

Measurement of nasal patency

Malm L. Measurement of nasal patency.
Allergy 1997; 52 (suppl 40): 19–23. © Munksgaard 1997.

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Definitions

Patency emanates from the word “patent”, which is equivalent to the word “open”. Nasal patency is thus a measure of how open the nose is, and it is not equivalent to airflow or resistance to airflow. If the word patency is used in a correct way it should only comprise cross-sectional areas of a nasal cavity or the volume of a part or the whole of a cavity. According to such a definition, methods to measure nasal patency can be presented as in Table 1A. Many authors, however, include methods for recording nasal airflow with or without simultaneous pressure recordings among nasal patency methods. Therefore those, presented in Table 1B, are also discussed.

Computed tomography and magnetic resonance imaging

Computed tomography (CT) is invaluable pre-operatively for endoscopic and other kinds of sinus surgery, and CT and magnetic resonance imaging both give a very good idea of the probable occurrence of polyps not seen endoscopically. However,

due to radiation doses and costs, respectively, none of these methods are generally used for systematic follow-up of polyposis treatment. Van Camp & Clement used CT before and after short-term treatment of nasal polyposis with high oral doses of prednisolone, and they found that only 52% of the patients showed a clear improvement on CT of the paranasal sinuses (1). They did not try to evaluate nasal polyposis with CT.

Volumetry

Among the methods presented in Table 1, the volumetric ones do not seem useful for the study of rhinitis. Those methods have almost exclusively been used in anaesthetised animals, e.g. by Tschalussow in 1913 (2). He closed the anterior and posterior openings of the nose and connected the closed chamber to equipment for pressure or volume recordings. Very recently, a similar, but much more sophisticated, method has been invented for human studies (3). To achieve closure of the nasal cavity posteriorly the subjects have to blow a manometer up to 40 mbar pressure to elevate the soft palate against the posterior pharyngeal wall. For animal experiments the volumetric method became simpler by using thin-walled intranasal balloons (4). However, volumetric methods of the above-mentioned types will probably be of no value for studies of rhinitis.

Rhinostereometry

Rhinostereometry is in principle a very simple way of recording changes in the thickness of the nasal mucosa (5). The equipment consists of a surgical microscope placed on a micrometre table. The test subject is fixed firmly to the microscope with an individually made plastic splint adapted to the teeth. The microscope has a shallow depth of focus, and by adjusting the microscope to a sharp image on the antero-medial side of the inferior turbinate, changes of the thickness of the mucosa can be recorded along a millimetre scale. Rhinostereo-

Table 1. Methods for measuring nasal patency and nasal airflow/resistance to airflow

A. Nasal patency	
	Computed tomography
	Magnetic resonance imaging
	Volumetry
	Closed cavities
	Intranasal balloons
	Rhinostereometry
	Acoustic rhinometry
B. Nasal airflow/resistance to airflow	
	Rhinomanometry
	Active anterior
	Active posterior
	Passive anterior
	Nasal peak flow
	Expiratory
	Inspiratory

metry is an accurate method with good reproducibility for the study of nasal reactivity to histamine applied locally to the nose. The method has been used in a number of studies, one of which focused on demonstrating a development of a hyper-reactive mucosa in healthy volunteers after 4 weeks of treatment with a common decongestant nasal spray three times a day (6). The method, however, does not appear useful for studying nasal polyps *in situ*. If the polyps are large, they probably move too much; if they are small, they are situated too far into the cavity for the method. The method does seem suitable, however, for studying the reactivity of the inferior turbinate in rhinitis.

Acoustic rhinometry

Equipment and techniques

Most equipment uses an acoustic pulse from a spark source for the measurements. The pulse wave is transmitted along the respiratory tract, mainly in the nose, and is then reflected back, determined by changes in the cross-sectional area of the nasal cavity. The reflected sound passes via a microphone to a computer, where it is processed and then presented as an area-distance graph. The acoustic waves can also be produced from a sound generator, which has the advantage that the sound is well defined as to amplitude, frequency and number of waves (7).

The first useful acoustic rhinometer was produced in Aarhus, Denmark, and studies with that equipment were published in 1989 (8). The coefficient of variation in repeated measurements at weekly intervals and for decongested mucosa was found to be 4% (9). In a later study the same group found considerably higher coefficients of variation when their subjects were placed in a horizontal position (around 20–25%) (10). Soon after the first Aarhus publication, results from a similar apparatus were published from Ulm, Germany, and their coefficients of variation for decongested mucosa were given as less than 6% (11). Fouke & Jackson, the latter one of the authors of the first publication from the Aarhus group, used an index of nasal cavity volume calculated from the right and left cavities and found a mean of the intra-subject coefficient of variation of 7.9% (12). A very careful study of the reproducibility of acoustic rhinometric measurements was recently published by Philip Cole's group in Toronto (13). He and his co-workers studied the variability for measurements minute-to-minute, hour-to-hour, day-to-day, and week-to-week, and they found the total (both sides together) minimal cross-sectional area to have coefficients of variation of 5–17% and the total nasal volume coefficients of 4–9%. When they

changed the angle between the wave tube and the head of the subject, there was a 5–16% change of the coefficients of variation. According to them, a good adaptation between the wave tube and the nose, a stand for the wave tube, and a support for the chin are necessary to achieve a low coefficient of variance. Other investigators have come to the same conclusions. Fisher & Boreham also stress the importance of a good stand for the wave tube (14). In another study, Fisher and coworkers demonstrated how a changed angle of the wave tube in the sagittal plane and the axial plane, respectively, affects the acoustic rhinometer graphs (15).

A simple stand for the wave tube on a table, used for eye investigations, can be used. Angles are given on the table; and for repeated measurements in the same patients, the wave tube is used at the same angles. A freely moveable wave tube kept close to the nostril by a technician gives high coefficients of variation and must be avoided (personal communication by this author).

When the main interest is focused on the valve area, such as in studying septal deviations, it is very important that the adapter (the connection between the wave tube and the nose) does not deform that area. In such a case, it is best if the adapter only is connected to the outer parts of the nostril with very little pressure (7, 15). Then a soundproof seal is necessary, e.g. with a petroleum jelly-like vaseline. If changes further back in the nose are the most interesting, such as in nasal polyposis, an adapter that is connected to the interior of the nostril can be used. Whichever adapting technique is used, maintaining the same angle of the wave tube for repeated measurements seems necessary.

There are still different opinions regarding whether the patient or subject should breathe through the nose or the mouth during recording, or if he or she should be recorded during a brief breathing pause. Fouke & Jackson from the USA have suggested recording during oral respiration at end-expiration (12). Fisher et al. (15), in their very careful study of practical aspects of acoustic rhinometry, feel that cessation of nasal respiration produces traces of similar quality. Tomkinson & Eccles have also published a thorough investigation of errors caused by different techniques when using acoustic rhinometry (16). They found differences in minimal cross-sectional areas between results obtained during a breathing pause, inspiration, and expiration through the nose, and they thus recommend that acoustic rhinometry should be performed during a brief breathing pause.

There is a general opinion that more than one reading should be taken, and as many as eight traces, being averages per nostril, have been

recommended (17). Three readings is the usual recommendation, e.g. by Fisher et al. (15). The general experience is, however, that of three readings, sometimes one of them differs greatly from the others. Tomkinson & Eccles have also studied that aspect, and they recommend using the mean of three consecutive readings as long as the three readings have a coefficient of variation for the nasal volume that is less than 20% (18). They get the coefficient of variation directly after the third reading, and can in case of a value higher than 20% go further with new readings until they have three accepted consecutive ones.

Limitations for detection changes with acoustic rhinometry

Lenders et al. (19) have tried to find how large an intranasal tumor or mass must be in order to be detected by acoustic rhinometry. They did so in connection with a study of controlling operated inverted papilloma. They concluded that acoustic rhinometry does not deliver more information than obtained by video-endoscopy and CT to detect tumour recurrence in the nasal cavity. To imitate tumour recurrence, small pieces of wax were inserted in different parts of the nasal cavity of patients. A piece of wax with a volume of 0.3 ml could not be detected when it was placed in the posterior part of the nose, but when it was located at the anterior part of the inferior turbinate and about 2–3 cm backwards, it was clearly demonstrated.

Fisher et al. (20) were able to detect silicone spheres 3 mm in diameter in only a minority of healthy volunteers' noses, but with spheres of 5 mm about half of them were detected. Spheres of 7 mm were detected in 80% by area changes and in 100% by volume changes. The spheres were placed in the nose under endoscopic control and either in the middle meatus about 4 cm from the tip of the nosepiece or in the valve region 1.5–2 cm from the tip.

Min & Jang from Seoul in Korea compared cross-sectional areas obtained by acoustic rhinometry and CT (21). The two measurements showed a better linear correlation in the anterior part of the nasal cavity up to 2.4 cm from the nostril than in the posterior part of the nasal cavity behind that point. It is also known from studies in nose models and simple tubes that an anterior narrowing increases the inaccuracy in the posterior parts (22).

The uncertainty in the posterior parts limits the usefulness of acoustic rhinometry in evaluating pathology in the nasopharynx. Pre- and post-operative recordings of severe adenoidal obstruction

have been published by Fisher and coworkers (23). They conclude that acoustic rhinometry has potential for preoperative evaluation at adenoidectomy, but that the predictive value is low unless combined with clinical factors.

Nasal polyposis studies with acoustic rhinometry

It is this author's opinion that acoustic rhinometry is the method of choice for objective control of treatment of nasal polyposis. This opinion is based on the possibilities of a high reproducibility when following the recommendations given by the above-cited authors. So far, very few well-controlled studies on nasal polyposis and acoustic rhinometry have been published, and one of the reasons may be that the above recommendations were only presented very recently, although they have been well known to some investigators for many years.

In one of the studies of the Aarhus group, the effect of intramuscular injections of a corticosteroid on nasal polyposis was controlled by acoustic rhinometry, a nasal index, and nasal expiratory peak flow (24). Eight patients with a long-term history of nasal polyps repeatedly treated by surgery (2–29 times) were selected. The nasal volume for a length of 5.8 cm was evaluated. In all the cases the effect of the steroid was manifested by improvement of all three parameters.

Acoustic rhinometry has also been used in some of the many recent studies performed by Valerie Lund and co-workers in London, e.g. in one study testing the effect of intranasal lysine aspirin in 18 patients with recurrent nasal polyposis (25). Symptomatic polyp recurrence during the 15-month study was significantly delayed compared with previous experience while on intranasal steroids. They treated one nasal cavity with lysine aspirin and the other one with saline solution, and they found a tendency for the lysine aspirin-treated side to have less polyp tissue as assessed by endoscopy and acoustic rhinometry.

Rhinomanometry

Rhinomanometry, which does not record nasal patency, has also been used for evaluation of nasal obstruction. Active anterior rhinomanometry, which is the most common rhinomanometric method and also the one recommended by the Standardisation Committee of the European Rhinologic Society (26), records nasal airflow and air-pressure differences during quiet breathing in one cavity at a time; more than 80% of the nasal airway resistance is produced in the region of the valve and the head of the inferior turbinate (27).

This is the narrowest part of a healthy nose, and rather big polyps situated behind that part may not reduce the cross-sectional area to less than the valve area. Thus, the latter area will still be the most resistant region, which makes active anterior rhinomanometry a rather insensitive method for nasal polyposis. This fact is reflected in the literature, with very few papers found using active anterior or posterior rhinomanometry to monitor treatments of nasal polyposis. With posterior rhinomanometry, airflow and pressure differences are recorded from both cavities (the "total nose") at the same time.

In 1977, Deuschl & Drettner treated patients with nasal polyposis with beclomethasone intranasally and found a significant better effect with the active substance than with placebo ($P < 0.05$) with posterior rhinomanometry (28). Some years later, Drettner and co-workers compared flunisolide intranasally with placebo after polypectomy and found a significant effect on symptoms but no effect on active (posterior) rhinomanometry (29). Passive anterior rhinomanometry, i.e. when a known flow of air from an external source is blown into a nasal cavity and the resistance to that flow is recorded, could, by the dilation of the valve area and with a flow higher than that at quiet breathing, possibly be better than the active method for following changes in the size of nasal polyps. On the other hand, reflexes due to the forced airflow, may make that method less reproducible.

Rhinomanometry, especially active anterior rhinomanometry, is best applicable not to nasal polyposis, allergic rhinitis, or other inflammatory disorders but to surgery of the nose. It offers an objective control of surgery on cartilage and bone provided the mucosa is decongested. Furthermore, anterior rhinomanometry, also after proper decongestion of the mucosa, has been shown to help in the selection of patients who after functional septoplasty will be satisfied with the surgical result (30, 31).

Nasal peak flow

The nasal peak flow method has attracted more interest than rhinomanometry because it is inexpensive, quick, and easy to handle by the patient him/herself. It is useful for repeated examinations and compares well with rhinomanometry (32, 33). The nasal inspiratory peak flow technique is usually to be preferred to the expiratory one, which produces mucus in the flow meter. A common objection from those who are not familiar with the inspiratory technique is that vestibular collapse may easily occur. The risk for that, however, is rather small. In a total of 327 inspira-

tory peak flow measurements in 12 allergic patients challenged with the proper allergens in increasing doses, only six times was no value achieved because of total occlusion of the nose (32). A vestibular collapse during maximal inspiration can, to some extent, be counteracted by instructing the patient to actively contract the alar muscles ("flaring") (32).

The same objection to peak flow measurements as to rhinomanometry should be valid; i.e. the narrowest part of the nasal cavity has the most influence on the recorded results. Changes in size of small polyps situated in the usual place in the middle of the nose should thus not be detected by nasal peak flow (or rhinomanometry). It is possible that the forced inspiration or expiration at peak flow measurements improves the sensitivity compared with rhinomanometry, but the reason why the peak flow method has been more used in studies of rhinitis than rhinomanometry may mainly be due to the much easier handling.

Placebo-controlled studies of nasal polyposis with steroid therapy have shown improvement of nasal expiratory peak flow during active treatment (24, 34–37). Also, nasal inspiratory peak flow measurements have been used in such studies and have shown improvement (38). In one of the above studies, nasal expiratory peak flow, nasal index based upon a self-assessment score, and acoustic rhinometry have been followed to monitor the effect of an intramuscular injection of a steroid in the treatment of nasal polyps (24).

Other airflow methods

Head-out body plethysmography, oscillometry, and nasometry (measuring "nasalance") are airflow methods described in the literature but not in connection with nasal polyposis. They were recently reviewed briefly by Eccles (39).

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