5 Functional Diagnostic Tools in Rhinoplasty: Italian Experience

Francesco Maria Passali, Eleonora Ciaschi, Laura Loccisano, and Stefano Di Girolamo

5.1 Introduction

Rhinoplasty is a plastic surgery procedure aimed to correct and reconstruct the nose. There are two types of rhinoplasty surgeries: functional rhinoplasty, used to improve the shape and function of the nose, and cosmetic rhinoplasty, the goal of which is to improve its appearance. To distinguish, in the "functional rhinoplasty", patients look for improvements in nasal breathing and olfaction, without radically changing the aesthetic of the nose. In most cases, functional improvements may be achieved without significantly altering the shape of the nose, such as when a septoplasty or certain types of nasal vestibular stenosis (valve) repair are performed.

The success of a cosmetic rhinoplasty is very important for patients, as the operation fundamentally changes a part of their appearance that has bothered them for years. However, rhinoplasty has relatively low satisfaction rates compared to other cosmetic procedures, causing high revision operation rates (about %15) and hence more physical and financial discomfort for the patient; nasal airway obstruction was found to be the most common indication for secondary surgery [1].

One of the reasons for the low satisfaction rate is failing to set the patient's expectations right before operation, due to the lack of the right use of communication and diagnostic tools. The perception of the patient and the surgeon might be different for the results of the operation. It is of utmost importance to reach a mutually agreeable set of expectations during the pre-surgery consultation utilizing the tools available for pre-surgery planning [2].

It is well known that breathing through the nose is the only physiological form of breathing, as it is proved by the anatomical, functional, and psycho-behavioural alterations induced by breathing through the mouth. However, this natural and

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apparently simple way of breathing implies the existence of fine mechanisms and functions of cleaning and heating of the air breathed in, with which the nasal mucosa is endowed. It is, indeed, the role of the nose to change the physical characteristics (temperature and humidity) of the air, making them suitable for the gas exchange in the lungs and providing in addition a barrier from pollution, allergens, viruses and bacteria.

The nose is a distinct landmark in facial aesthetics, being it the focal point of the face with a complex three-dimensional structure. The morphological integrity of the osteo-cartilaginous structures, as well as of the mucosa and epithelium that cover them, is an indispensable prerequisite to carry out a physiological nasal breathing and for the ventilation of the paranasal cavities. Reductive rhinoplasty reduces nasal size and may compromise nasal airway width; thus, the ideal rhinoplasty includes preservation or improvement of the respiratory function.

To measure nasal function objectively is a constant challenge for plastic surgeons, otolaryngologists, speech pathologists, physiologists and allergists. The patient's perception is important but does not define the degree of obstruction or the degree of improvement after a certain treatment.

Nasal breathing takes place under conditions of resistance over 50% higher than that of the oropharyngeal tract. In the course of breathing in, the inspired volume of air, which crosses the nasal valve at the speed of 2–3 m/s, is distributed in three main streams: the main one passes through the middle meatus, another accounting for 5–10% with an almost vertical route reaches the olfactory bulb, and the third one laps the nasal floor. Moreover, to this laminar flow crossing the three meati, microturbulences are added, especially behind the nasal valve. Microturbulences are required in order to guarantee an adequate flow's merging and to increase the contact between the air and the mucosa. This phenomenon is aimed to improve heating and humidification, as well as the cleaning process of the inspired air [3].

The internal nasal valve cross-section is delimited by the head of the inferior turbinate, the nasal septum and the upper lateral cartilage. The external nasal valve is bordered by the alar lobule, medial crus of the lower lateral cartilage, caudal septum, alar rim and nasal sill [4]. The nasal valves are responsible for one-third of total nasal resistances [5], they respond to mechanical stresses and are modulated by voluntary muscles. Two-thirds of nasal resistances are due to the turbinates valve [6], i.e. the neurovascular control cavernous tissue of the turbinates [7]. This is why it is more correct to speak about the "nasal valve area" (Fig. 5.1) or "flow-limiting segment" [8] where cartilages, muscles, mucosa, and epithelium contribute to prepare and provide the air for the lower respiratory apparatus and for the pulmonary gas exchanges.

Thanks to the *nasal valve area*, the airflow through the nasal cavities follows the Poiseuille's law with a laminar flow and microturbulences around the unevenness of the nasal fossae walls. This way, the contact of the air with the mucosa is increased, reaching the ideal air temperature and humidity, and promoting the cleansing from pollution, allergens, viruses and bacteria made by the ciliated epithelium.

The important role of the internal nasal valve in nasal airflow has been widely discussed in literature [9]. Iatrogenic internal nasal valve obstruction is frequently

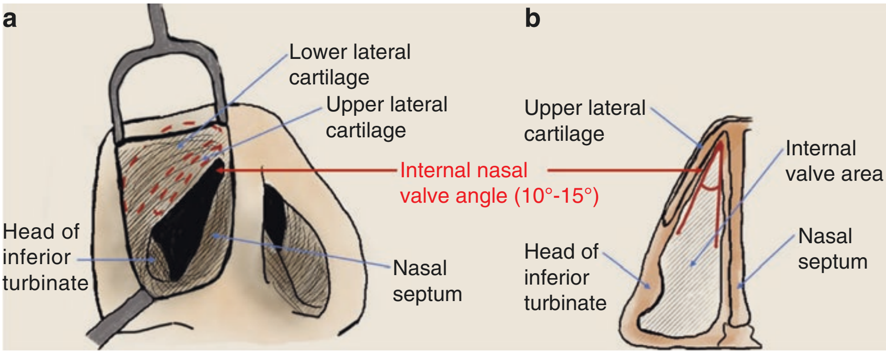

Fig. 5.1 Schematic view of the "nasal valve area". (**a**) The internal nasal valve area is delimited by the head of the inferior turbinate, the nasal septum and the upper lateral cartilage. (**b**) The internal nasal valve angle mesures usually 10–15°

secondary to collapse of the mid-vault after composite dorsal hump reduction or vestibular stenosis [10]. Moreover, if an iatrogenic cause of obstruction is identified, such as internal nasal valve collapse or synechiae, the rhinoplasty revision treatment will be required but should be delayed for at least 1 year to allow complete resolution of edema and maturation of scar tissue.

Studies have demonstrated that air flowing from the nostrils to the nasopharynx increases to 95% humidity and nearly 30 °C [11]. In fact, the air conditioning is guaranteed by the presence of the cavernous tissue and the arterious-venous shunts of the turbinates' microcirculation. The breathing of cold air enhances, in a reflex way, the opening of the arterious-venous shunts, increasing the heat exchanges at the air–mucus interface, while, on the other hand, breathing in hot air leads to the constriction of afferent arterioles.

The degree of repletion of the cavernous spaces, moreover, is modulated by the conditions of environmental humidity: if the air is dry, the water transudes from the turgid sinusoids toward the mucosa surface as a result of osmotic phenomena.

Previous studies have focused on the involvement of tactile receptors and mechanoreceptors in the sensation of nasal airflow. The major distribution of mechanoreceptors has been proved to be on the nasal vestibule, which is therefore the predominant sensitive nasal area. Indeed, the nasal vestibule represents the start of the respiratory system and histologically resembles skin lined by stratified squamous epithelium. The high concentration of mechanoreceptors and thermoreceptors in the anterior nasal valve/vestibule region may reflect an optimized confluence of trigeminal sensitivity to allow the detection and modulation of inspiratory air [4].

Worth of mention, among all these complex functions and the neurovegetative reflexes controlling them, is the presence of cold thermoreceptors involved in nasal patency sensation.

The idea of cold thermoreceptors in the nasal mucosa was proposed several years ago by Eccles [12], who reported that menthol topic administration produces the illusion of decongestion and improves nasal airflow without actually altering nasal morphology. Recent studies have shown the presence of TRP (transient receptor potential) M8 channel using immunostaining in human nasal tissue principally in the epithelium, secretory glands, and vessels [13]. The transient receptor potential (TRP) channel superfamily is a nonselective cation channel and can be classified into six subfamilies; melastatin 8 (TRPM8) subfamily is activated by cold temperatures and menthol.

The distribution of thermoreceptors parallels that of mechanoreceptors, with a higher density of both types of thermoreceptors, warm and cold, in the nasal vestibule, in the nasal cavum or adjacent malar skin. Moreover, general somatosensitivity comprises both mechano- and thermoreceptors and should reflect the degree of trigeminal sensitivity across branches of ophthalmic and maxillary nerves within the nasal cavity.

The dynamic cooling, though, is not just a function of the static air temperature or humidity in the environment; it also depends on the interaction between an individual's nasal airway structures (cartilages and mucosa) and the inspired air flow. Sensation of the nasal cavity mucosa is supplied by branches of the maxillary and ophthalmic divisions of the trigeminal nerve [4].

The preoperative consultation for rhinoplasty serves as an opportunity to obtain the patient's nasal history, to examine the nasal airway and perform nasofacial analysis. In this chapter, we will discuss about the functional diagnostic tools in rhinoplasty.

5.2 Assessment of Nasal Airflow

A good preoperative nasal breathing is not a guarantee of same postoperative breathing. The main idea behind volumetric rhinoplasty is as follows: If the size of the nose is reduced, the internal elements should be adjusted even if the patient has no impairments in nasal breathing for an adequate nasal airway width. Minimal septal deviations, concha bullosa, weak lateral cartilages or any other potential breathing problem not reported before the rhinoplasty may cause nasal obstruction [14].

This phenomenon is quite common and, if considered in itself, it limits the outcomes of functional surgery: After a reduction rhinoplasty, a decrease in the internal volume may be expected. According to Sheen et al. [15], this situation can be seen in about 75% of patients, nonetheless only about 10% of subjects develop nasal obstruction.

This complex array of variables may vary as a consequence of the surgical procedure. Thus, it is important to assess nasal airflow both before and after the rhinoplasty.

The patient should be examined for collapse of the external nasal valves on deep inspiration, and a Cottle test should be performed to evaluate patency of the internal nasal valves. Internal nasal examination is aided with the use of a nasal speculum. Narrowing or collapse of the internal valves with inspiration should be reported as well as inferior turbinate hypertrophy, which is typical in patients with septal deviation.

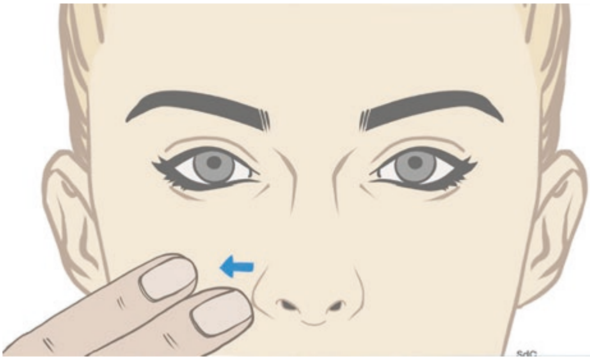

Fig. 5.2 Cottle manoeuver

The Cottle manoeuver (Fig. 5.2) is performed by gently pulling laterally on the cheek directly adjacent to the nose to open the nasal valve on the side of the nose being evaluated [16].

Septal deformities such as deviation, tilt, spurs and perforations must be identified. The shape and the availability of the septal cartilage has to be assessed, as this is the main source of autogenous graft material. The presence of nasal polyps or tumours may require further investigations and specific treatment [10].

Most measurements developed for nasal function have focused on evaluating nasal obstruction. They can be divided into two categories: **patient-reported (subjective)** and **objective** measurements.

5.2.1 Objective Methods

Traditionally, nasal ventilation is **objectively** measured using rhinomanometry or acoustic rhinometry.

Rhinomanometry is a dynamic test of nasal function that calculates nasal airway resistance (NAR) by measuring transnasal pressure and airflow in the nasal passage during respiration [17].

The following three kinds of rhinomanometry are used:

- The most commonly used method is *active anterior rhinomanometry (AAR)*, in which the patient actively breathes through one nasal cavity while the transnasal pressure, or difference in pressure from the naris to the nasopharynx, is measured with a pressure probe placed at the contralateral nostril.
- *Passive anterior rhinomanometry* the pressure is also measured for each nasal cavity separately, but at a given airflow.
- *Active posterior rhinomanometry* measures choanal pressure with a sensor placed at the back of the nasal cavity via the mouth [18].

In AAR, two parameters are recorded: *flow* and *pressure gradient* from the nostril to the rhinopharynx.

Acoustic rhinometry (AR) is a simple, reproducible technique for measuring the volume of the nasal cavity based on the analysis of sound waves reflected from the nasal walls. By sending a sound pulse into the nose and recording and analysing the reflected sound, a two-dimensional picture of the nasal cavity is made, from which the volume and the geometry of the nasal cavity can be deduced [19]. The clinical value of AR is its ability to measure the nasal cavity dimensions in terms of a curve describing the cross-sectional areas (MCA) as a function of distance, identifying the narrowest part of the nasal cavity that usually corresponds to the nasal valve area or to the head of the inferior turbinate. This curve describes nasal airway patency and gives an impression of the degree of nasal obstruction [20], but on the other hand it does not give the details of the nasal airflow.

The area-distance curve usually shows three minimum notches or deflections, which represent the narrowest parts in the nasal cavity. Two of these notches are situated in the most anterior part of nasal cavity (up to 3 cm from the nares), representing the nasal valve and the head of the inferior turbinate [21].

All types of rhinomanometry are supposed to determine a relationship between pressure and flow. In other words, this method can reveal how much pressure decay in the nasal cavity is needed to bring about the amount of flow that meets the demands of adequate nasal physiology and the needs for respiration and gas exchange.

Since 1984, the permanent Standardization Committee on Rhinomanometry [22] published the following statements to perform rhinomanometry on uniformity: concerning pressure gradient measure, the basic method is the adhesive tape technique which gives an airtight seal with a minimal distortion of the nostril and is easy to perform.

To assess the flow, a facial mask is usually employed: the advantages are minimum-to-no nasal valve deformation and little chance of leakage at the level of the nostril. However, any kind of mask that does not result in deformation of the nose and does not allow leaks is acceptable. The mask should be transparent so that deformation of the nostril or kinking of the pressure tube can be noted and eliminated. Calibration of equipment is needed, the recording should always be performed during quite breathing, and the patient should be in a sitting position and have a rest and adaptation time to the environment temperature. The $x - y$ recording is considered the best because it shows very well the relationship between pressure gradient and flow. The resistance is preferably expressed at the fixed pressure of 150 Pa, and the flow is expressed in cm^3/s [3].

With rhinomanometry, the dynamic changes of airway resistance during respiration are continuously assessed. To obtain a single outcome value, the nasal airflow at a transnasal pressure difference of 150 Pa is frequently reported. This pressure difference reflects conditions at low physical efforts, provides information on nasal resistance when mixed laminar and turbulent flow prevails and can be achieved also by patients with poor respiratory strength. Mucosal decongestion with α-imidazoles may help to differentiate mucosal congestion from skeletal abnormalities. Mean flow increases ranging between 20 and 40% after mucosal decongestion have been reported [18].

However, despite the efforts of the *International Standardization Committee*, the introduction of the computerized analysis of the results, the studies of different authors devoted to solving methodological problems and the realization of technical devices, after more than 35 years since its first appearance into the clinical practice, AAR still represents a topic of discussion and a subject for critical reviews [22].

At this regard, for example, the problem of standardization does not end with the reference variables (flow measured in cm^3/s at a fixed pressure of 150 Pa) but includes many aspects that have a decisive influence on the results. Among them, the method of application of the receptors does not represent a triviality, on the contrary, it constitutes an element of extreme importance for the reliability of the collected data: this delicate phase, key to the entire test, is subjected exclusively to the examiner expertise. Consequently, his/her degree of experience and attention represent a variable that can influence the validity of the exam in a positive or negative sense [3].

Another method to measure nasal airflow is the peak nasal inspiratory flow (PNIF). This method assesses the highest airflow through both nostrils during the maximum forced nasal inspiration, but does not measure the transnasal pressure difference and does not reflect the dynamic changes of nasal resistance during breathing, neither represents physiological conditions because normal oronasal breathing starts at much lower tidal volumes compared to the maximum nasal inspiration.

PNIF measures the forced maximal inspiratory airflow through the nose. A portable Youlten peak flow meter is used to assess maximal inspiratory flow; the patient is asked to do about three satisfactory maximal inspirations each time at basal condition and in sitting position, with at least 30 s interval between each inspiration. After this, only the highest of the three values recorded is considered [23].

Peak nasal inspiratory flow is a reliable, cheap and simple method to assess nasal airflow with an acceptable correlation with anterior active rhinomanometry both in healthy and obstructed noses [24].

Recently, the use of four-phase rhinomanometry (4PR) has been recommended to assess nasal obstruction. Nasal airway resistance is calculated using hundreds of resistances continuously recorded during the whole breathing cycle [22]. In 4PR, the most important parameters are the *effective resistance* of the entire breath (Reff) and its *logarithmic value* (logReff). Four-phase rhinomanometry (4PR) is advantageous because a result can be obtained for all patients, as it is not necessary to reach a designated pressure on the pressure–flow curve [25]. Two different studies compared 4PR and PNIF in the study of rhinological patients finding the two instruments to be comparable in results, with PNIF correlating better than 4PR with the nasal symptoms. Both studies concluded that PNIF, being inexpensive, fast, portable, simple and reliable, has practical advantages over 4PR and should be available in daily practice for the assessment of nasal obstruction [26, 27].

The biggest problem, however, is the frequent detection of a discrepancy between the subjective sensation of the degree of nasal obstruction/patency, the objective parameter recorded with rhinomanometry, and the endoscopic picture. The patient's perception is important but does not define the degree of obstruction or the degree of improvement after a certain treatment.

However, the fact that the patient's subjective complaints of nasal obstruction cannot be verified objectively does not mean they are not real and valid symptoms originating from a physical abnormality.

This problem has been pondered over for decades [28]. Several studies have demonstrated that applying substances such as camphor, eucalyptus, L-menthol, vanilla or lignocaine to the nasal or even palatal mucosa can cause a marked sensation of increased nasal airflow without any change in nasal resistance as measured by rhinomanometry. Conversely, infiltration or topical application of local anaesthetics in the nasal vestibule or damage of trigeminal sensory nerve endings may cause a sensation of decreased nasal patency, again without any measurable effect on nasal resistance.

Accordingly to Bermuller et al. [23] approximately 25% of symptomatic patients with functionally relevant nasal structural deformity remained undetected with both AAR and PNIF. Both methods are considered helpful to support the diagnosis of functionally relevant nasal structural deformities, but a negative test outcome does not exclude functionally relevant nasal stenosis. About that patient-centred questionnaire may represent a more practical and informative option to discern outcomes for the rhinoplasty patient. These data are critical in guiding surgical counselling for patients [29].

5.2.2 Subjective Methods

Beyond all the aforementioned objective evaluation methods used to assess nasal obstruction, it would be important to highlight the importance of the subjective evaluation methods as in rhinoplasty the patient perception must be taken under consideration. The aesthetic goals following rhinoplasty are largely dependent on the patient's concerns and expectations. For patients who present without nasal airway impairment, respecting and preserving the key structures is a fundamental requisite. Moreover, patients require careful attention in pre-surgical consultations, and clear communication should be prioritized to ensure that the surgeon understands the patient's expectation. At this regard, patient-reported questionnaires are increasingly becoming a tool to better assess the patient's appeasement and the nasal functional condition.

Subjective analysis of nasal patency is generally based on patient-reported outcome measures (PROMs) with visual analogue scales and/or questionnaires. In relatively recent publications few questionnaires used by plastic surgeon for rhinoplasty were used to assess both the cosmetic or psychosocial aspects, and pre/post-operative functional evaluations [30].

These validated questionnaires were the *Standardized Cosmesis and Health Nasal Outcomes Survey* (SCHNOS) and the "*nasal obstruction symptom evaluation test"* (NOSE), which have the specific goal of evaluating nasal symptoms including subjective obstruction [29].

The **Nasal Obstruction Symptom Evaluation** (NOSE) is a five-item, disease-specific patient-reported outcome measure of nasal obstruction [31]. Elements are scored from 0 to 4, or “Not a problem” to “Severe problem”. Total point is summed and multiplied by 5 to allow a minimum score of 0 and a maximum score of 100. Higher results correlate with severity of nasal obstruction. In literature NOSE is described as the most common subjective questionnaire used for rhinoplasty [29] and a total score of 30 is established as the cut off to differentiate between a normal nasal airflow and nasal obstruction. Moubayed et al. developed a classification in which patients are categorized in **mild** (range, 5–25), **moderate** (range, 30–50), **severe** (range, 55–75), or **extreme** (range, 80–100) nasal obstruction [32].

The **Standardized Cosmesis and Health Nasal Outcomes Survey** (SCHNOS) is a 10-item, disease-specific patient-reported outcome measure for functional and cosmetic rhinoplasty: The elements from 1 to 4 are about the nasal obstruction; the item from 4 to 10 evaluate patient perception of the nasal aesthetic. Elements are scored from 0 to 5, or “No problem” to “Extreme problem,” for a maximum score of 50; the maximum score is 100 [32].

5.3 Our Experience

In our experience, the most used diagnostic tool in rhinoplasty is the standardized photography, characterized by the frontal projection, lateral, oblique and basal ones. Moreover, an additional photo during smiling is taken because it may reveal nasal tip ptosis, static or dynamic, with a shortening of the upper lip or a transverse crease in the mid-philtral area [10]. This procedure is mandatory for every patient in the pre-surgical stage, as it is a crucial component of the medical record for preoperative planning and evaluation of postoperative results.

The use of diagnostic imaging techniques such as CT scan is required for the analysis of nasal patency, especially the internal nasal valve area. Moreover, imaging techniques are also needed in order to obtain more anatomical details of the structural causes of nasal obstruction for a better pre-surgical functional planning.

Besides morphological tools, we also administer NOSE questionnaire, a scale for the symptomatic measurement of nasal obstruction both in presurgical evaluation and in postoperative follow up. Subjective methods such as NOSE were found to be a promising and reliable tool to assess symptomatic improvement of nasal obstruction, especially after functional rhinoplasty [33].

To a lesser degree for the preoperative planning of functional rhinoplasty, we analyse the nasal breathing using rhinomanometry and acoustic rhinometry. The main advantage of those objective measurements is the possibility to show any asymmetry in the nasal passage during the exam. Besides in patients that undergo functional rhinoplasty for severe nasal obstruction, it would be advisable to repeat AR and RMM after surgery to objectify the post operative results.

5.4 Conclusions

Accurate preoperative evaluation of the nasal airway, along with the clarification of both the patient's expectations and the surgeon's goals, is the key to cosmetic and functional good result. Considering both subjective instruments of nasal obstruction evaluation (such as the *Nasal Obstruction Symptom Evaluation Scale*—NOSE and *Standardized Cosmesis and Health Nasal Outcomes Survey*—SCHNOS) and objective parameters such as rhinomanometry or acoustic rhinometry, patient history, and objective examination, it can be generally stated that: when anatomic anomalies on one or both sides are present, the symptom of nasal obstruction is constant, and the inspection assesses the kind and location of the stenosis. In the preoperative planning for rhinoplasty, nasal history should be investigated as well as a thorough examination of the nasal airway should be performed, together with nasofacial analysis. Also, intraoperatively, adequate anatomical exposure of the nasal deformity, preservation and restoration of the normal anatomy, correction of the deformity and restoration or preservation of the nasal airway are required. These steps added to a thorough evaluation of patient's expectations is the key that leads to successful outcomes following rhinoplasty.

References

1. Thomson C, Mendelsohn M. Reducing the incidence of revision rhinoplasty. J Otolaryngol. 2007;36(2):130–4. https://doi.org/10.2310/7070.2007.0012.
2. Saleh HA, Beegun I, Apaydin F. Outcomes in rhinoplasty. Facial Plast Surg. 2019;35(1):47–52. https://doi.org/10.1055/s-0039-1677829.
3. Passali F, Ottaviano G, Passali G, Girolamo S. The role of rhinomanometry and nasal airflow evaluation in the diagnosis of atrophic rhinitis. 2020. pp. 77–87. https://doi.org/10.1007/978-3-030-51705-2_7.
4. Shen J, Hur K, Li C, Zhao K, Leopold DA, Wrobel BB. Determinants and evaluation of nasal airflow perception. Facial Plast Surg. 2017;33(4):372–7. https://doi.org/10.1055/s-0037-1603788.
5. van Dishoeck HAE. Elektrogramm der Nasenflügelmuskeln und Nasenwiderstandskurve. Acta Otolaryngol. 25(4):285–95. https://www.tandfonline.com/doi/abs/10.3109/00016483709127966. Accessed 15 Apr 2021.
6. Haight JS, Cole P. The site and function of the nasal valve. Laryngoscope. 1983;93(1):49–55. https://doi.org/10.1288/00005537-198301000-00009.
7. Kern EB. Surgical approaches to abnormalities of the nasal valve. Rhinology. 1978;16(3):165–89.
8. Bloching MB. Disorders of the nasal valve area. GMS Curr Top Otorhinolaryngol Head Neck Surg. 2007;6:Doc07.
9. Howard BK, Rohrich RJ. Understanding the nasal airway: principles and practice. Plast Reconstr Surg. 2002;109(3):1128–46; quiz 1145–1146. https://doi.org/10.1097/00006534-200203000-00054.
10. Rohrich RJ, Ahmad J. Rhinoplasty. Plast Reconstr Surg. 2011;128(2):49e–73e. https://doi.org/10.1097/PRS.0b013e31821e7191.
11. Sommer F, Kroger R, Lindemann J. Numerical simulation of humidification and heating during inspiration within an adult nose. Rhinology. 2012;50(2):157–64. https://doi.org/10.4193/Rhino11.231.

12. Eccles R, Jones AS. The effect of menthol on nasal resistance to air flow. J Laryngol Otol. 1983;97(8):705–9. https://doi.org/10.1017/s002221510009486x.
13. Liu S-C, Lu H-H, Fan H-C, et al. The identification of the TRPM8 channel on primary culture of human nasal epithelial cells and its response to cooling. Medicine (Baltimore). 2017;96(31):e7640. https://doi.org/10.1097/MD.0000000000007640.
14. Kamburoglu HO, Bitik O, Vargel İ. Airflow considerations and the effect of Webster's triangle in reduction rhinoplasty. Aesthetic Plast Surg. 2021;45(5):2244–54. https://doi.org/10.1007/s00266-021-02168-9.
15. Sheen JH. Spreader graft: a method of reconstructing the roof of the middle nasal vault following rhinoplasty. Plast Reconstr Surg. 1984;73(2):230–9.
16. Das A, Spiegel JH. Evaluation of validity and specificity of the Cottle maneuver in diagnosis of nasal valve collapse. Plast Reconstr Surg. 2020;146(2):277–80. https://doi.org/10.1097/PRS.0000000000006978.
17. Zhao K, Frye RE. Nasal patency and the aerodynamics of nasal airflow in relation to olfactory function. In: Handbook of olfaction and gustation. Hoboken: Wiley; 2015. p. 353–74. https://doi.org/10.1002/9781118971758.ch16.
18. André RF, Vuyk HD, Ahmed A, Graamans K, Nolst Trenité GJ. Correlation between subjective and objective evaluation of the nasal airway. A systematic review of the highest level of evidence. Clin Otolaryngol. 2009;34(6):518–25. https://doi.org/10.1111/j.1749-4486.2009.02042.x.
19. Grymer LF, Hilberg O, Pedersen OF, Rasmussen TR. Acoustic rhinometry: values from adults with subjective normal nasal patency. Rhinology. 1991;29(1):35–47.
20. Ottaviano G, Fokkens WJ. Measurements of nasal airflow and patency: a critical review with emphasis on the use of peak nasal inspiratory flow in daily practice. Allergy. 2016;71(2):162–74. https://doi.org/10.1111/all.12778.
21. Nigro CEN, de Aguiar Nigro JF, Voegels RL, Mion O, Mello Junior JF. Acoustic rhinometry: anatomic correlation of the first two notches found in the nasal echogram. Braz J Otorhinolaryngol. 2005;71(2):149–54. https://doi.org/10.1016/s1808-8694(15)31303-3.
22. Vogt K, Bachmann-Harildstad G, Lintermann A, Nechyporenko A, Peters F, Wernecke KD. The new agreement of the international RIGA consensus conference on nasal airway function tests. Rhinology. 2018;56(2):133–43. https://doi.org/10.4193/Rhin17.084.
23. Bermüller C, Kirsche H, Rettinger G, Riechelmann H. Diagnostic accuracy of peak nasal inspiratory flow and rhinomanometry in functional rhinosurgery. Laryngoscope. 2008;118(4):605–10. https://doi.org/10.1097/MLG.0b013e318161e56b.
24. Døsen LK, Kvinnesland K, TarAngen M, Shiryaeva O, Gay C, Haye R. Unilateral and bilateral PNIF in quality control of nasal septal surgery. Int J Otolaryngol. 2018;2018:7846843. https://doi.org/10.1155/2018/7846843.
25. Vogt K, Zhang L. Airway assessment by four-phase rhinomanometry in septal surgery. Curr Opin Otolaryngol Head Neck Surg. 2012;20(1):33–9. https://doi.org/10.1097/MOO.0b013e32834e6306.
26. van Egmond MMHT, van Heerbeek N, Ter Haar ELM, Rovers MM. Clinimetric properties of the Glasgow health status inventory, Glasgow benefit inventory, peak nasal inspiratory flow, and 4-phase Rhinomanometry in adults with nasal obstruction. Rhinology. 2017;55(2):126–34. https://doi.org/10.4193/Rhin16.296.
27. Ottaviano G, Scadding GK, Iacono V, Scarpa B, Martini A, Lund VJ. Peak nasal inspiratory flow and peak expiratory flow. Upright and sitting values in an adult population. Rhinology. 2016;54(2):160–3. https://doi.org/10.4193/Rhin15.180.
28. Burrow A, Eccles R, Jones AS. The effects of camphor, eucalyptus and menthol vapour on nasal resistance to airflow and nasal sensation. Acta Otolaryngol. 1983;96(1–2):157–61. https://doi.org/10.3109/00016488309132886.
29. Okland TS, Kandathil C, Sanan A, Rudy S, Most SP. Analysis of nasal obstruction patterns following reductive rhinoplasty. Aesthet Plast Surg. 2020;44(1):122–8. https://doi.org/10.1007/s00266-019-01484-5.

30. Barone M, Cogliandro A, Di Stefano N, Tambone V, Persichetti P. A systematic review of patient-reported outcome measures after rhinoplasty. Eur Arch Otorhinolaryngol. 2017;274(4):1807–11. https://doi.org/10.1007/s00405-016-4359-9.
31. Stewart MG, Witsell DL, Smith TL, Weaver EM, Yueh B, Hannley MT. Development and validation of the nasal obstruction symptom evaluation (NOSE) scale. Otolaryngol Head Neck Surg. 2004;130(2):157–63. https://doi.org/10.1016/j.otohns.2003.09.016.
32. Moubayed SP, Ioannidis JPA, Saltychev M, Most SP. The 10-item Standardized Cosmesis and Health Nasal Outcomes Survey (SCHNOS) for functional and cosmetic rhinoplasty. JAMA Facial Plast Surg. 2018;20(1):37–42. https://pubmed.ncbi.nlm.nih.gov/28880988/. Accessed April 14, 2021.
33. Shafik AG, Alkady HA, Tawfik GM, Mohamed AM, Rabie TM, Huy NT. Computed tomography evaluation of internal nasal valve angle and area and its correlation with NOSE scale for symptomatic improvement in rhinoplasty. Braz J Otorhinolaryngol. 2020;86(3):343–50. https://doi.org/10.1016/j.bjorl.2019.08.009.