*B-ENT*, 2010, **6**, 3-11

# Rhinomanometry and acoustic rhinometry in rhinoplasty

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**Key-words.** Rhinomanometry; acoustic rhinometry; rhinoseptoplasty

**Abstract.** Acoustic rhinometry (AR) and rhinomanometry (RMM) study two different parameters of nasal ventilation: respiratory function and the anatomy of nasal cavities. This article looks at their usefulness, in particular in the surgical field. We list the normal values for these tests. Nasal obstruction is a symptom of multifactorial origin. Nasal patency is only one factor influencing the sensation of nasal ventilation. Despite the range of divergent opinions in both the literature and among rhinological clinicians, the objective assessment of nasal patency in functional rhinoplasty or septorhinoplasty seems to be advisable. The roles of AR and RMM still have to be established.

## Introduction

Rhinomanometry and acoustic rhinometry are the two most popular techniques for the objective assessment of nasal patency[1]. However, a lack of consensus about the methods for assessing nasal patency, the poor correlation between the objective measures of nasal patency and patients' complaints, and, finally, accepted standards mean that the importance of objective measures for nasal patency in the clinic is a subject of heated debate. Some authors consider these measures to be worthless,[2-4] while others see them as being useful,[5] complementary, or even important in the evaluation of nasal obstruction.[6-14]

Many believe that these techniques are mainly appropriate for research,[15, 16] while others think they are the best way of determining nasal obstruction objectively, using them in their clinical practice[1] for monitoring nasal congestion and evaluating the subsequent treatment.[13]

Rhinomanometry and acoustic rhinometry seem to be more established in the field of clinical research, including the study of nasal physiology, for the objective evaluation of surgical techniques and medical treatment, or for assessing response to various allergens or mediators of inflammation.[1, 7]

The purpose of this paper is to consider:

- the relationship, often described as poor, between the sensation of nasal obstruction and nasal dyspermeability;
- the evaluation of nasal patency in clinical practice, which is often only assessed on the basis of patient history and the clinical examination;
- the difficulty of establishing normative values for objective measures and their variability.

## Evaluating nasal patency

Evaluation is difficult because of the physiological regulation of nasal patency, which depends on both the nasal valve (the elastic properties of the fibro-cartilaginous skeleton, muscle tone, changes in pressure) and the turbinate valve (the mucosa, the nasal cycle, and various stimuli such as heat, psychological factors, endocrine factors...).[6, 17]

The subjective sensation of nasal obstruction is multifactorial and so an evaluation with objective measures that considers only the values for volume, surface or flow cannot be expected to produce a perfect correlation.

A detailed history, physical examination and nasal endoscopy are still considered to the best ways of evaluating nasal obstruction.[15, 18]

Nevertheless, these methods remain subjective and quantification is difficult.

A semi-quantitative subjective assessment is possible and this approach is considered useful for assessing the severity of nasal congestion and its evolution under treatment.[13]

Nasal patency can be assessed objectively with three tests:

– active rhinomanometry (RMM), which quantifies flow, pressure and nasal resistance;
– acoustic rhinometry (AR), which evaluates the cross-sectional areas, mostly anterior, and the volumes of the nasal cavities;
– PNIF (Peak Nasal Inspiratory Flow), or the measure of the inspiratory flow during a maximal inhalation. This measure is considered to be reliable, reproducible, less expensive, fast and easy to perform.[13, 14] The drawbacks relate to the simultaneous evaluation of both nasal cavities, the medial attraction of the wing of the nose, causing a possible change in the nasal valves, the indispensable cooperation of the patient and the possible limitation of the flow resulting from pulmonary disorders.[18] The sensitivity of this examination in the evaluation of nasal patency seems to identical to that of AR and RMM. As with AR and RMM, the correlation between the values for PNIF and the subjective sensation of nasal obstruction is controversial.[13, 14, 18-20]

Rhinomanometry assesses nasal airflow, whereas acoustic rhinometry assesses geometry. The first technique provides a dynamic and functional evaluation, the second one a static, geometrical and anatomical evaluation. The two tests are often seen as complementary.[1, 3, 7, 9, 13, 21]

Both tests suffer from measurement variability which is operator-dependent, but they are reproducible (5 to 10% reproducibility for AR; 8 to 15% et for RMM).[21, 22] They are considered similar in terms of sensitivity.[3]

It seems that the severity of nasal obstruction assessed subjectively (Visual Analogue Scale) is more closely correlated with NAR, (Nasal Airway Resistance) measured by RMM than with MCA (Minimum Cross-Sectional Area) assessed by AR.[13, 23, 24]

AR is more specific and more sensitive than RMM for the diagnosis of structural abnormalities in patients complaining of nasal obstruction, while RMM is more sensitive and specific in patients with functional nasal obstruction (rhinitis).[18, 25]

Both techniques are sensitive to the cross-sectional dimensions of the nasal lumen and modifications of the lumen,[7, 10, 21, 23, 26, 27] particularly RMM, since resistance to airflow is exponentially related to lumen cross-sectional areas.[21]

A recent study of a large series of 7283 patients complaining of nasal obstruction demonstrated a significant difference in mean values for total inspiratory nasal resistance assessed by active anterior RMM between patients with septal deviation and control individuals with normal anatomy.[28]

### *Rhinomanometry*

Rhinomanometry was first described by Courtade in 1903. Active rhinometry (anterior and posterior) was introduced subsequently.

This technique allowed for a better understanding of the physiology of nasal ventilation.[6, 17]

Until now, hundreds of studies have been published in which rhinomanometry is used as a technique for assessing nasal patency[3]. The methodology has been extensively described.[6]

To minimise the variability of the results, the International Committee for the Standardisation of Rhinomanometry proposed a guideline in 1981[29] based on 42 years of experience and 10,000 tests.

An update was conducted in 1984[30] and in 2000,[16] including, in particular, recommendations for provocation tests.

A more recent consensus in 2005 reassessed the use of rhinomanometry and acoustic rhinometry, with a particular emphasis on a standardised nasal decongestion technique.[31]

Active anterior rhinomanometry is used most frequently and it has been described as simple, fast, well tolerated and feasible in all patients, especially in children. Its disadvantages are the risk of distortion of the nasal vestibule and the impossibility of using it when there is nasal perforation or complete obstruction. In addition, the use of rhinomanometry is difficult in anxious patients who cannot control the stability of their respiration.[6, 18] It takes more time to complete this test than the AR.[18]

Active posterior rhinomanometry is more respectful of physiological conditions (bilateral ventilation) and it reduces the risk of the deformation of nasal structures. However, it is not feasible for every patient,[6] mainly due to nauseous reflexes induced by the intra-oral positioning of the captor in the region of the velum.

Some believe that RMM can identify the site of obstruction at the level of the anterior nasal valve or turbinate valve and therefore differentiate between mucosal pathology and skeletal deformation.[6] Others believe that active anterior RMM cannot accurately assess the resistance of a specific area or identify the location of the nasal obstruction.[7, 18]

The reproducibility of the method, which is a subject of

controversy, its low correlation with the subjective sensation, the lack of uniformity of results, the variability between author sequences and between the examination manoeuvres (anterior/posterior/active/passive) explain why the RMM is not used routinely in the clinic.[3, 17]

Some people, however, are more positive about the method, seeing it as useful or necessary, or even important for the evaluation of preoperative or allergic nasal obstruction.[5, 6, 10, 12]

### *Acoustic rhinometry*

Hilberg introduced acoustic rhinometry in 1989.[32]

The technique reliably evaluates the dimensions of the first five centimetres of the nasal cavities by recording the reflection of an acoustic wave.[3, 18, 21, 33]

The parameters measured are the volume of the nasal cavity and the area of the cross-section in a specific location. The minimum cross-sectional area (MCA) is the most common parameter used.

In a normal nose, the MCA is located at the level of the nasal valve or at the head of the inferior turbinate. After decongestion, the MCA is found more anteriorly.[34, 35]

AR is described as accurate (accuracy 5-10%), reproducible (5-10%), reliable, non-invasive, quick, easy and requiring minimal patient cooperation.[3, 18, 21, 22, 36, 37]

AR can identify the exact site of obstruction in the nose, but the level of inaccuracy in the posterior part of the nasal cavity and beyond a marked narrowing[18] is high. AR is considered easier to perform than rhinomanometry.[3]

AR has been used to understand the anatomy and physiology of the nasal cavity, in particular by confirming that the region of the nasal valve is the narrowest area in the nasal cavity.[3]

Since the first publication about clinical application in 1989,[35] AR has been used in various fields of rhinology: to evaluate nasal obstruction, nasal permeability before and after provocation tests[38] or the efficacy of surgical[35, 39] or medical treatment.[3, 40]

Guidelines about the method and recommendations for its use have been described.[3, 36, 38, 41, 42] These guidelines are considered by the authors to be preliminary and they are subject to change with time depending on technological developments or new knowledge.

AR provides valuable information about the anatomy of the nasal cavity. However, that information is not adequate in itself to establish a diagnosis of nasal obstruction.[43] The data must be combined with the history and the clinical examination.

For some authors, AR is mandatory in the diagnosis and study of the effects of treatment on nasal obstruction, despite the relatively weak relation between the subjective and objective evaluation. AR is not only a tool for "article writers".[3]

The discrepancies in the results published in the literature and the cost limit its use in clinical practice.

### Normative values

The establishment of a level distinguishing between healthy individuals and patients is not possible because of individual and ethnic variations[44] and because the sensation of nasal obstruction does not depend on the size of the nasal cavity only.[3]

### *Rhinomanometry*

Formulating results is beset with difficulties because of the non-linear relationship between the flow variations and pressure variations measured resulting from the variability of the ventilatory regime (linear, turbulent or, more often, mixed).

It is therefore impossible to assign a single numerical value for the precise assessment of the complaints of a given patient.[6]

The mean normal values for nasal resistance vary little from one author to another: for binasal resistance equal to or less than 3 or 3.5 cm $H^2O$/l.sec. for a flow rate of 0.5 /.sec; the majority of normal values are between 1 and 2 cm $H^2O$/l.sec.,[6] 0.23 Pa/$cm^3$/sec (0.15 – 0.39),[45] 0.24 Pa/$cm^3$/sec (0.12-0.52),[10] 0.31 Pa/$cm^3$/sec (0.13-0.84).[46]

However, large individual variations have been observed in all studies.

For some, binasal resistance greater than 0.25 Pa/$cm^3$/s indicates nasal obstruction.[21]

In children, nasal resistance values rise with younger patient age.

Unilateral nasal values vary considerably depending on the vasomotor cycle. In adults, they can reach +/- 37.5 cm $H^2O$/l/sec during the peak of the vasomotor cycle.[6]

A few studies have compared rhinomanometry values of healthy and pathological subjects. Overall, there is a significant difference between the mean values for total nasal resistance between healthy subjects and subjects with

nasal pathologies. However, individually, patients with nasal disease may have resistance values within the normative range.[10]

In French standards, unilateral or bilateral resistance are considered to be pathological when they exceed values of 6 cmH20/l/s and 3 cm H20/l/s respectively and, after decongestion, 4 cm H2O/l/s uninasally and 2 cm H20/l/s binasally.[47]

### *Acoustic rhinometry*

Since AR was introduced in 1989, several articles have examined the normative values (Table 1).[36, 37, 48-50] Although there are currently no established standards and although there are large inter-individual and ethnic variations, it is accepted by some authors that, when MCA is less than 0.5 $cm^2$, the sensation of nasal obstruction is reported as severe.[3]

Otherwise, interpretation and obtaining curves depend very much on the experience and practice of each practitioner.[46] Studies exploring the correlation between AR values and the sensation of nasal obstruction show that values vary significantly between patients who complain and those who do not.[35] Patients who are not satisfied after septal surgery have significantly lower MCAs than those who are.[35] An MCA of 0.50 $cm^2$, a cross-sectional area at the pyriform aperture of 0.70$cm^2$, and a clear effect of decongestion on the MCA (more than 0.20 $cm^2$) are the best variables for distinguishing between normal noses and blocked noses.[21, 40]

The reference values can vary more or less depending on the homogeneity of the selected patients.[36] Normality is defined by the subjective sensation of normal breathing, with or without rhinoscopic evaluation in homogeneous groups in terms of race, weight, height and age.[44] The establishment of local standards would therefore seemto be useful.

In a patient complaining of nasal obstruction, an MCA of less than 0.35 $cm^2$ indicates, for some authors, that the narrowing may play a role in the patient's subjective complaints.[36]

## Nasal obstruction and dyspermeability are not synonymous

Nasal obstruction is a symptom, a subjective sensation of discomfort with the flow of air to the nasal cavities resulting from different

Table 1
Acoustic rhinometry: normal values

| Authors | Year | Population | MCA non-decongested | MCA decongested | NV non-decongested | NV decongested |
|---|---|---|---|---|---|---|
| Hilberg O[36] | 2000 | **1756** | 0.60 $cm^2$ +/- 0.18 (SD)<br>Median 0.517 $cm^2$<br>5 percentile 0.360 $cm^2$<br>2.5 percentile 0.320 cm<br>(non-decongested ?) | | | |
| Larsson C[37] | 2001 | **102**<br>(51 M, 51F)<br>**98** children<br>(7.1-16.9 years) | Men: 0.65 +/-0.2 $cm^2$<br>Women: 0.51 +/-0.12 $cm^2$<br>Children: 0.52+/-0.14 $cm^2$ | | | |
| Strasszek SP[48] | 2007 | **146** adults<br>(127 M, 19 F)<br>**53** children<br>(9-11 years)<br>caucasians | Adults: 0.61 $cm^2$<br>(0.58-0.64)<br>Children:0.33 $cm^2$<br>(0.31-0.35) | Adults: 0.73 $cm^2$<br>(0.70-0.77)<br>Children: 0.36 $cm^2$<br>(0.35-0.38) | NV (2-5 cm)<br>Adults: 3.73 $cm^3$<br>(3.56-3.91)<br>Children: 2.48 $cm^3$<br>(2.34-2.62) | NV(2-5 cm)<br>Adults: 5.28 $cm^3$<br>(5.07-5.49)<br>Children: 3.71 $cm^3$<br>(3.58-3.84) |
| Trindade IE[49] | 2007 | **30** adults<br>(14 M, 16 F)<br>(18-30 years) | | | V1: 1.68+/-0.32<br>V2: 3.98+/-1.21<br>V3: 17.67+/-3.57<br><br>V1 = 10-32 mm<br>V2 = 33-64 mm<br>V3 = 70-120 mm | V1: 1.82+/-0.30<br>V2: 5.53+/-1.03<br>V3: 22.72+/-4.06 |
| Gomes A[50] | 2008 | **30** adults<br>(14 M, 16 F)<br>(18-30 years) | 0.54 +/-0.13 $cm^2$<br>(CSA1) | 0.56 +/-0.13 $cm^3$<br>(CSA1) | | |

neurophysiological mechanisms which are not fully elucidated.[13, 51.] Several factors are involved: mucosal (vasomotor cycle, presence of secretions), structural, nervous receptors (pressure, temperature, pain) and psychological factors.[1, 3, 4, 7, 13, 14, 40, 43, 52, 53]

Quantification in clinical practice remains difficult. One possibility is a self-report evaluation (Visual Analogue Scale)[13, 54] with complementary rhinoscopic examination.

The dimensions of the nasal cavities depend on mucosal and anatomical factors. The results of evaluation, both in the clinic and rhinomanometry or acoustic rhinometry, cannot be strictly correlated with patient complaints, which include psychological dependence. The fact that nasal patency is not affected in some patients complaining of nasal obstruction or, conversely, that nasal patency is drastically reduced in other patients without obstructive complaints is a familiar phenomenon in clinical practice.[10, 13, 17]

A sensation of nasal obstruction does not always mean that there is an obstruction that can be identified objectively. The individual and subjective assessment of nasal ventilation, which has been clearly demonstrated, calls for objective methods for an objective evaluation of nasal patency.[8]

For example, atrophy of the sensory nerve endings in mucosal atrophy or somatised anxiety may result in the over-estimation of the severity of nasal obstruction.[25] Since the introduction of the objective technical assessment of nasal patency, many conflicting articles have been published about the relationship between the values obtained and patient complaints. Many studies show no significant correlation between the values for AR or RMM and the severity of patient complaints.[2, 6, 8, 10, 25, 27, 37, 52, 55]

Several explanations have been given: the considerable individual variation in, and ethnic values for, nasal resistance or minimum area,[7, 9] the subjective nature of ventilatory discomfort,[25] the complexity of the subjective sensation of nasal obstruction (dependent on thermal , algesic and chemical receptors)[27] and the difficulty of making an objective assessment of the ventilatory disorder with a single numerical value.[6] The sensation of nasal obstruction depends on receptors located in the nasopharynx, the area around the inferior turbinate, whereas nasal resistance is primarily determined by the anterior portion of the nasal cavity.[52]

The different evaluation methods look at various aspects of nasal ventilation and so they must instead be viewed as complementary rather than contradictory.[11]

Several studies indicate a certain degree of correlation between subjective evaluation and the objective assessment of nasal obstruction.[1, 7, 8, 9, 12-14, 21, 35, 37, 54]

Correlation has been found when patients evaluate unilateral permeability[7, 8, 21] or in cases of severe obstruction,[8] as well as when the complaints result mainly from the obstructive swelling of the mucosa, for example during rhinitis or during provocation tests with histamine, or after nasal decongestion or the application of topical steroids,[1, 9, 13, 37] before and after turbinectomy, or in the context of allergic rhinitis or chronic rhinosinusitis.[54]

With chronic nasal complaints or nocturnal ventilatory disorders, there is a small but significant correlation between the subjective sensation of nasal obstruction and volume measurements, surfaces and flow assessed respectively with AR and the Peak Nasal Inspiratory Flow.[14]

Discrepancies between subjective sensation and objective measures of nasal patency are a given. Despite this, many studies perform objective assessments of nasal patency to quantify and compare the results.

## Functional exploration of nasal patency and rhinoseptoplasty

In Belgium, the objectivisation of nasal dyspermeability is required for the reimbursement of a functional rhinoplasty or rhinoseptoplasty by the Social Security System.

An accurate, objective assessment of nasal dyspermeability may also be requested as part of a forensic examination.

Putting aside legal and financial considerations, an objective assessment of nasal obstruction can be particularly useful for evaluating permeability before and after surgery and for evaluating the functional impact of surgical procedures on nasal patency. In clinical practice, there is a belief that that a good, or even the best, indication for the objectivisation of nasal obstruction is to evaluate surgical results[1, 17, 56] or to predict the expected benefit when an additional functional treatment is added to the rhinoplasty.[39, 57, 58]

Others believe that the correlation between the subjective sensation of nasal patency and the values obtained from rhino-

manometry and acoustic rhinometry values is too weak.[4, 55]

Patients with high resistance values or low values for the cross-sectional area are more likely to be satisfied after surgery.[19]

In clinical practice, we also see that patients are more satisfied with their surgery when the complaints are consistent with the clinical assessment and objective measures.

Some authors see rhinomanometry as a integral part of the assessment of nasal patency in patients complaining of nasal congestion before rhino(septo)-plasty,[12] in particular for assessing nasal valve function,[58] which is a potential cause of nasal obstruction.[59]

Acoustic rhinometry may be of particular interest in assessing pre- and postoperative patients with complex nasal deformities, as in cleft palate.[43, 60]

In nasal valve surgery, as with turbinate surgery,[61] obstruction is most often assessed clinically.[56]

Rhinoplasty is a well-known cause of nasal valve insufficiency.[4, 18] Ten percent of aesthetic rhinoplasties are reported to be associated with a reduction of nasal patency.[39] The most frequent causes of alterations in nasal ventilation by surgery are: the resection of the cartilaginous dorsum with the disinsertion of septo-triangular sutures, over-radical alar cartilage resection and lateral osteotomies.[43, 59]

Studies with acoustic rhinometry made it possible to document and objectify these clinical findings.[26, 39, 43, 62] It should be noted that a significant reduction in MCA as observed with AR does not necessarily result in impairment of subjective nasal breathing.[39, 43]

## What do Belgian rhinologists think?

A questionnaire was sent to the members of the Belgian Rhinology Society.

Sixteen responses were obtained, corresponding to an annual total of 1356 rhinoseptoplasties, 15% of which were performed for aesthetic reasons, 45% for functional reasons, and 40% for mixed indications. Most procedures were therefore functional rhinoseptoplasty (85%).

The assessment of nasal obstruction is essentially anamnestic and clinical (Table 2).

Discrepancies relate mainly to opinions about rhinomanometry and acoustic rhinometry.

There is far from being a consensus about the use of these tests, either with respect to indications or normative values.

As far as rhinomanometry is concerned, some clinicians look only at the symmetry of the curves, others make their assessments on the basis of flow values, and others on the basis of nasal resistance values, which vary from one practitioner to another.

Turning to acoustic rhinometry, some practitioners assess the symmetry of the curves, others use MCA values, and still others work with NV values, which also vary from one practitioner to another.

Even though consensus about normative values is often considered unrealistic, rhinologists are demanding better information and training about 'good practice' with these objective techniques, which continue to depend on individual practice.

This finding is not surprising given the lack of consensus about the assessment of nasal obstruction.

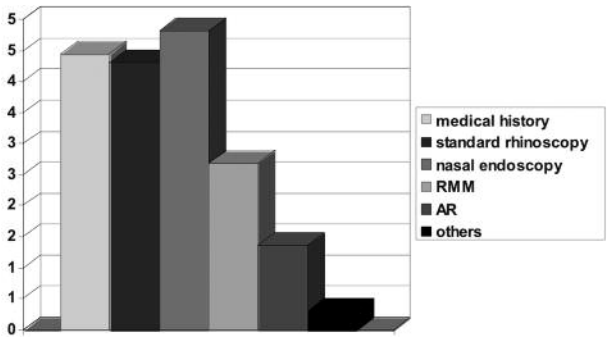
## Conclusion

Rhinoplasty (and rhinoseptoplasty) can have adverse or beneficial consequences on nasal ventilation.

The objective assessment of nasal patency with acoustic rhinometry or rhinomanometry before functional or mixed rhinoseptoplasty is a conventional procedure in Belgium as part of an application for reimbursement by the National Health Care system. Its usefulness in the evaluation of nasal obstruction is highly controversial. Nasal obstruction is a highly subjective symptom and burdened with psychological factors. Its assessment is based on subjective anamnestic and clinical data.[15, 56]

The objective assessment techniques are often used in the field

Table 2
Evaluation of nasal obstruction (0: not important to 5: very important)



of clinical research, but their place in clinical practice remains controversial and poorly established.[16]

Despite the conflicting results about the relationship between the subjective and objective evaluation of nasal obstruction, several authors recommend the use of rhinomanometry and/or acoustic rhinometry in the pre-operative evaluation of septorhinoplasties.[12, 39, 56, 58, 59, 60, 62]

Objective assessments seem, independently of any psychological factors, to be necessary, in particular in the area of rhino(septo)-plasty to avoid over-treatment (the nasal complaints may be indicative of psychosomatic disorders and serve as pretexts for unfounded complaints) and to improve patients' understanding of their respiration and therefore patient satisfaction after treatment.

For purely aesthetic rhinoplasty, the assessment of nasal patency may not seem useful. However, we must remain cautious about the functional impact of certain surgical procedures.

Putting aside any legal or financial considerations, the place of rhinomanometry and acoustic rhinometry in rhinoplasty or in the rhinology clinic remains to be established. The use of these tests is too dependent on individual practice.

This work may serve to trigger a shared and constructive debate in our Belgian ENT association about the use in our daily practice of rhinomanometry, acoustic rhinometry and PNIF. In particular, a consensus should be established about standards.

A joint approach could result in the establishment of courses and training for the standardisation of practice and the more efficient use of these techniques.

## References


1. Schumaker MJ. Nasal Congestion and Airway Obstruction: the validity of available objective and subjective measures. *Curr Allergy Asthma Rep*. 2002;2(3):245-251.
2. Kim CS, Moon BK, Jung DH, Min YG. Correlation between nasal obstruction symptoms and objective parameters of acoustic rhinometry and rhinometry. *Auris Nasus Larynx*. 1998;25(1):45-48.
3. Hilberg O. Objective measurement of nasal airway dimensions using acoustic rhinometry: methodological and clinical aspects. *Allergy*. 2002; 57(Suppl 70):5-39.
4. Andre RF, D'Souza AR, Kunst HP, Vuyk. Sub-alar batten grafts as treatment for nasal valve incompetence; description of technique and functional evaluation. *Rhinology*. 2006;44(2): 118-122.
5. Schumacher MJ. Rhinomanometry. *J Allergy Clin Immunol*. 1989;83(4): 711-718.
6. Mélon J, Daele J. Functional and endoscopic studies in rhinology [in French]. *Acta otorhinolaryngol Belg*. 1979;33(5):631-870.
7. Roithmann R, Cole P, Chapnik J, Barreto SM, Szalai JP, Zamel N. Acoustic rhinometry,rhinomanometry, and the sensation of nasal patency: a correlation study. *J Otolaryngol*. 1994;23(6):454-458.
8. Sipilä J, Suonpää J, Silvoniemi P,Laippala P. Correlations between subjective sensation of nasal patency and rhinomanometry in both unilateral and total nasal resistance. *ORL J Otorhinolaryngol Relat Spec*. 1995; 57(5):260-263.
9. Numminen J, Ahtinen M, Huhtala H, Rautiainen M. Comparison of rhinometric measurements methods in intranasal pathology. *Rhinology*. 2003;41(2):65-68.
10. Suzina AH, Hamzah M, Samsudin AR. Objective assessment of nasal resistance in patients with nasal disease. *J Laryngol Otol*. 2003; 117(8): 609-613.
11. Lam DJ, James KT, Weaver EM. Comparison of anatomic, physiological, and subjectives measures of the nasal airway. *Am J Rhinol*. 2006; 20(5):463-470.
12. Oeken J, Kiefer MC. About the functional aspect of septorhinoplasty [in German]. *Mund Kiefer Gesichtschir*. 2006;10(2):82-88.
13. Van Spronsen E, Ingels KJ, Jansen AH, Graamans K, Fokkens WJ. Evidence-based recommendations regarding the differential diagnosis and assessment of nasal congestion: using the new GRADE system. *Allergy*. 2008;63(7):820-833.
14. Kjaergaard T, Cvancarova M, Steinsvag SK. Does nasal obstruction mean that the nose is obstructed? *Laryngoscope*. 2008;118(8):1476-1481.
15. Fraser L, Kelly G. An evidence-base approach to the management of the adult with nasal obstruction. *Clin Otolaryngol*. 2009;34(2):151-155.
16. Malm L, Gerth van Wijk R, Bachert C. Guidelines for nasal provocations with aspects on nasal patency, airflow, and airflow resistance. International Committee on Objective Assessment of the Nasal Airways, International Rhinologic Society**.** *Rhinology*. 2000; 38(1):1-6.
17. Lund VJ. Objective assessment of nasal obstruction. *Otolaryngol Clin North Am*. 1989;22(2):279-290.
18. Chandra RK, Patadia MO, Raviv J. Diagnostic of nasal airway obstruction. *Otolaryngol Clin North Am*. 2009;42(2):207-225.
19. Starling-Schwanz R, Peake HL, Salome CM, Toelle BG, Marks GB, Lean ML, Rimmer SJ. Repeatability of peak nasal inspiratory flow measurements and utility for assessing the severity of rhinitis. *Allergy*. 2005; 60(6):795-800.
20. Bermüller C, Kirsche H, Rettinger G, Riechelmann H. Diagnostic accuracy of peak nasal inspiratory flow and rhinomanometry in functional rhinosurgery. *Laryngoscope*. 2008;118 (4):605-610.
21. Cole P. Acoustic rhinometry and rhinomanometry. *Rhinol Suppl*. 2000; 16:29-34.
22. Silkoff PE, Chakravorty S, Chapnik J, Cole P, Zamel N. Reproducibility of acoustic rhinometry and rhinomanometry in normal subjects. *Am J Rhinol*. 1999;13(2):131-135.
23. Szücs E, Clement PA. Acoustic rhinometry and rhinomanometry in the evaluation of nasal patency of patients with nasal septal deviation. *Am J Rhinol*. 1998;12(5):345-352.

24. Strunski V, Stramandinoli E. Exploration physique et fonctionnelle des fosses nasales. *Encycl Méd Chir Oto-rhinolaryngologie*. Elsevier SAS, Paris, 2003;20-420-A-10:6p.
25. Passali D, Mezzedimi C, Passali GC, Niti D, Bellussi L. The role of rhinomanometry, acoustic rhinometry, and mucociliary transport time in the assessment of nasal patency. *Ear Nose Throat J*. 2000;79(5):397-400.
26. Roithmann R, Chapnik J, Zamel N, Barreto SM, Cole P. Acoustic rhinometric assessment of the nasal valve. *Am J Rhinol*. 1997;11(5):379-385.
27. Tomkinson A, Eccles R. Comparison of the relative abilities of acoustic rhinometry, rhinomanometry and the visual analogue scale in detecting change in the nasal cavity in a healthy adult population. *Am J Rhinol*. 1996;10(3):161-165.
28. Canakcioglu S. Nasal patency by rhinomanometry in patients with sensation of nasal obstruction. *Am J Rhinol Allergy*. 2009;23(3):300-302.
29. Kern EB. Committee report on standardization of rhinomanometry. *Rhinology*. 1981;19(4):231-236.
30. Clement PA. Committee report on standardization of rhinomanometry. *Rhinology*. 1984;22(3):151-155.
31. Clement PA, Gordts F, Standardisation Committee on Objective Assessment of the Nasal Airway, IRS, and ERS. Consensus report on acoustic rhinometry and rhinomanometry. *Rhinology*. 2005;43(3):169-179.
32. Hilberg O, Jackson AC, Swift DL, Pedersen OF. Acoustic rhinometry: evaluation of nasal cavity geometry by acoustic reflection. *J Appl Physiol*. 1989;66(1):295-303.
33. Min YG, Jang YJ. Measurements of cross-sectional area of the nasal cavity by acoustic rhinometry and CT scanning. *Laryngoscope*. 1995;105(7 Pt 1):757-759.
34. Grymer LF, Hilberg O, Pedersen OF, Rasmussen TR. Acoustic rhinometry: values from adults with subjective normal nasal patency. *Rhinology*. 1991;29(1):35-47.
35. Grymer LF, Hildberg O, Elbrond O, Pedersen OF. Acoustic rhinometry: evaluation of the nasal cavity with septal deviations, before and after septoplasty. *Laryngoscope*. 1989;99 (11):1180-1187.
36. Hilberg O. Pedersen OF. Acoustic rhinometry: recommendations for technical specifications and standard operating procedures. *Rhinol Suppl*. 2000;16:3-17.
37. Larsson C, Millqvist E, Bende M. Relationship between subjective nasal stuffiness and nasal patency mesuared by acoustic rhinometry. *Am J Rhinol*. 2001;15(6):403-405.
38. Parvez L, Erasala G, Noronha A. Novel techniques, standardization to enhance reliability of acoustic rhinometry measurements. *Rhinol Suppl*. 2000;16:18-28.
39. Grymer LF. Reduction rhinoplasty and nasal patency: change in the cross-sectional area of the nose evaluated by acoustic rhinometry. *Laryngoscope*. 1995;105(4 Pt 1):429-431.
40. Grymer LF, Hilberg O, Pedersen OF. Prediction of nasal obstruction based on clinical examination and acoustic rhinometry. *Rhinology*. 1997;35(2): 53-57.
41. Djupesland PG, Lyholm B. Technical abilities and limitations of acoustic rhinometry optimised for infants. *Rhinology*. 1998;36(3):104-113.
42. Tomkinson A, Eccles R. Errors arising in cross-sectional area estimation by acoustic rhinometry produced by breathing during measurement. *Rhinology*. 1995;33(3):138-140.
43. Grymer LF. Clinical applications of acoustic rhinometry. *Rhinol Suppl*. 2000;16:35-43.
44. Morgan NJ, MacGregor FB, Birchall MA, Lund VJ, Sittampalam Y. Racial difference in nasal fossa dimensions determined by acoustic rhinometry. *Rhinology*. 1995;33(4): 224-228.
45. Morris S, Jawad MS, Eccles R. Relationships between vital capacity, height, and nasal airway resistance in asymptomatic volunteers. *Rhinology*. 1992;30(4):259-264.
46. Shelton DM, Eiser NM. Evaluation of active and posterior rhinomanometry in normal subjects. *Clin Otolaryngol Allied Sci*. 1992;17(2):178-182.
47. Coffinet L, Bodino C, Brugel-Ribere, Marie B, Grignon Y, Coste A, Jankowski R. Explorations physiques et fonctionnelles des fosses nasales. *Encycl Méd Chir Oto-rhino-laryngologie. Elsevier SAS, Paris*. 2003; 20-280-A-10:14p.
48. Straszek SP, Schlünssen V, Sigsgaard T, Pedersen OF. Reference values for acoustic rhinometry in decongested school children and adults: the most sensitive measurement for change in nasal patency. *Rhinology*. 2007;45(1):36-39.
49. Trindade IE,Gomes Ade O, Sampaio-Teixeira AC, Trindade SH. Adult nasal volumes assessed by acoustic rhinometry. *Braz J Otorhinolaryngol*. 2007;73(1):32-39.
50. Gomes Ade O, Sampaio-Teixeira AC, Trindade SH, Trindade IE. Nasal cavity geometry of healthy adults assessed using acoustic rhinometry. *Braz J Otorhinolaryngol*. 2008;74 (5):746-754.
51. Klossek JM, Dufour X, Desmons-Grohler C, Fontanel JP. Physiologie de la muqueuse respiratoire nasale et troubles fonctionnels. *Encycl Méd Chir. Oto-Rhino-Laryngologie. Elsevier SAS, Paris,*.2000;20-290-A-10:10p.
52. Jones AS, Willatt DJ, Durham LM. Nasal airflow: resistance and sensation. *J Laryngol Otol*. 1989;103 (10):909-911.
53. Eccles R. The effects of oral administration of (-)-menthol on nasal resistance to airflow and nasal sensation of airflow in subjects suffering from nasal congestion associated with common cold. *J Pharm Pharmacol*. 1990; 42(9):652-654.
54. Mora F, Cassano M, Mora R, Gallina AM, Ciprandi G. V.A.S. in the follow-up of turbinectomy. *Rhinology*. 2009;47(4):450-453.
55. Reber M, Rham F, Monnier Ph. The role of acoustic rhinometry in the pre- and postoperative evaluation of surgery for nasal obstruction. *Rhinology*. 1998;36(4):184-187.
56. Spielmann PM, White PS, Hussain SS. Surgical techniques for the treatment of nasal valve collapse: a systematic review. *Laryngoscope*. 2009;119(7):1281-1290.
57. Piccini A, Biagini C, Sensini I. Nasal dimorphism and respiratory dysfunction. Preoperative selection of patients and follow-up using computerized rhinomanometry [in Italian]. *Acta Otorhinolaryngol Ital*. 1991;11(2): 143-149.
58. Ricci EP, Palonta F, Preti G, Vione N, Nazionale G, Albera R, Staffieri A,

Cortesina G, Cavalot AL. Role of nasal valve in the surgically corrected nasal respiratory obstruction: evaluation through rhinomanometry. *Am J Rhinol*. 2001;15(5):307-310.
59. Constantian MB, Clardy RB. The relative importance of septal and nasal valvular surgery in correcting airway obstruction in primary and secondary rhinoplasty. *Plast Reconstr Surg*. 1996;98(1):38-54.
60. Trindade IE, Bertier CE, Sampaio-Teixeira AC. Objective assessment of internal nasal dimensions and speech resonance in individuals with repaired unilateral cleft lip and palate after rhinoseptoplasty. *J Craniofac Surg*. 2009;20(2):308-314.
61. Batra PS, Seiden AM, Smith TL. Surgical management of adult inferior turbinate hypertrophy: a systematic review of the evidence. *Laryngoscope*. 2009;119(9):1819-1827.
62. Grymer LF, Gregers-Petersen C, Baymler Pedersen H. Influence of lateral osteotomies in the dimensions of the nasal cavity. *Laryngoscope*. 1999;109(6):936-938.

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