Rhinology, XVII, 107–114, 1979

Methodological aspects of rhinomanometry

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SUMMARY

Rhinomanometry is an objective method for determining nasal patency; its reliability and relevance as an aid in defining and solving problems connected with nasal obstruction have, however, received scant attention. In the present study more than 200 subjects were submitted to rhinomanometry – most of them only by the posterior technique. In 50 of these subjects duplicate determinations of the pressure drop across the nose at the flow rate of 0.3 l/s were made within a short interval; the coefficient of variation was 20–25 per cent.
The rhinomanometric values in a small group showed a day-to-day variation of 55 per cent. Because rhinomanometry allows only a moderate level of accuracy the method is unsuitable for detecting a borderline case.
As the influence of the variability of the method is smaller in large materials, rhinomanometry is more suitable for comparison of groups than of individual patients.

There is need in rhinology for a test of nasal function comparable in simplicity and precision to the pure tone audiogram. Despite the large number of function tests and their modifications that have been reported, the ideal method has yet to be found. A widely adopted principle in the determination of nasal patency and testing of nasal function is to measure the flow through, and the pressure drop across, the nose – a method usually referred to as rhinomanometry (Kern, 1977).

For a rhinomanometric test to be acceptable it must be possible to distinguish between subjects with a normal nasal passage and those where there is obstruction. The apparatus must then be adequate for the purpose (Aschan et al., 1958). Normal values and the coefficient of variation have been discussed by Ingelstedt et al. (1969). Bachmann (1976, 1978) has investigated the relevance of rhinomanometry with respect to obstructive symptoms and signs. A cyclic

Paper presented at the 7th Congress of the European Rhinologic Society. Davos (Switzerland), September, 1978.

variation of the swelling of the nasal mucous membranes has been postulated (Ogura et al., 1968; Stocksted, 1952; Keuning, 1968). Ogura found no significant day-to-day variation such as would be expected if the postulate is correct. Exhaustive descriptions of the method, including critical analysis, are regrettably few. We accordingly undertook this study with the purpose of determining the reliability and relevance of rhinomanometry as a diagnostic tool.

RHINOMANOMETRIC APPARATUS AND THE PROCEDURE

Rhinomanometry in this context is the simultaneous measurement of the transnasal pressure drop and the resulting flow rate. The posterior technique used is that described by Aschan et al. (1958). The measuring device consisted of two electromanometers (EMT 32C), a Fleisch pneumotachograph, an oscilloscope (Tektronix) and a Polaroid camera. In posterior rhinomanometry the postnasal pressure was transmitted to the manometer by means of a polythene tube held in the mouth. In anterior rhinomanometry (Masing, 1967; Neff, 1972) the manometer tube was affixed to the relevant nostril with pliable tape.

The flow and the pressure drop were fed to the X and Y plates of an oscilloscope and the resulting curves were photographed with a Polaroid camera. Measurements on the photographs were made with vernier calipers. Each photograph represented at least 3 tracings of respiratory cycles.

The subject, seated, was examined before and after decongestion with an oxymetazolin spray (Nezeril, Draco).

TESTING OF THE EQUIPMENT

To test the dynamic performance of the equipment a shock wave was applied to the flowmeter and the pressure transducer. For both systems the rise time was 0.018 s. The upper limit of the frequency was 24 Hz, as calculated from the rise time. Tests with a pump generating sinusoidal pressure waves showed the two systems to produce a linear characteristic up to 20 Hz.

The static performance of the systems was examined by graphical analysis of the linearity. The characteristic was linear over the measuring range. Replicate measurements of a known flow or pressure showed a variability of less than 1.5 and 1.0 per cent for the flowmeter and pressure transducer systems, respectively.

ANALYSIS OF THE METHOD

To examine the effect of any leakage between the face and the mask a model experiment was conducted, using a mask containing holes the diameter of which ranged from 0.5 to 5.5 mm. A comparison was made of the pressure drop recorded with these holes patent and then with them blocked. At a flow rate of 0.2 l/s the error was never greater than 5 per cent of the true values for holes up to 3 mm in diameter.

To obtain the maximum amount of information the highest flow rates common to all the patients were used in the various experiments.

The coefficients of variation were obtained from duplicate measurements during the inspiratory phase at a flow rate of 0.3 l/s. The values are presented in Table 1.

Table 1. Coefficient of variation for the pressure drop at inspiration at a flow rate of 0.3 l/s.

	No decongestion	After decongestion
Breathing through both nostrils		
Number of duplicate determinations	52	62
Coefficient of variation, per cent	20	24
Breathing through one nostril		
Number of duplicate determinations	50	77
Coeficient of variation, per cent	16	26

Comparisons of the pressure drop in the inspiratory and expiratory phases were made at a flow rate of 0.4 l/s, with breathing through both nasal cavities. Measurements were performed on 50 subjects. The expiratory values exceeded the inspiratory for most of the patients, the mean difference being 10 per cent.

In 32 patients both anterior and posterior manometry were performed and the calculations were made at a flow rate of 0.25 l/s. After administration of decongestant the values were higher with the posterior method for both inspiration and expiration (Table 2).

Table 2. Mean difference $\triangle P_{ant} - \triangle P_{post}$ at a flow rate of 0.25 l/s.

	No decongestion	After decongestion
Inspiratory phase		
Number of duplicate determinations	39	50
Difference $\triangle P_{ant} - \triangle P_{post}$, Pa[a]	—12	—20[b]
Expiratory phase		
Number of duplicate determinations	29	48
Difference $\triangle P_{ant} - \triangle P_{post}$, Pa[a]	—17	—18[b]

[a] 1 Pa (Pascal) = 0.102 mm H_2O
9,81 Pa = 1 mm H_2O
[b] difference of significance, $p = 0.001$

THE DAY-TO-DAY VARIATION

To ascertain the influence of any variation in nasal patency from day to day 17 subjects were examined once a day on 3–5 consecutive days. The maximum deviation from the mean pressure drop in each subject – expressed as a percentage – was determined. The arithmetic mean of all the maximum deviations was then calculated for the whole group. The results are presented in Table 3.

Table 3. Day-to-day variation for the inspiratory phase at a flow rate of 0.3 l/s. On each subject between 3 and 5 determinations were made.

	No decongestion	After decongestion
Breathing through both nostrils		
Number of replicate determinations	15	15
Day-to-day variation, per cent	52	36
Breathing through one nostril		
Number of replicate determinations	15	33
Day-to-day variation, per cent	52	27

THE RELEVANCE OF RHINOMANOMETRY

The relevance of rhinomanometry as a means of grading nasal obstruction observed by the rhinologist and experienced by the patient was examined in the following way. In 144 subjects the width of each nasal cavity was estimated by eye at defined sites by one of the authors (HS) and a former collaborator. On the basis of the results so obtained the width of each nasal cavity was graded as extremely narrow, narrow, normal and wide. The same patients were interrogated concerning their opinion on the nature of the nasal obstruction (periodic, constant, left–right variation); for this purpose a prepared questionnaire was used. The subjects were finally required to grade the sensation of discomfort caused by the nasal obstruction according to the scale: none, slight, moderate, severe.

Over the flow range 0–0.50 l/s the pressure drop was read at intervals of 0.05 l/s. The pressure drop was measured for each nasal cavity and for the whole organ both before and after decongestion. The mean pressure drop and the standard deviation were calculated at each of the 10 flow rates for all the patients reaching the respective flow levels. For the comparison of the "discomfort" groups pressure drop values recorded in the more obstructed nasal cavity of each patient was chosen.

The entire material was thus divided into four groups according to nasal patency and four groups according to the level of discomfort caused by nasal obstruction. By means of rhinomanometry it was possible to differentiate between the former (Figure 1) but not the latter four groups at the 5 per cent level.

DISCUSSION

The presentation of pressure and flow in a coordinate system has important

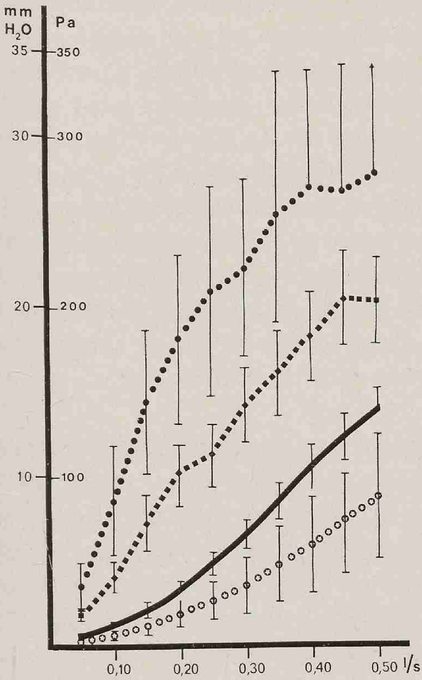

Fig. 1. Pressure-flow curves for each nasal cavity after decongestion; 144 subjects. The 95 per cent confidence limits are shown. Each nasal cavity is classified according to its estimated width. The number of subjects decreases as the flow rate increases especially in the "extremely narrow" and "narrow" groups. Abscissa; flow rate through the nose in the inspiratory phase and ordinate; pressure-drop across the nose.

advantages. For example, any blocking of one limb of the manometer due to interruption of the communication with the nasopharynx by the tongue or soft palate is noticed immediately. In addition, phase shifts between pressure and flow registration are clearly manifested by hysteresis. One advantage of the posterior method is that both nasal cavities can be examined simultaneously. A common opinion is that too many patients are unable to perform posterior rhinomanometry. According to our experience more than 70 per cent of examined patients can manage the posterior technique.

It has been found by Drettner (1961) in experiments in man and by Fischer (1969) in model experiments that the air flow through the nose is largely turbulent. For the relationship between the generating pressure and the resultflowing these authors have used the expression $\triangle P = kV^n$, where the exponent n lies between 1.7 and 2.0. If the pressure—flow curve for all the subjects examined – that is to say, those with normal passage and those with severe nasal obstruction – could be represented by a single number, a considerably better statistical analysis might be possible than when this analysis is based on the coordinates for a single point on the pressure—flow curve. In a comparison of patients by means of one arbitrarily chosen coordinate on the pressure – flow curve a number of difficulties may be encountered. If it is chosen to make the readings at a low pressure or low flow rate, it is only possible to distinguish between subjects with extreme pathological conditions and normal subjects. If, in the other hand, the comparison is made at high values of pressure or flow rate the patients with obstructed flow will not be included, and they will therefore be lost to the study. These methodological shortcomings complicate the interpretation of all the results. The fact that the use of a double logarithmic scale in our material did not disclose a linear relationship between pressure and flow in the interval from 0 to 0.5 l/s suggests that this relationship is not as simple as is represented by the above expression. As we found it impossible to characterize the pressure—flow relationship by a single number, we had to be content with working with pressure drops at a given flow rate – despite the attendant disadvantages discussed above. The highest possible flow was chosen consistent with the inclusion of a reasonably proportion of subjects in the study.

When the mucous membranes were decongested a fairly static situation would be expected, but in fact the reserve seemed to be the case, as if the increase in the coefficient of variation reflected an increased reactivity of the mucous membranes. A possible explanation of this is that not all the patients with the most severe nasal obstruction recorded so high a flow rate as 0,3 l/s without decongestion – as is evident from the fact that the number of subjects composing the sample was greater when decongestion had been performed.

Duplicate measurements were performed so as to be able to obtain the error of the method from the time the mask was fitted until the determination of the pressure-flow relationship. To minimize the influence of any changes in the nasal mucosa the interval between the measurements was made as short as possible. The analysis of the day-to-day variation, on the other hand, was performed in order to examine the implications of biological variations in the nose.

The observations of a greater pressure drop with posterior than with anterior rhinomanometry is to some extent consistent with the findings of other workers (Neff, 1972). This difference may be due to the fact that a longer section of the respiratory tract is measured with the former than with the latter method.

As regards the relevance of rhinomanometry, Figure 1 shows a fairly close agreement between the rhinological findings and the observed pressure flow values. The level of significance for the differences between the anatomic groups is, however, low, and this means that it is difficult to differentiate reliably between the adjacent groups.

The absence of an agreement between the patient's experience of obstruction and the actual observations may either be real or it may be due to inadequacy of the method. For example, our choice of reference point on a pressure–flow curve might not be properly representative of the subject's respiratory pattern.

CONCLUSIONS

Until the pressure–flow curve over a given interval can be described by a single number, the method has serious shortcomings. Because of the large variability displayed by individual rhinomanometric values, the method would seem to be unsuitable as a basis for deciding for or against surgical intervention – except in serious cases, when the method is, anyway, superfluous. In a comparison of the values of the individual subjects before and after treatment the long-term variations must be borne in mind. The most important application of the method would appear to lie in the comparison of large groups before and after treatment. The effect of the scatter is then reduced by virtue of the size of the group.

ZUSAMMENFASSUNG

Rhinomanometrie ist eine objektive Methode zur Bestimmung der Durchgängigkeit der Nase. Unserer Meinung nach ist es noch nicht festgestellt, ob die Methode zuverlässig und adequat als Indikator von Nasalstenoskorrelierten Symptomen ist. Bei diesen Untersuchungen wurden mehr als 200 Versuchspersonen mit Rhinomanometrie, und zwar die Mehrheit mit der posterioren Technik studiert. Bei 50 von diesen Versuchspersonen wurden Doppelbestimmungen vom Druckfall über der Nase beim gleichen Atemstrom mit kurzem Intervall gemacht. Ein Variationskoeffizient von 20–25% wurde daraus berechnet. In einer kleinen Gruppe wurden tägliche Rhinomanometrische Bestimmungen im Laufe von 3–5 Tagen gemacht; die Variation betrug etwa 55%. Da die Methode nur eine mässige Genauigkeit gewährleistet, ist sie nicht für einzelne Patienten im Grenzgebiet zwischen normalen und pathologischen Befunden zum Unterscheiden geeignet. Da die Einwirkung von der Variation der Methode weniger in grossen Patientengütern ist, eignet sich die Methode besser zum Vergleichen von Gruppen als von Einzelfällen.

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