REVIEW

Correlation between subjective and objective evaluation of the nasal airway. A systematic review of the highest level of evidence

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Background: There is no consensus about the value of objective measurements of nasal patency.
Objective: To assess the correlation between the subjective sense of nasal patency and the outcomes found with rhinomanometry and acoustic rhinometry.
Type of review: Structured literature search.
Search strategy and evaluation method: Review of English-language articles in which correlations were sought between subjective nasal patency symptoms and objective scores as found with rhinomanometry [nasal airway resistance (NAR)] and acoustic rhinometry [minimal cross-sectional area (MCA)]. Correlations were related to unilateral or combined assessment of nasal passages and to symptomatic nasal obstruction or unobstructed nasal breathing.
Results: Sixteen studies with a level of evidence II-a or II-b fit the inclusion criteria and were further analysed. Almost every possible combination of correlations or lack thereof in relation to the variables included was found. However, when obstructive symptoms were present, a correlation between the patency symptoms with nasal airway resistance and minimal crosssectional area was found more often than in the absence of symptoms. In cases of bilateral assessment a correlation was found almost as often as it was not between patency symptoms and total nasal airway resistance or combined minimal crosssectional areas, while in the limited amount of studies in which unilateral assessment was done a correlation was found each time between patency symptoms and nasal airway resistance.
Conclusions: The correlation between the outcomes found with rhinomanometry and acoustic rhinometry and an individual's subjective sensation of nasal patency remains uncertain. Based on this review, it seems that the chance of a correlation is greater when each nasal passage is assessed individually and when obstructive symptoms are present. There still seems to be only a limited argument for the use of rhinomanometry or acoustic rhinometry in routine rhinologic practice or for quantifying surgical results.

Introduction

The complaint of a blocked nose is often a complex clinical problem involving mucosal, structural, and even psychological factors. In clinical practice, it is frequently difficult to assess the relative importance of individual factors contributing to nasal obstruction and to decide on the therapy most likely to be effective in restoring satisfactory nasal breathing. The perception of nasal airflow ultimately is a subjective sensation and therefore, by definition, difficult to quantify. Even so, efforts are continuously being made to improve our ability to 'objectively' measure nasal patency. The gold standard would be a quantifiable, reproducible, objective test with a strong correlation to the subjective perception of nasal airflow. Such a test would help us in diagnosing the degree, and sometimes even the location and the cause of nasal obstruction. It would also be useful for evaluating the results of medical and surgical interventions aimed at improving nasal patency. Considering the complexity and variability of the subjective sense of

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nasal patency, one may justifiably wonder if such a test will ever be available.

Since the late 1950s, over a thousand articles have been published in which rhinomanometry has been described or involved in one way or another. Since the late 1980s, more than 500 studies have used acoustic rhinometry. A relatively small number of these studies attempted to investigate the correlation between rhinomanometry and/or acoustic rhinometry and the subjective sensation of nasal patency. They showed conflicting results. In this article we discuss the current status of our ability to objectively measure nasal patency, and more specifically, we review the literature on how this relates to the subjective sensation of nasal airflow. From this, we tentatively deduce what the role of objective measurements may be in clinical practice at the present time.

Measuring nasal patency

Rhinomanometry

Rhinomanometry is a dynamic test of nasal function that calculates nasal airway resistance (NAR) by measuring transnasal pressure and airflow in the nasal airway during respiration. Rhinomanometry yields flow-pressure curves. Laminar airflow increases with increased transnasal pressure, but higher pressures lead to turbulent flow. Turbulent flow results in an exponential limitation of flow generated despite greater transnasal pressure differences. Collapsibility of the lateral nasal wall and irregularities in the lining of the nasal cavity may enhance the development of turbulences.

The following three kinds of rhinomanometry are used.[1]

1 The most commonly used method is active anterior rhinomanometry, 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.

2 In passive anterior rhinomanometry the pressure is also measured for each nasal cavity separately, but at a given airflow.

3 Active posterior rhinomanometry measures choanal pressure with a sensor placed at the back of the nasal cavity via the mouth.

Acoustic rhinometry

Acoustic rhinometry is based on the analysis of sound waves reflected from the nasal cavity. 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. The main benefit of acoustic rhinometry is its capacity to identify the narrowest part of the nasal cavity or minimal cross-sectional area (MCA). This usually corresponds to the nasal valve area or to the head of the inferior turbinate.[2]

To help distinguish between mucosal hypertrophy and structural deformity as a cause of nasal obstruction, it is advisable to make the measurements before as well as after decongestion. This applies to both rhinomanometry and acoustic rhinometry.

Materials and methods

The main question we wished to address was if any conclusions could be made about the correlation between objective measurements and the subjective sensation of nasal patency. To this end, we conducted a systematic search of the literature published in English from 1980 in which this topic was addressed, either directly or indirectly. First, we screened all studies in PubMed in which the word rhinomanometry and/or acoustic rhinometry was used. We also made combined MeSH searches with the words rhinomanometry, acoustic rhinometry and nasal obstruction to minimize the chance that any relevant article might be overlooked. We then screened the abstracts and when they contained information that suggested the possibility of relevance for our study, the full text article was examined. The aim of this search was to trace those studies that looked for statistically significant correlations between objective outcomes and subjective patient assessments. The studies that fit this minimum requirement were rated according to their respective levels of evidence according to the guidelines of the 'Oxford Centre for Evidence-based Medicine'. The essential parameter included in every article reviewed was the subjective analysis of nasal patency ('patency symptoms'). The two other parameters, of which at least one was required for a study to be included, were MCA as measured by acoustic rhinometry and NAR as measured by rhinomanometry. Although we were primarily interested in correlations between patency symptoms and either NAR or MCA, correlations between NAR and MCA were also noted when addressed in a study. The correlations were related to the following variables (when reported in the study): unilateral or combined assessment of nasal passages and the absence or presence of sensations of nasal obstruction.

Results

We found 21 studies that met the criteria mentioned above. Four studies were rated as II-a (evidence obtained from a well designed controlled trial without rando-

Table 1. Studies in which the correlation between subjective analysis of nasal patency (SA) and nasal airway resistance (NAR) and/or minimum cross-sectional area (MCA) was addressed

	Study	Year	Level of evidence	Population characteristics	Method of objective rhinometry	Method of scoring subjective symptoms	Use of vasoconstriction	Pharmacologica intervention	Surgical intervention	Brief description of study and outcome
1	Gordon *et al.* [3]	1989	II-1	74 Patients	AARM	Questionnaire	No	No	Yes	Correlation between nasal obstruction symptoms and NAR before surgery, but not after surgery, overall NAR nor malized after surgery
2	Jones *et al.* [4]	1989	II-2	250 Volunteers ± symptoms	AAMR	VAS	No	No	No	No correlation between subjective sensation of nasal airflow and NAR in patients attending a clinic
3	Grymer *et al.* [5]	1989	II-1	42 Patients	AR	Questionnaire	Yes	No	Yes	Significant correlation between MCA and the subjective feeling of nasal patency both before and after septoplasty
4	Sipilä *et al.* [6]	1994	II-2	102 Patients	AARM	Question: which side of nose most obstructed?	Yes	No	Yes	The side of the nose indicated as being the narrowest, by patients referred for septoplasty, correlated with NAR roughly 75% of the time, compared to 50% of the time in individuals without com plaints
5	Marais *et al.* [7]	1994	II-2	16 Patients	AR	VAS	No	No	Yes	A correlation between patients' satisfaction after septal surgery and increase in MCA
6	Sipilä *et al* .[8]	1995	II-2	200 Patients	AAMR	VAS	Yes	No	No	A strong correlation between SA and NAR when evaluating unilateral obstruction compared to total nasal evaluation
7	Simola & Malmberg [9]	1997	II-2	101 Patients	AAMR	VAS	No	Yes	No	Significant correlations between SA and NAR during changes in nasal patency caused by histamine challenge in patients with history of allergic or non-allergic rhinitis

Table 1. (*Continued.*)

8	Shemen & Hamburg [10]	1997	II-2	24 Patients	AR	'patients reported improvement'	Yes	No	Yes	A significant correlation between MCA and SA both before and after septoplasty
9	Szücks & Clement [11]	1998	II-1	50 Patients	AAMR and AR	VAS	Yes	No	No	Stronger correlation between the SA and NAR than between SA and MCA in patients with deviated nasal septum
10	Reber *et al.* [12]	1998	II-2	27 Patients	AR	VAS	Yes	No	Yes	No correlation between SA and MCA pre- and post-septoplasty
11	Gungor *et al.* [13]	1999	II-2	10 Volunteers without symptoms	AR	VAS	Yes	No	No	No correlation between SA and MCA changes during the nasal cycle
12	Naito *et al.* [14]	2001	II-2	50 Patients	AAMR and AR	Questionnaire	No	No	Yes	Correlation between SA and MCA and SA and NAR, but no correlation between MCA and NAR before and after nasal and/or sinus surgery
13	Numminen *et al.* [15]	2003	II-2	69 Patients	AAMR and AR	VAS	No	No	No	A significant correlation between patency symptoms, MCA and NAR in patients with acute viral rhinitis
14	Suzina *et al.* [16]	2003	II-1	200 Patients	AAMR	'with or without symptoms'	No	No	No	A significantly higher mean NAR in patients with nasal disease compared to individuals without nasal disease, but no significant difference in total NAR between patients with obstructive symptoms and those without symptoms
15	Clarke *et al.* [17]	2005	II-2	60 Volunteers with URTI	PR	VAS	No	No	No	A significant correlation between unilateral SA and NAR, but no correlation between total SA and total NAR in patients with URTI
16	Clarke *et al.* [18]	2006	II-2	60 Patients with common cold	PR	VAS	No	No	No	The bigger the difference of the NAR between nasal passages, the more likely that the passage subjectively indicated as more obstructed concurred with NAR

AARM, active anterior rhinomanometry; PR, posterior rhinomanometry; AR, acoustic rhinometry; VAS, visual analogue scales from 0 to 10 denoting the subjective sense of unilateral or total nasal obstruction; URTI, upper respiratory tract infections.

misation), 12 studies as II-b (evidence obtained from a well designed cohort or case control analytic study), and five studies as III or lower (opinions of respected individuals based on clinical experience, descriptive studies, or reports of expert committees). None of the 21 studies were randomized controlled trials (level of evidence I). The five level III or lower studies were excluded. The remaining 16 papers are briefly described in Table 1.[3–18] For each study we noted the correlations between parameters (Table 2). We attempted to batch the studies into rational subgroups, but because of the differences and the overlapping similarities between the studies we found no logical way to do this that would enhance our ability to analyse the outcomes. Because of differences in study design and other variables (e.g., different patient populations, unilateral or total nasal patency, use of different kinds of rhinomanometry, lack of uniform assessment of patency symptoms or use of validated questionnaires, divergent reporting methods, involvement of surgery, inclusion of nasal cycle etc.), a direct, accurate and comprehensive comparison between outcomes is not possible and the data reported in the studies were not in the form to allow appropriate meta-analysis. In many of the studies more than one correlation, or lack thereof, between parameters was found, sometimes because more possible correlations were investigated, sometimes because the correlations depended on the inclusion of different variables, as mentioned above. We found almost every possible combination of correlations or lack thereof in conjunction with the variables included. In the 16 studies covered by this review, a correlation between the three main parameters was found on 19 occasions (10x patency symptoms/NAR, 8x patency symptoms/MCA, 1x NAR/MCA). No correlation was found between the parameters on 11 occasions (6x patency symptoms/NAR, 3x patency symptoms/MCA, 2x NAR/MCA). The finding of correlations or lack thereof was evenly distributed over the studies without showing a clear relationship to study design and the chance of finding a correlation did not depend on the level of evidence of the study under consideration.

Discussion

Strengths/weaknesses of the review, methodological issues and validity of the scoring and reporting methods of the subjective outcomes

While various objective methods to investigate nasal patency have been described, two of these are most commonly used: rhinomanometry and acoustic rhinometry. Rhinomanometry measures nasal airway resistance during breathing. Acoustic rhinometry provides a reflection of the anatomy of the nasal passages, from which the volume and the geometry of the nasal cavity can be deduced. Considering the amount of literature on these tests, and the increasing value that is attributed to them for validating surgical results, it is surprising that relatively little attention has been paid to how the outcomes of these tests relate to subjective symptoms. Subjective analysis of nasal patency is generally based on patient self-assessment with visual analogue scales and/or questionnaires. In relatively recent publications validated questionnaires such as the 'sino-nasal outcome test' (SNOT-22) and the 'nasal obstruction symptom evaluation test' (NOSE) have been described with the specific goal of evaluating nasal symptoms including subjective obstruction.[19,20] While the majority of the studies reviewed made use of visual analogue scales to quantify the subjective sensation of nasal obstruction, others made use of questionnaires querying various nasal symptoms with several scoring systems; none of which were referred to as being validated. The non-use of validated questionnaires may be explained by the fact that most of the studies pre-dated the publications of the SNOT-22 and NOSE tests. The use of these now available validated subjective scoring tools is strongly advised for future studies on this subject so as to enhance the reliability of conclusions concerning the correlation between objective and subjective outcomes. The point that no validated questionnaires were used in the studies in this review, in combination with the heterogeneity of the study designs and impossibility of rational pooling of the studies, without even taking into account some of the other shortcomings of the studies, precluded a proper meta-analysis. So strictly speaking, no firm deductions can be made from this review concerning the correlation between objective and subjective analysis of nasal patency. On the other hand, this is the first review that has attempted to map the literature on this subject and to see if conclusions can be drawn that are based on more than 'expert opinion'.

Relationship between pressure/resistance and flow

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. The flow in the nose is turbulent to a large extent. This is illustrated by the fact that nasal respiration is nearly always audible, even in resting conditions. The turbulence is responsible for the contact between the in- and expiratory gasses and

Table 2. Correlation (+) or lack thereof (−) between parameters in relation to variables

Correlation between parameters	Subjectively blocked nose/unilateral assessment	Subjectively blocked nose/bilateral or total assessment	Subjectively good-improved patency/unilateral assessment	Subjectively good-improved patency/bilateral or total assessment
Patency symptoms/NAR+	5[6,8,11,17,18]	4[3,9,14,15]	0	1[14]
Patency symptoms/MCA+	0	4[5,10,14,15]	0	4[5,7,10,14]
NAR/MCA+	0	1[15]	0	0
Patency symptoms/NAR−	0	4[4,8,16,17]	0	2[3,6]
Patency symptoms/MCA−	0	1[12]	0	2[12,13]
NAR/MCA−	0	1[14]	0	1[14]

This table refers to the 16 studies in Table 1. The cell values indicate how often a correlation was (+) or was not (−) found between the parameters SA, NAR, and MCA in relation to the variables named in the column headings.
NAR, nasal airway resistance; MCA, minimal cross-sectional area.

the nasal mucosa, a pre-requisite for nasal functioning. Thus, there is no linear relationship between pressure and flow. The amount of turbulence depends not only on the patency of the nasal airway but also on the shape of the nasal cavity. As a consequence, a low patency may be accompanied by a high as well as a low resistance, depending on the presence or absence of irregularities in the shape of the nasal cavity.[21]

Subjective sensation of nasal patency and nasal resistance

Another question concerns the uncertain relation between nasal resistance and the subjective sense of nasal patency. This problem has been pondered over for decades.[22–33] 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.[22–31] 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.[30–33] It was postulated that specific nasal sensory nerve endings, probably of the major palatine nerve, might be responsible for the subjective perception of nasal patency. It appears that the sensation of nasal airflow, at least under certain circumstances, can be entirely independent of any objectively measurable change in nasal resistance.

Clinical applicability

When used as part of the overall evaluation of a patient's complaints, 'objective tests' may provide additional information. However, considering the extra time, effort, and investment it takes to include these tests in a diagnostic work up, one would need to be confident that the information they might yield would make a meaningful contribution to the diagnostic and therapeutic process of patients with symptoms of nasal obstruction. In our own past experience this did not seem to be the case, as we frequently found discrepancies between the objective measurements and a patient's complaints (or lack thereof).

Synopsis of key findings

We found just three studies that used rhinomanometry as well as acoustic rhinometry.[11,14,15] One of them demonstrated a correlation between the results from both methods in patients with a subjectively blocked nose,[15] which is in line with methodologic considerations.[21] Twenty-one studies addressed the possible correlation between the results of objective measurements and patency symptoms. Only 16 of them had a level II-a or II-b of evidence. None of the studies were randomized controlled trials (level of evidence I). It must be emphasized; however, that the very nature of the question would make such a study design difficult, if not impossible. It may seem that there were almost as many outcomes as there were studies. Nonetheless, a few tentative conclusions could be drawn by evaluating the number of times a correlation or lack thereof was found between the parameters in relation to the variables.

It seems that in the presence of obstructive symptoms, a correlation is more likely to be found with either NAR or MCA. Conversely, for individuals with no symptoms, it may be more difficult to find a correlation with objective measurements. In other words, when a patient has subjective complaints of obstruction, the likelihood that the measurements found with objective tests will concur with this subjective sensation may be greater. This has a few interesting implications. If the correlation between an objective test of the nasal airway and the subjective sensation of nasal patency is generally strong, one may wonder what its added value is in clinical practice. If the correlation is strong, the subjective sensation alone may reliably describe the 'objective' nasal airway, thereby decreasing the need for objective measurements. On the other hand, if the correlation is generally weak, one must be cautious about relying on objective tools in the therapeutic decision-making process. However, with a strong and reproducible correlation, objective tests could play a role in measuring the effect of therapeutic interventions or in challenge studies. Indeed, one of the main uses for which objective measurements are recommended is to evaluate the results of nasal surgery aimed at improving patency. The results of the studies considered here suggest an interesting paradox: the greater the improvement caused by nasal surgery, the more difficult it may be to measure it, because the range of outcomes is larger in the absence than in the presence of obstructive symptoms (Table 2).

Conclusion

The perception of nasal airflow is primarily a subjective sensation but is related to nasal resistance and to the anatomy of the nasal passages. Since many factors may be of influence, no single objective test, however qualitatively and technically reliable, will reproducibly correlate with this perception. On the other hand, the tools commonly used for rating the subjective sense of nasal patency are not without flaws and the questionnaires used in the studies in this review were not validated. Taking this point and the fact that a true meta-analysis could not be done into account, a cautious conclusion based on this review might be that when a sensation of obstruction is present, this is more likely to correlate with objective tests than in the absence of symptoms. There also seems to be a greater likelihood of a correlation between unilateral symptoms (or lack thereof) and unilateral objective measurements than between bilateral symptoms and total nasal resistance or combined mean cross-sectional areas. As these objective tests only relate to nasal airway resistance and cross-sectional areas, not all factors involved in nasal patency disturbances are included. To elevate 'objective measurements' above subjective symptoms on the basis of the currently available data is unfounded and is more likely to be based on a general philosophical viewpoint than on facts in the case of nasal obstruction. In light of these findings and considerations, it seems unlikely that further research or technical refinements of the methods to measure nasal patency will solve the problem. At this point in time, there seems to be a limited argument for the routine use of either rhinomanometry or acoustic rhinometry in routine rhinologic practice or for validating therapeutic outcomes. Even though lacking in objectivity, a patient's subjective sensation of nasal patency, preferably rated with validated questionnaires and on visual analogue scales, still seems to give the most valuable information concerning the degree of nasal obstruction.

Keypoints

- There is continuing divergence of opinion about the value of objective measurements of nasal patency in clinical practice.
- There is no consensus about the correlation between objective measurements and subjective nasal patency symptoms.
- Objective measurements of nasal patency are frequently used to validate the results of therapeutic interventions.
- No firm conclusions can be based on this review, as the questionnaires used were non-validated and a true meta-analysis could not be done. However, no basis was found to elevate the value of objective outcomes above subjective patency symptoms, neither in routine rhinologic practice, nor for the evaluation of therapeutic interventions.

Conflict of interest

None to declare.

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