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FACIAL PLASTICS: FUNCTIONAL RHINOPLASTY(TD WANG AND CZ JOHNSON, SECTION EDITORS)

Algorithm for Management of Nasal Valve Collapse

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Abstract
Purpose of Review Nasal obstruction is a very common challenge in daily ENT clinical and surgical practice. A common source of lack of satisfaction after septoplasty could be the impairment of the nasal valve area in both static and dynamic conditions.
Recent Findings Currently there is no consensus to a standard diagnostic algorithm for nasal valve collapse. We performed a review of the last 10 years of literature focused on recent innovations regarding physical examination, radiological diagnosis, subjective, and objective measurement of nasal valve collapse. Finally, we try to formulate a pre-surgical protocol, based on our experience, as well as a model follow-up to evaluate surgical outcomes.
Summary Though there are numerous surgical techniques for the treatment of nasal valve collapse, ENT surgeons would have difficulty selecting the most indicated one. A standardized pre-operative assessment should be mandatory to address a tailored surgery to patient clinical features.

Keywords Nasal valve collapse · Rhinomanometry · Acoustic rhinometry · Septoplasty · Rhinoplasty

Introduction

Nasal obstruction is a very common challenge in daily ENT clinical and surgical practice.

Septal deviation is a common cause of nasal obstruction affecting up to 80% of the population [1]. Many cases of septal deviation are asymptomatic, and the degree or severity of deviation has little to no correlation with the degree of obstruction experienced by the patient [2, 3]. However, patient satisfaction after septoplasty ranges between 65 and 80% [4]. The most common cause of lack of satisfaction after this surgery can often be found in impairment in the nasal valve area.

This article is part of the Topical collection on *FACIAL PLASTICS: Functional Rhinoplasty*

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The nasal valve is a complex structure which determines 70% [5] of nasal airway resistances. Any morpho-structural alteration of this region has a significant impact on respiratory dynamics and nasal flow, presenting as nasal obstruction. Hence, an adept knowledge of nasal valve anatomy is essential to understand nasal valve collapse (NVC) and its complexity for the rhinoplasty surgeon.

The internal nasal valve (INV) area is defined by the nasal septum medially, the floor of the nose inferiorly, and the upper lateral cartilage and the head of the inferior turbinate laterally. The external nasal valve (ENV) is form by the septum, the medial and lateral crura of the lower lateral cartilage, and the premaxilla. The normal angle between septum and upper lateral cartilages (ULCs) ranges from 10 to 15° (Mink's valve) [6] (Fig. 1). The rigidity of the lateral walls of the nasal valve prevents the collapse during inspiration.

In 2004, we suggested a tridimensional definition of the nasal valve area [5] that better explains structure and function of the nasal valve. This area is in fact delimited superolaterally, from the caudal end of the ULCs; laterally, from the "empty triangle" (Fig. 2), an approximately triangular region, without cartilaginous support structures made of fibrous-adipose tissue up to the margin of the piriform aperture, where the accessory cartilages can be found; medially,

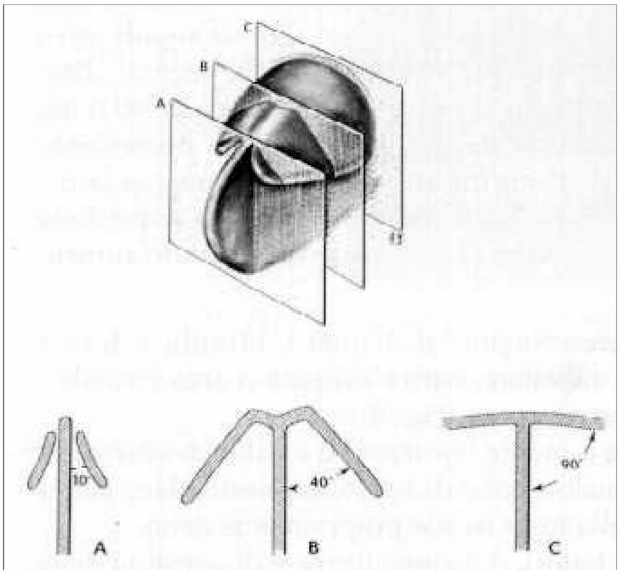


Fig. 1 Schematic representation of coronal sections between quadrangular cartilage and upper cartilages: Mink's valve (**A**), (**B**) coronal section conducted in the middle of the ULCs (**C**) coronal section conducted at the end of the ULCs

from the cartilaginous septum; inferiorly, from the inferior margin of the piriform aperture; infero-medially, from the wings of the spine and from the premaxilla; posteriorly, from the head of the inferior turbinate. The external nasal valve is described as the cross-sectional area caudal to the internal valve under the alar lobule, bounded supero-laterally by the caudal edge of the UCL, laterally by the nasal alar and ligamentous attachment of the lateral crus, medially by the caudal septum and columella, and inferiorly by the nasal sill.

NVC can be secondary to static structural deformities and/or dynamic abnormalities: in particular infero-medially ULCs displacement, narrowed pyriform aperture, septal deviation and inferior turbinate hypertrophy can cause INV disfunction. Static ENV afflictions come from scar or synechia after vestibule surgery. Facial palsy with nose musculature involvement and weakening of the fibro-cutaneous structures can be a cause of dynamic impairment.

Primary rhinoplasty is the most common cause of NVC [7]. Iatrogenic NVC can be consequence of MOHS surgery or endoscopic sinus surgery. Also congenital, post-traumatic, and aging changes are possible causes of NVC. Nasal Valve Collapse prevalence is up to 13% [8].

Methods

Due to a lack of a standard algorithm for NVC management, an in-depth literature review was performed using PubMed as the main electronic database. As starting-point the consensus statement in 2010 [9•] was chosen. Recent literature from the last decade was reviewed, initially searching the items "nasal valve collapse management," with the results of 39 papers. For each diagnostic step in NVC collapse management, we considered recent innovations with focus on physical examination, radiological diagnosis, subjective, and objective measurement (in particular rhinomanometry and acoustic rhinometry).

Finally, we try to formulate a protocol, based on our experience, and a model for follow-up to evaluate surgical outcomes.

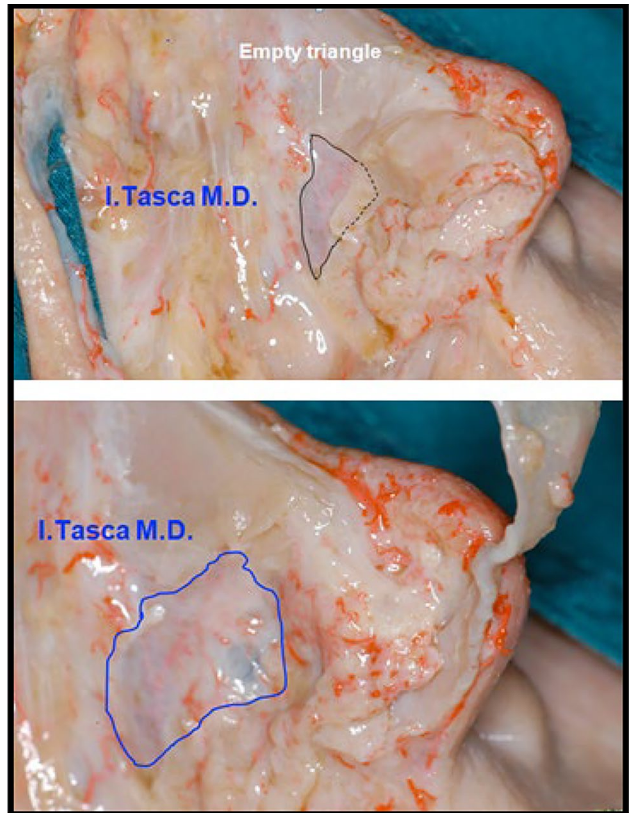


Fig. 2 Anatomical dissection of the nasal valve area. After removing alar cartilage, an empty triangle area is exposed. This fibrous structure is crucial to understand the tridimensional complexity of the nasal valve

Discussion

NVC can be consequence of different afflictions for the INV and ENV and several surgical techniques are available in NVC treatment [10••]. Hence, it is impossible to consider a standard treatment universally effective for every patient. Rather treatment should be tailored to each patient.

Accurate pre-operative diagnosis and subsequent selection of appropriate intervention ensure the best outcomes for patients with NVC.

Furthermore, nasal obstruction is a subjective symptom that is not always in accordance with nasal clinical examination or functional testing. A consensus statement by the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) states that although many such tests are available, there is no gold standard [9•].

Clinical History

First, clinicians should carefully query about possible NVC etiology to better understand INV or ENV involvement. Previous rhinoplasty esthetic or functional can influence the surgical treatment, as well as a history of previous sinus surgery, Mohs excision, or other head and neck surgery.

Physical Valve Examination

Physical valve examination is one of the most important components in the management of NVC. It can be performed using anterior rhinoscopy but also with endoscopic investigation. In a 2010 publication, Rhee et al. [9•] considered nasal endoscopy a useful tool to evaluate eventual static/anatomic alteration in the nasal valve, even if it is not mandatory for the clinician. In our experience, endoscopic examination has an important role, because the introduction of the speculum in the nasal vestibule can deform nasal valve structures. Furthermore, with this exam it is possible to detect signs of rhinosinusitis. In 2018, Patel et al. [11] proposed a grading system, based on endoscopic visibility of the middle turbinate. This grading system is an economic, reliable, and reproducible score to measure INV patency.

Among available methods for assessing the nasal airflow, the Cottle maneuver [12] is among the most used. The Cottle maneuver is performed by gently pulling laterally on the cheek directly adjacent to the nose (or if using a modified Cottle maneuver, a curette is inserted into the nostril) to open the nasal valve on the side of the nose being evaluated. Patients indicate the degree of airflow obstruction they experience before and after the nasal valve has been widened. To many physicians, an improvement in airflow constitutes a positive test and indicates surgical intervention may be beneficial to correct the obstruction. Despite widespread use of this test, the Cottle maneuver and modified Cottle maneuver are not a reliable method of determining the presence of symptomatic nasal valve collapse necessitating surgical intervention, even though the test is readily available and of practical utility [13]. In an interesting Canadian survey in 2019, Wang and Bonaparte calculated Cottle maneuver accuracy. They consider physical examination (39.5%) and this maneuver (62.8%) as the most important tools for evaluating ENV and INV impairment [1].

Radiological Examinations

In 2010, the panel [9•] argued that MRI is useful for confirming the diagnosis of NVC, and there was no consensus but general disagreement that CT scan is useful for this purpose. There is a debate in the literature regarding the use of imaging for evaluation of internal nasal valve collapse. In 2012, Moche et al. found that a radiographically measured valve area of 0.30 cm [2] on computed tomography (CT) scan was correlated with clinical narrowing with a sensitivity of 71.4% and specificity of 88.9% [14]. In 2014, Sedaghat et al. [15] found that no significant correlation between physical examination findings and CT scan of the nasal valve. Studies have shown, however, that CT scans reformatted in the plane of the nasal valve are most accurate and reliable for evaluation of the nasal valve angle. While there is not currently a consensus on methods of reporting nasal valve repair outcomes, the reformatted CT scan is the most validated current method of radiographic evaluation [16].

Subjective Measurement

VAS and satisfaction or QOL scales can be considered as possible instruments to evaluate and measure subjective discomfort related with NVC. Moreover, these economic and useful tests are also available as indicators of surgical outcomes.

In 2010, Rhee et al. [9•] stated that these tools are more specific indicators of successful intervention, even if consensus could not find a selected and univocal test to measure patient satisfaction.

NOSE score (Nasal Obstruction Symptom Evaluation) is a questionnaire validated [17] in 2003 that includes in its final version 5 items to investigate a subjective sensation such as nasal obstruction. Each item is scored on a 5-point Likert scale with the final total multiplied by 5 to make a total score between 0 and 100, with higher scores indicating worsened nasal obstruction symptoms.

A recent meta-analysis in 2017 [18] by Floyd et al. demonstrated in a series of 15 studies NOSE score improvement 12-month after functional rhinoplasty. This paper considers different interventions with the term "functional rhinoplasty," performed by different surgeons so, in our opinion, there is a huge bias that prevents understanding how different techniques could improve patient QoL.

Additional tools, such as the sinonasal outcomes test-22 (SNOT-22), also demonstrate utility in evaluating the patient-centered outcomes of nasal obstruction and septoplasty [19–21]. SNOT-22 is recommended by the European Position Paper on Rhinosinusitis and Nasal Polyps EPOS 2012 [21] as the most adequate tool to evaluate the effectiveness of surgery for chronic rhinosinusitis. Kordjian and

Poirrier with their statistical analysis demonstrated that SNOT-22 is a suitable tool for functional rhinoplasty.

Furthermore, the Glasgow Benefit Index (GBI) [22] was specifically designed to evaluate the benefit of ENT procedures. It consists of 18 questions, with six questions in each of three subscale domains: general benefit, physical benefit, and social benefit. Valsamidis et al. have demonstrated improvement following septoplasty [23], with confirmation of the role of the subjective measurements for surgical NVC management.

In 2020, Ziai and Bonaparte developed the Ottawa valve collapse scale (OVCS) [24] as a to categorize the severity of NVC pre-operatively. According to the OVCS grading scale, a zero is defined as no external valve collapse. A grade of one is defined as unilateral partial valve collapse [i.e., an active narrowing of the external nasal valve occurring during deep inspiration without complete airflow blockage (≤ 99%)]. A grade of two is defined either bilateral partial collapse (≤ 99%) or unilateral complete collapse [i.e., complete airflow blockage and nasal side alar or lower lateral side mucosa contacting the septum medially (100%)]. A grade of three is defined as complete bilateral nasal valve collapse (100%). Even if the OVCS scale did not demonstrate a predictive value of patient-centered outcomes 1 year following septoplasty at the end of their statistical analysis [25], they suggested that this scale assists surgeons in determining which patients need formal nasal valve surgery in addition to a standard septoplasty.

Objective Measurements

It is still a matter of controversy to what extent the sense of nasal obstruction is associated with objective measures for nasal space and air flow. Objective measurement of external nasal valve patency is a challenging endeavor due to the limitations of the tests and the problem of the test interfering with the results [26].

In 2020, Rhee et al. [9•] met near consensus about the relative importance of objective measures, with a general conclusion that patient-oriented outcome measures are more important than objective measures.

Acoustic rhinometry can measure the volume of the nasal passage but will not account for the dynamic nature of valve collapse. Placement of masks for rhinomanometry may stent the valve like a Cottle maneuver, thereby creating an artificially improved airway. Similarly, any probes placed in the nose may act as stents themselves [27].

Anterior Active Rhinomanometry

Anterior active rhinomanometry (AAR) is a dynamic means to examine nasal cavity patency and nasal function; it aims at establishing nasal resistance, which is the difficulty of passing air through the nose with measurement of transnasal pressure and air flow. In the presence of nasal valve compromise, rhinomanometry, performed after decongestion test, presents a very typical curve: in fact, the curve shows a reduction in airflow even with an increase in negative pressure [28].

The XY recording is considered the best way of representing rhinomanometry. The mirror image display of the curves for both sides of the nose is recommended; when applying it, quadrants I and III are used for the right nasal cavity, II and IV for the left nasal cavity. Quadrants I and IV are used for the graphic representation of the inspiratory half of the curve, II and III for the representation of the expiratory half on the curve.

The ordinate represents the flow, the abscissa the narichoanal differential pressure. Pressures are to be given in pascal (Pa), the flow in cm [3] s^{-1}. One hundred fifty pascal is the reference pressure.

In 2016, Vogt et al. [29] performed a powerful multicentric retrospective analysis of 36,563 clinical measurements with 4-phase rhinomanometry (4PR). Reliable technical requirements are given by fast digital sensors and modern information technology that improved classic rhinomanometry. Introduction of new indicators such as logarithmic effective resistance (Reff) and Vertix resistance (VR) proved to be capable of measuring the degree of obstruction of the nasal airway. The additional information provided by VR is important for the numeric description of the effect of the nasal valve in curves with expressed hysteresis due to valve phenomena.

Hysteresis is a characteristic graphic representation in AAR that highlights the impossibility of increasing the nasal respiratory flow as the pressures increase, once a plateau is reached due to the resistances imposed by the valve collapse (Fig. 3).

Posterior Active Rhinomanometry

Posterior active rhinomanometry (APR) is an objective measurement of choanal pressure obtained with a tube placed in the back of the mouth for both nasal cavities simultaneously.

In 2016, Maalouf et al. [30] suggested a functional tool to differentiate nasal valve collapse from other causes of nasal obstruction: the FRIED test (difference between the pressure flow of the inspiratory and expiratory phases during posterior rhinomanometry flow rate inspiratory-expiratory difference). A cut-off of − 0.008 l/s with a good sensitivity (82%) and a specificity of 59% constitutes an objective and easy-to-apply technique to diagnose nasal valve collapse in daily practice. FRIED score was inferred with unilateral resistance measurement while the contralateral nostril was tightly closed using surgical tape. Surgical tape sealing of

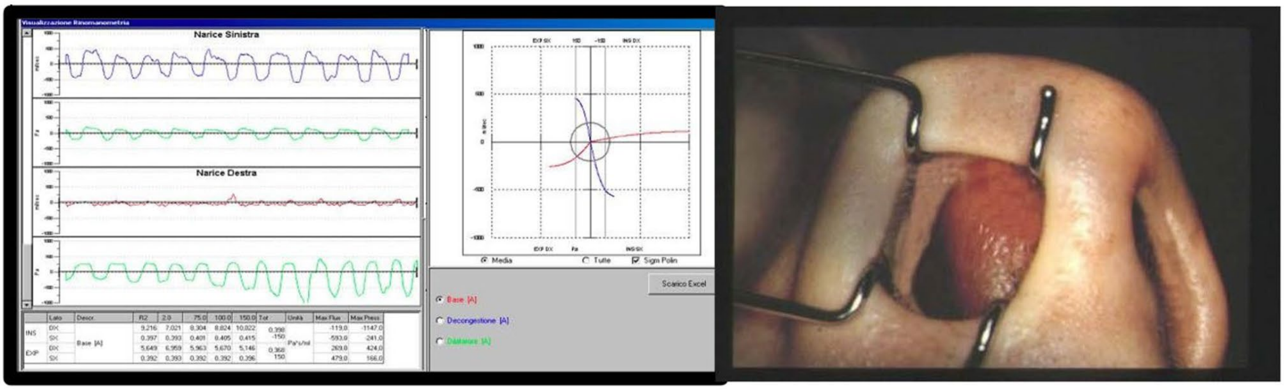


Fig. 3 Typical basal rhinomanometric tracing in valve stenosis with the distinguishing "hysteresis" inspiratory loop. On the right, corresponding patient physical evaluation

one nostril presents the advantage of having no effect on the shape or the dynamic of the studied nostril. The choice to infer FRIED score from the opposing nostril was made in order to be able to detect unilateral nasal valve collapse.

In our daily practice, APR is limited to physiological studies or nasal patency assessment in septal perforation or in complete unilateral nasal stenosis. This exam is difficult to perform because some subjects are unable to relax the oropharyngeal muscles while holding the pressure sensing tube in the mouth, and others repeatedly obstructed the end of the tube with their tongue [31]. Nevertheless, this poor reproducibility of measurement can bias outcomes.

Acoustic Rhinometry

Acoustic rhinometry (AR) is a technique developed by Hilberg et al. in the 1980s [32], used to measure the cross-sectional area of the nasal cavity as a function of the distance into the nasal cavity from the nasal sill. This measurement is performed by analyzing the amplitude of the reflection of sound waves projected into the nose (Fig. 4). The minimum cross-sectional area identified within the first 3 cm of the nose typically corresponds with the INV. Topical spray consisting of 0.1% xylometazoline was administered 5 min prior to measurement. Nosepiece sizing was chosen to provide an appropriate acoustic seal for each patient without altering nasal anatomy. Measurements were performed during a breathing pause by the patient. Nasal patency is assessed by a curve describing cross-sectional areas in the nasal cavity as a function of the distance. Software calculations make it possible to measure nasal volume between two chosen cross-sectional areas.

Video-Rhino-Hygrometer

Video-rhino-hygrometer (VRH) is a device performing non-invasive measurement of the patient's breathing, based on a so-called mirror fogging test described by Zwaardemaker in 1894 [33]. VRH is a simple and comfortable instrument to quantify nasal obstruction [34]. VRH analyzes the shape of the impressions produced by the condensation of the expired airstream on the thermoregulated surface via a specific digital image process algorithm.

NVC Diagnostic Management in Our ENT Department

A careful analysis of patient with nasal obstruction is crucial for a correct nasal surgery planning. In our protocol, every patient underwent in a strict diagnostic workup. A general examination is the first approach to patient: it is based on an amnestic collection of symptoms and inspection of external and internal characteristics of the nose. Anterior rhinoscopy for the study of the nasal cavity is completed by a nasal endoscopy, with a 0° rigid nasal endoscope of

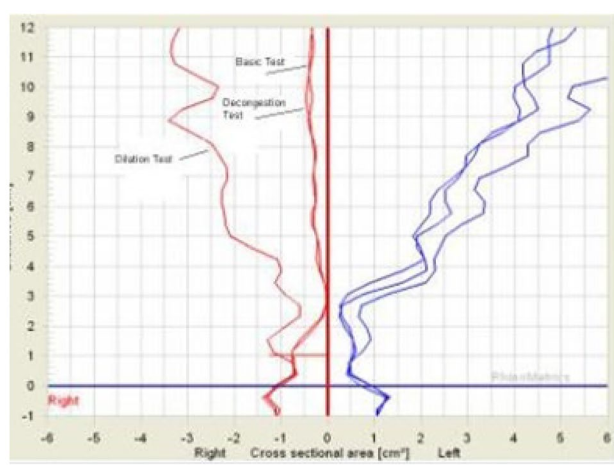
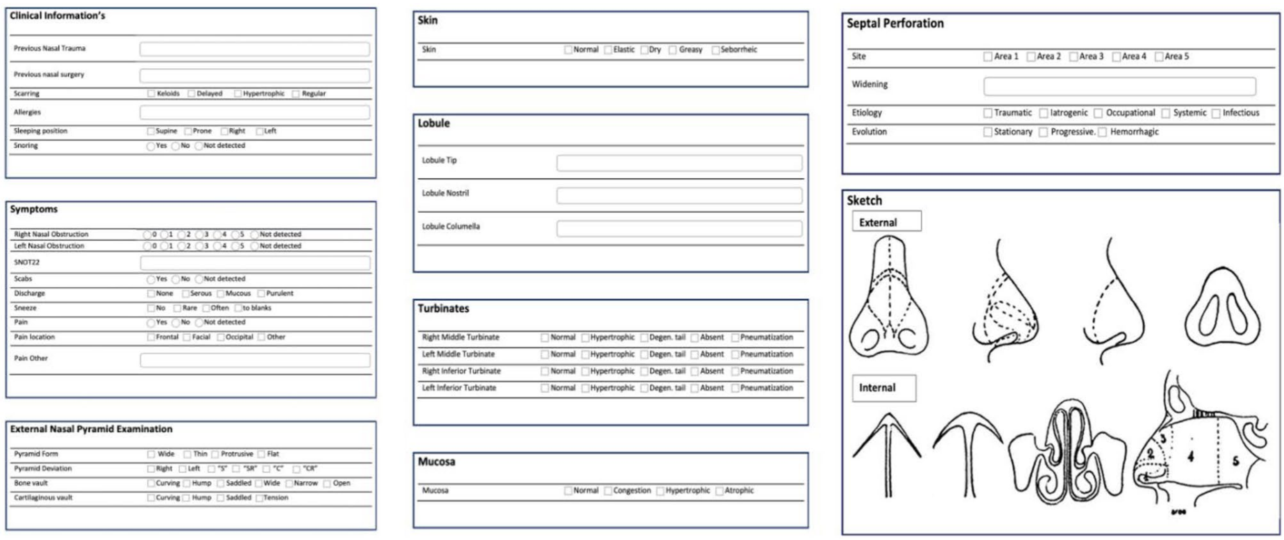


Fig. 4 Acoustic rhinometry graphic showing right NVC



Clinical Information's

Previous Nasal Trauma	
Previous nasal surgery	
Scarring	☐ Keloids ☐ Delayed ☐ Hypertrophic ☐ Regular
Allergies	
Sleeping position	☐ Supine ☐ Prone ☐ Right ☐ Left
Snoring	◯ Yes ◯ No ◯ Not detected

Symptoms

Right Nasal Obstruction	◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ Not detected
Left Nasal Obstruction	◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ Not detected
SNOT22	
Scabs	◯ Yes ◯ No ◯ Not detected
Discharge	☐ None ☐ Serous ☐ Mucous ☐ Purulent
Sneeze	☐ No ☐ Rare ☐ Often ☐ to blanks
Pain	◯ Yes ◯ No ◯ Not detected
Pain location	☐ Frontal ☐ Facial ☐ Occipital ☐ Other
Pain Other	

External Nasal Pyramid Examination

Pyramid Form	☐ Wide ☐ Thin ☐ Protrusive ☐ Flat
Pyramid Deviation	☐ Right ☐ Left ☐ "S" ☐ "SR" ☐ "C" ☐ "CR"
Bone vault	☐ Curving ☐ Hump ☐ Saddled ☐ Wide ☐ Narrow ☐ Open
Cartilaginous vault	☐ Curving ☐ Hump ☐ Saddled ☐ Tension

Skin

Skin	☐ Normal ☐ Elastic ☐ Dry ☐ Greasy ☐ Seborrheic

Lobule

Lobule Tip	
Lobule Nostril	
Lobule Columella	

Turbinates

Right Middle Turbinate	☐ Normal ☐ Hypertrophic ☐ Degen. tail ☐ Absent ☐ Pneumatization
Left Middle Turbinate	☐ Normal ☐ Hypertrophic ☐ Degen. tail ☐ Absent ☐ Pneumatization
Right Inferior Turbinate	☐ Normal ☐ Hypertrophic ☐ Degen. tail ☐ Absent ☐ Pneumatization
Left Inferior Turbinate	☐ Normal ☐ Hypertrophic ☐ Degen. tail ☐ Absent ☐ Pneumatization

Mucosa

Mucosa	☐ Normal ☐ Congestion ☐ Hypertrophic ☐ Atrophic

Septal Perforation

Site	☐ Area 1 ☐ Area 2 ☐ Area 3 ☐ Area 4 ☐ Area 5
Widening	
Etiology	☐ Traumatic ☐ Iatrogenic ☐ Occupational ☐ Systemic ☐ Infectious
Evolution	☐ Stationary ☐ Progressive. ☐ Hemorrhagic

Sketch

External

Internal

Fig. 5 Rhinologic schedule

4 mm diameter, for the diagnosis or exclusion of a concomitant rhinosinusitis and a better characterization of the nasal valve in static and dynamic condition. Normally nasal cavities are considered as a non-collapsing part of the airways, but in some pathological condition there is a nasal valve collapse near to "empty triangle" due to reduced support of this area. During visualization with the nasal endoscope, we performed a dynamic examination of nasal valve by the closing the contralateral nostril with a finger and having the patient perform calm and forced inspiration.

The SNOT-22 questionnaire is administrated to patients to evaluate the subjective grade of discomfort of nasal obstruction due to the NVC or a sinus disease.

All data collected are registered in a schedule that we called "rhinologic schedule" as it is shown in Fig. 5.

Subsequently the patient is assessed with pre-operative rhinomanometry and acoustic rhinometry to perform a functional and objective evaluation of nasal obstruction. In accordance with the recommendation of SCOANA and using RhinoPocket® device, an anterior active rhinomanometric study with a full face mask is conducted in base condition, after administration of 0.1% xylometazoline decongestant and then with the help a nasal dilator (DAN-AIR®) (Fig. 6). The acoustic rhinometry helps integrate the results of the rhinomanometry by providing spatial definition data of nasal cavity. A single experienced technician performed the measurements.

We use the full face mask (Fig. 7) to avoid nasal valve deformation without leakages of pressure. We have three kinds of masks: one type for adults and two types for children.

To establish a complete diagnostic framework, all patients reporting symptoms suspicious for concomitant chronic rhinitis undergo a skin prick test (SPT). The test is conducted by pricking the volar surface of forearm with a lancet through a drop of an allergen extract. Patients with a negative SPT are subjected to an exfoliative cytology sampling with the use of a sterile cytology brush. Two

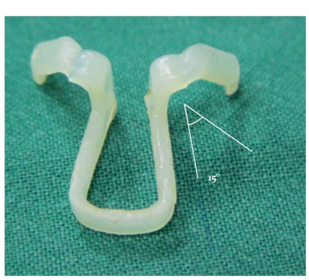


Fig. 6 DAN-AIR®

Fig. 7 Full face mask used in our daily clinical activity

smears are taken from the nasal mucous membrane of the medial part of both inferior nasal turbinates. The cells on the brush are spread by hand on the slide and immediately fixed and stained with May-Grunwald-Giemsa method and the samples are analyzed using a microscope.

In this algorithm believe that both VAS and QoL questionnaires and objective techniques are useful instruments to evaluate intervention outcomes.

Then the surgical address is the result of a careful selection of the patient in relation to the individual anatomical characteristics, as well as the exclusion of concurrent pathologies that may limit the surgical outcome. The role of surgery of the nasal valve is to restore normal anatomy of the nasal valve. Based on the present evidence, there is no superior surgical technique compared to the other; so, in according to the philosophical principle of our school that the correction of an anatomical abnormality with the preservation of the function of the structure involved lead to the restoration of nasal patency, we adopt the following techniques [35] for the correction of nasal valve collapse.

1. Internal nasal valve correction according to Sulsenti technique: starting with the hemitransfixion incision, extramucosal skeletonization of the endonasal section of the middle vault allowed for the exposure of superomedial, superior, and lateral aspect of the valve area. Deformities of the caudal margin of the upper lateral cartilages (ULCs) were corrected, as well as thickening or deflections of the superior segment of the septum, thickening of the septal space caused by post-traumatic or post-surgical scar connective tissue. The septum-upper lateral cartilage complex was contoured to restore a normal anatomic relationship and a physiologic valve angle. Using the same maxilla-premaxilla approach, the anterior nasal spine was adequately exposed along with the piriform apertures and the caudal septal cartilage. In this way, anomalous positioning and structural defects were corrected. In case of particularly restricted nasal valves, spreader grafts were fixed to the exerted quadrangular cartilage and repositioned sub-perichondrially with the septum in order to enlarge the valve angles.
2. Columellar morphologic anomalies were corrected by columelloplasty. The acute naso-labial angle was adjusted by placing an intracolumellar strut. Lobule surgery was performed adopting a dome-preserving technique and a retrograde raising of the lower lateral cartilages (LLCs).
3. Inferior turbinate hypertrophy causing the obstruction of the nasal valve area was treated by the submucous resection technique according to Sulsenti.

Moreover, in our algorithm 1 month after intervention examination is a surgical key-point for relevant outcomes, up to this moment soft tissues and cartilages have a certain degree of plasticity.

A close follow-up is conducted by performing post-surgical rhinomanometry and acoustic rhinometry at 3, 6, and 12 months.

Conclusions

Though there are numerous surgical techniques for the treatment of nasal valve collapse, ENT surgeons would have difficulty selecting the most indicated one. A standardized pre-operative assessment should be mandatory to address a tailored surgery to patient clinical features.

Rhinomanometry, acoustic rhinometry, and video-rhinohygrometer are not so easily available in every ENT department. Hence, the diagnostic role of these techniques is underestimated.

In the future, objective measurements of nasal functionality should be implemented by further research. This would give a better clinical and medical-legal validity.

Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

Human and Animal Rights and Informed Consent The studies relevant to this review that were performed by the authors are in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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