones should also be assessed. The shape of the nasal bones should be assessed, particularly if there is any convexity or concavity present. This becomes especially important with a history of nasal trauma, as these convexities and concavities can help guide the need for medial or lateral osteotomies to straighten the nose and open the nasal airway.

Any step-offs between the nasal bone articulation and the upper lateral cartilage should be palpated. The presence of a step-off deformity at this junction often reflects as an inverted-V deformity. This deformity is caused by disruption of the upper lateral cartilage attachment to the dorsal septum, which in turn causes a medialization and depression of the upper lateral cartilage in relation to the nasal bone and the septum, thus giving the appearance of an inverted-V. Any rhinion horns, which are bony prominences on the nasal bones at the rhinion, should be noted, as well as the presence of a bony hump.

Middle Third

Deviation of the mid-vault should be noted. This is often a reflection of a deviated nasal septum, but it can also be due to asymmetry of the upper lateral cartilages, or even abnormal or asymmetric scarring from prior trauma or nasal surgery. The nasal valve should be assessed for any static or dynamic narrowing. The height of the middle vault should be assessed for the presence of a dorsal hump that is likely cartilaginous in nature or for evidence of a saddle nose deformity. A narrow or pinched middle third is often an external finding of internal nasal valve narrowing.

Supratip

Fullness of asymmetry should be assessed. Bulbous or boxy lower lateral cartilages can give the appearance of a full supratip region, which can extend into the middle third of the nose. Pollybeak deformity can also be assessed in this region. Pollybeak deformity can result from many etiologies including over-resection of the bony dorsum along with under-resection of the dorsal septum, over-resection of the caudal septum, over-resection of the alar cartilages, and excessively thick skin or excessive scarring in the supratip. Pollybeak deformity is a visual diagnosis, but the surgeon must be prepared to address any number of etiologies as a part of surgical planning when attempting repair.

Tip

The nasal tip should overall be assessed for asymmetry, deviation, projection, and rotation. Tip support can be examined by applying pressure to the tip and evaluating the degree of collapse posteriorly with this maneuver. Poor tip support can be the reflection of weak lower lateral cartilages, weak attachment of the medial crural footplates to the caudal septum, and/or compromise of the scroll region. Collectively, interruption of multiple minor tip support mechanisms can also lead to decreased tip support.

Tip projection and tip rotation should also be measured. There are various ways to measure tip projection. Commonly included measures for assessing tip projection include Simon's method, a one-to-one ratio of the upper lip length to the tip length, and Goode's method, according to which the ratio of the tip length to the dorsal length should be 0.66.[15] Nasal tip projection can also be measured by drawing a line in profile view from the anterior border of the lip superiorly along the nose. Tip projection is thought to be appropriate if

the amount of nasal tip anterior to this line is 50 to 60% of the of the total tip length from the tip defining point to the alar facial groove.[17] In males, the tip rotation should be between 90 and 95 degrees. In females, the tip rotation should be between 95 and 110 degrees.

Alar Base

The width of the alar base should be noted, as well as the symmetry from the midline of the columellar labial junction. The width of the alar base in a Caucasian nose should lie between the medial canthi.[15] In African American noses, the alar base should be roughly between the caruncles. A wider-than-ideal alar base could benefit from alarplasty.

Bulbosity or Boxiness

A bulbous or boxy tip may be caused by splaying of the interdomal ligaments, wide domes of the lower lateral cartilages, and convex orientation of the lateral crura, giving an overall domelike shape to the lower lateral cartilages. This shape to the lower lateral cartilages can extend beyond the nasal tip region and cause fullness of the supratip region and even the middle third of the nose. A domelike configuration of the lower lateral cartilages results in a trapezoidal shape of the tip.

Columella

The position of the columella relative to the midline of the columellar labial junction and to the tip should be documented. The height of the columella should also be measured. The columellar base, columella, and nasal tip should each be about one-third in height. The base of the columella should be assessed for excessive width, which can be caused by splaying of the medial crura or medial crural footplates, excess scar, cartilage grafts, a wide anterior nasal spine, and/or caudal septal deviation.

Columellar show should be documented with a normal columella between 2 and 4 mm from the inferior border of the columellar to the alar margin. A line can be drawn bisecting the apices of the nostrils. Above that line to the alar margin would be the alar height and below that line to the inferior border of the columella would be the columellar hang. Alar retraction or a congenitally high arch is present when the alar height is greater than 2 mm. In prior nasal surgery or trauma, this alar retraction can be most commonly due to soft-tissue loss, cartilage loss, or aggressive cephalic trims.

Conclusion

The nose is a very complex structure, largely due to its functional role in breathing and its essential aesthetic role in providing facial harmony. It requires mastery of the nasal mechanics and nasal physiology to formulate a surgical plan and effectively change the shape of the nose. Clinical evaluation is paramount in ultimately developing an appropriate surgical plan tailored to the patient. Assessing the nose in a systematic fashion and using objective measures can help quantify the patient's degree of nasal obstruction. Additionally, use of PROMs can allow for quantification of patient-perceived concerns and their subjective outcomes.

Conflict of Interest
None declared.

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