

The simplified oscillation method for measuring nasal resistance during provocation with allergens

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Summary

The simplified oscillation method was adapted to register nasal resistance because complicated and difficult procedures limited other known rhinomanometric tests. An initial study of thirty-nine subjects compared the effect of different-sized masks, revealing that the smaller the face mask, the smaller the capacitance and the higher the effective resistance. After an initial measurement, a second study group of twenty healthy and twenty pollinosis patients aged from 4 to 40 years underwent nasal provocation with grass pollen extract. Both study groups showed that despite high resistance, reactances were minor. This occurs because the nose acts as an aperture and an aperture has minimal reactances. With increasing concentrations of pollen extract, the nasal resistance of pollinosis subjects increased steadily, whereas the controls showed no change. Passive anterior rhinomanometry was measured for comparison and results contrasted sharply with the oscillation method: prior to provocation, initial values of control and pollinosis groups were already significantly different; after provocation, there was a statistically significant rise in resistance amongst the control as well as the pollinosis subjects. Further, the oscillation method for measuring nasal resistance proved to be simple, effective, and suitable for children.

Introduction

Provocation tests are becoming of increased importance as evidence accumulates that the correlation between a positive skin test and challenge of the allergic organ is only 50%. The measurement of nasal resistance using whole body plethysmography (Hofmann, Pflug & Woenne, 1979) and other anterior rhinomanometric tests (Van Dishoeck, 1973; Bachmann, 1972) has been limited by the complicated and stressful procedures which require the full co-operation of the patient. Since the oscillatory respiratory resistance is simple to measure, by a procedure which does not disturb the spontaneously breathing subject (Berdel *et al.*, 1979), we applied this method, which

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was first described by DuBois *et al.* (1956) and subsequently improved (Fisher, DuBois & Hyde, 1968; Cogswell, 1973). We adapted the simplified oscillation method (Landser *et al.*, 1976; Franetzki, Prestele & Korn, 1979; Korn, Franetzki & Prestele, 1979) for the nasal provocation.

Method

The oscillation method has, to date, been used only to measure respiratory resistance; we shall first explain the theory which was described in detail by Franetzki *et al.* (1979). The resistance flow in a simple tube is defined as the change in pressure to flow:

$$R = \frac{\Delta P}{\dot{V}}$$

To measure the nasal resistance we fitted a mask instead of the mouthpiece onto the Siregnost FD-5 (Fig. 1). The subject breathes via the mask through a tube which serves as a reference impedance (Z_o) and is connected parallel to the respiratory tract impedance (Z_x) (Fig. 2). The italicized symbols represent complex quantities. At the proximal end of the tube an imperceptible oscillation flow ($\dot{V}$) of 10 Hz and volume of 1.4 ml is superimposed, which flows partly across Z_o and partly across Z_x . The resulting alternating pressure signal (P) is produced. Since $\dot{V}$ and Z_o are known constants, Z_x can be obtained by the measurement of P .

When a sine wave of airflow $\dot{V}$ is applied to the tracheobronchial air column, the resultant transthoracic pressure (P) changes are related to the total impedance (Z) of the respiratory system:

$$P = Z \dot{V}$$

Impedance is the vector sum of the effective resistance and the effective reactance; the latter in turn is the sum of capacitance (negative sign) and inertance (positive sign) (Fisher *et al.*, 1968). The electrical equivalent to inertance is expressed as inductance. A round tube produces a positive inductance, whereas an expandable membranous structure produces a negative capacitance.

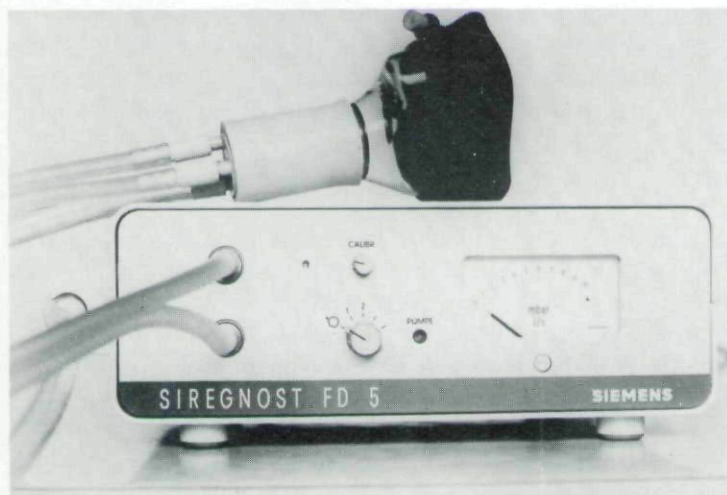


Fig. 1. Apparatus adapted with mask to measure nasal resistance using the simplified oscillation method.

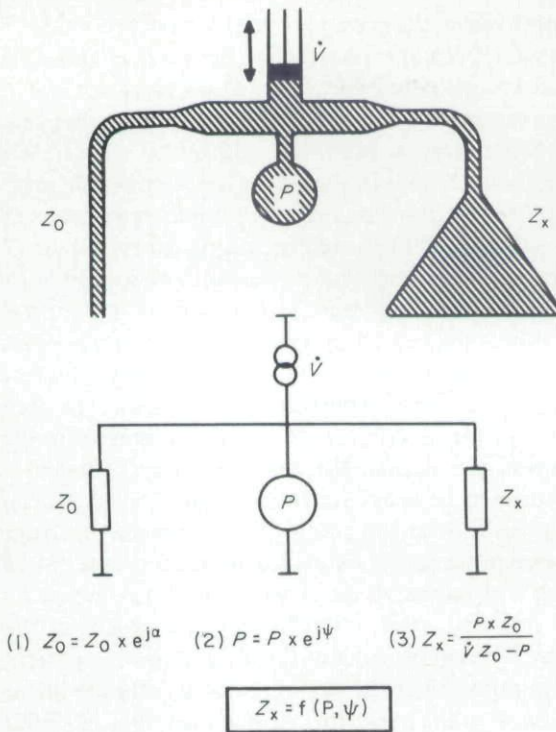


Fig. 2. Oscillation method theory and its equivalent electrical circuit. Z_0 , Reference impedance; $\dot{V}$, oscillating flow produced by a piston pump; P , alternating pressure; Z_x , respiratory tract impedance. For derivation of formulae see Franetzki *et al.* (1979).

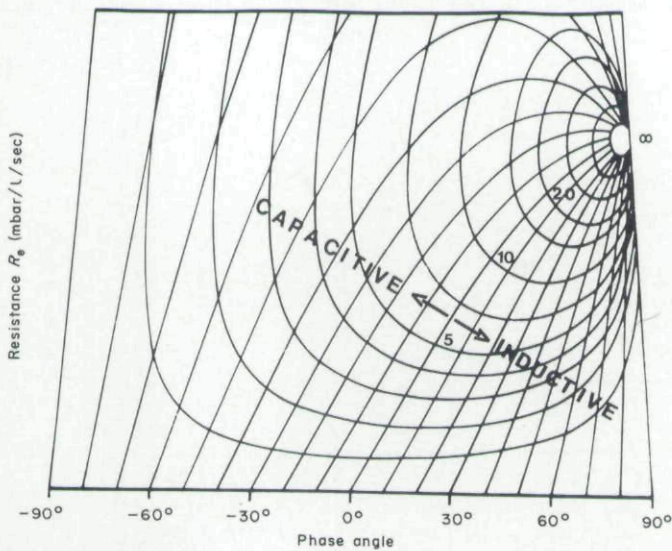


Fig. 3. Phase diagram. The respiratory impedance Z , expressed by its resistance R_e (mbar/l/sec) and by its phase angle ϕ can be read from the curved co-ordinates.

By using an X - Y recorder, the amplitude of the pressure signal is recorded on the Y axis, and the phase angle which results from the phase shift between P and $\dot{V}$ is recorded on the X axis. Using special co-ordinate paper (Fig. 3) which is calculated according to eqn 3 in Fig. 2, respiratory impedance in terms of effective resistance and phase angle can be obtained (Holle, Magnussen & Hartmann, 1979).

In contrast to the theory of this method, the measurement itself is very simple, with little stress to the patient. An initial study of thirty-nine subjects compared the effect of different-sized masks, whereby each subject was measured breathing through a size 2 and then a size 5 Ambu mask. We then measured forty subjects aged from 4 to 40 years of age at a time when they were free of allergic symptoms. Twenty served as a control group and twenty had grass pollen rhinitis diagnosed by history and a positive prick test. The subject breathed through both nostrils with the mouth closed while a clear plastic mask with an inflatable edge was firmly held to the face. The mask was attached to the measuring head and reference impedance. After an initial measurement (0) the nasal provocation with a neutral solution and standard grass pollen extract (Bencard, Neuss) was begun. The extract was diluted to concentrations of 10^{-1} to 10^{-4} . The neutral and extract solutions were applied with cotton swabs placed between the lower turbinate and nasal septum of both nasal passages. The swabs remained in place until a positive reaction of repeated sneezing and increased nasal secretion arose. When no reaction occurred, the swabs were removed after 3 min. Prior to measuring the resistance, secretions were removed by forceful blowing of the nose. After the patient had adapted to the mask for several minutes, the readings were taken from the linear scale (R_{0s}) and phase diagram (R_e) as soon as the indicators stopped vascillating. With high initial resistance, the phase diagram must be used in order to measure further increases above the 10 mbar/l/sec maximum reading of the linear scale (Fig. 4). In addition, a passive anterior rhinomanometric reading using the PAR instrument (Carl Heyer GmbH, Bad Ems) was taken on each subject at each point in time (Van Dishoeck *et al.*, 1973; Clement, van Dishoeck & Stoop, 1978).

If there was no increase in resistance within 15 min after application of the allergen,

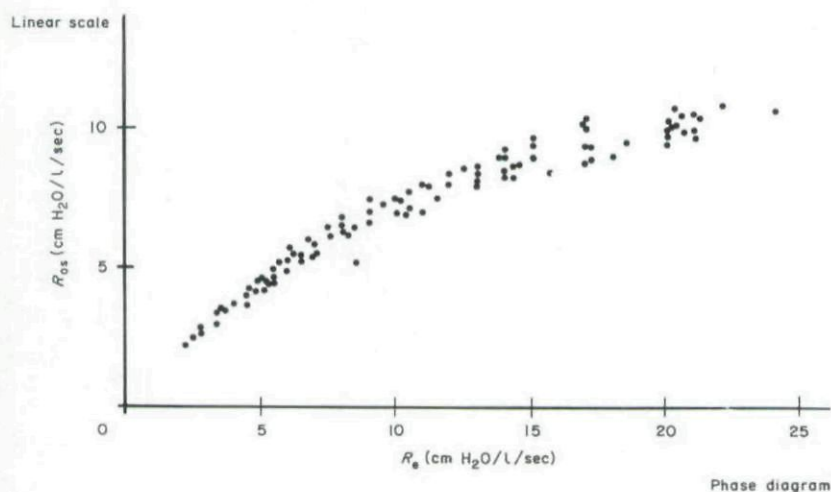


Fig. 4. The correlation of resistance measured with linear scale (R_{0s}) vs phase diagram (R_e) decreases after R_{0s} values of 5 have been reached. $n=97$.

the next highest concentration was applied. The examination was stopped when one of the three parameters secretion, irritation, or nasal resistance were strongly positive, as defined by Rudolph *et al.* (1976).

We calculated the mean resistance for each group, obtained with each instrument (Siregnost and PAR) for the different concentrations of solution. The differences between the two groups were analysed using the Student's *t*-test, the differences within the group between the different concentrations of solution were calculated using variance analysis with repeated measurements (ANOVA). In the pollinosis group the '0' values were compared with the value of the highest concentration measured, because sixteen subjects had such strong reactions that testing was stopped prior to reaching 10^{-1} concentrations.

Results

Measurement of the thirty-nine initial subjects showed that even with high effective resistance only small capacitances were registered, so that the values were distributed close to the 0 effective resistance line of the phase diagram (Fig. 5).

The nasal resistance was higher when the small mask was applied, the mean value being 11 mbar/l/sec for the small mask compared with 8.9 mbar/l/sec for the large mask. The large mask produced a greater capacitance of mean value -3.3 compared with $+0.12$ for the small mask.

The individual subjects' oscillatory nasal resistance during provocation is shown in Fig. 6. The initial readings (0) of the controls did not differ from the 0 readings of the pollinosis subjects.

The mean oscillatory nasal resistance before and after application of the neutral solution showed a slight decrease in both the control and pollinosis groups. With increase in concentration in pollen extract, the nasal resistance of pollinosis subjects

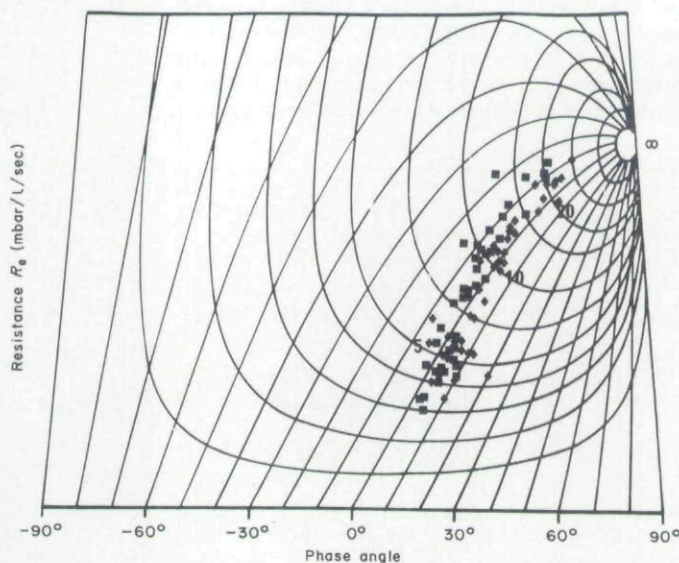


Fig. 5. Phase diagram comparing the nasal resistance of thirty-nine subjects using both a large (■) and a small (◆) mask for each subject. The higher capacitance of the large mask is evident ($n = 39$).

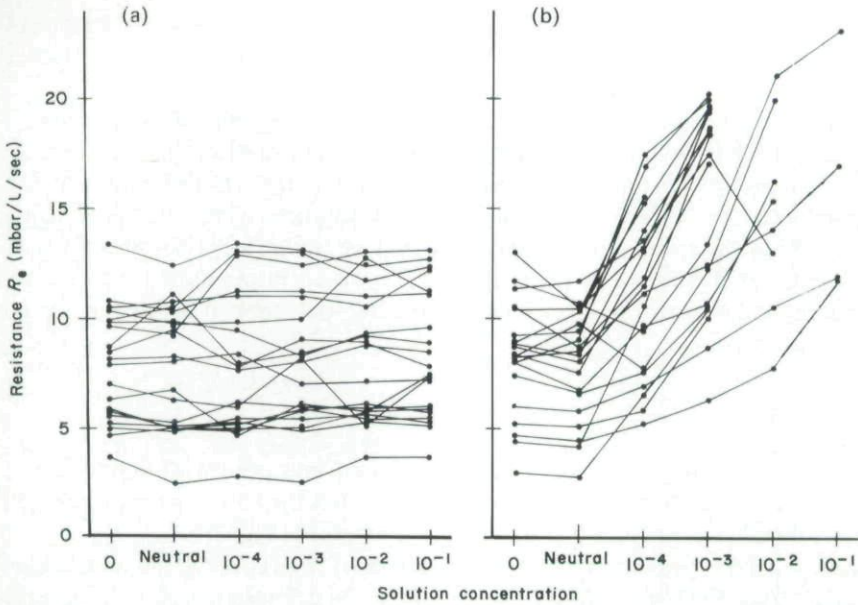


Fig. 6. Mean oscillatory nasal resistance of twenty control and twenty pollinosis subjects during nasal provocation with grass pollen extract (Bencard, Neuss). 0, resistance (R_n) prior to provocation; neutral, resistance after application of neutral solution; 10^{-4} – 10^{-1} , concentration of pollen extract. (a) Normal subjects; (b) pollinosis subjects.

Table 1. Mean nasal resistance of control and pollinosis subjects using passive anterior rhinomanometry (PAR) and the oscillation method with phase diagram (Siregnost FD-5). 0, resistance measured prior to nasal provocation; Neutral, measurement after application of neutral solution; 10^{-4} – 10^{-1} , concentration of grass pollen extract (Bencard, Neuss). Because of severe reactions during the provocation, not all subjects could be tested up to 10^{-1} concentrations; the number of subjects tested are noted after the mean value in parentheses.

Subjects	Method	Concentration					
		0	Neutral	10^{-4}	10^{-3}	10^{-2}	10^{-1}
Control	Siregnost (mbar/l/sec)	8.0 (20)	7.8 (20)	7.9 (20)	8.0 (20)	8.2 (20)	8.4 (20)
	Par	R* 21 (20)	22 (20)	23 (20)	26 (20)	26 (20)	28 (20)
	mm H ₂ O	L* 23 (20)	24 (20)	27 (20)	28 (20)	29 (20)	29 (20)
Pollinosis	Siregnost (mbar/l/sec)	8.2 (20)	7.9 (20)	11.0 (20)	16 (19)	19 (9)	17.6 (4)
	Par	R* 44 (20)	42 (20)	55 (20)	63 (19)	57 (9)	66 (4)
	(mm H ₂ O)	L* 49 (20)	46 (20)	63 (20)	80 (19)	66 (9)	73 (4)

*R, right nostril; L, left nostril.

increased steadily (Table 1). The difference between the initial value and the final resistance is highly significant ($P < 0.001$). The mean of the controls showed no statistically significant change between the various concentrations. The maximal values of the pollinosis subjects are significantly higher than those of the controls ($P < 0.001$).

The analysis of the PAR values revealed a statistically significant increase from the 0 readings to the maximal readings in the control group as well as in the pollinosis group! Furthermore, the 0 PAR values of the control *vs* pollinosis group were significantly different, whereas the Siregnost 0 values did not differ.

During the grass pollen extract testing, five of the twenty control subjects had strong reactions with sneezing and marked nasal secretion, but the resistance remained normal.

Discussion

When measuring the nasal resistance with the oscillation method, one can usually neglect the reactances of the nose because the structures responsible for inductance and capacitance are also small: the passage is short and there is little expandable membranous structure. As a result, the nasal passages are anatomically close to the ideal model of an aperture. Since impedance is defined as the vector sum of the reactances and the effective resistance, when both reactances balance each other or are negligible in value, the effective resistance alone is measured. An aperture has imperceptible reactances. Thus it is understandable that measurement of our anatomical aperture, namely the nose, resulted in only minimal reactances.

The smaller the face mask, the smaller the capacitance and the higher the effective resistance. This implies that a large mask acts as an expandable structure with large volume and thereby causes a greater capacitance. To obtain the mean values of the two groups, only the small mask was used.

To obtain the actual nasal resistance one would have to subtract the oscillatory airway resistance measured via mouthpiece from the total resistance measured via mask; the latter is composed of the airway resistance plus nasal resistance. The advantage of nasal provocation is that the nasal mucosa alone is affected without any adverse effects on the remaining respiratory system. Thus the airway resistance remains unchanged, which was verified by the oscillatory airway resistance remaining stable throughout our testing. For our purposes of provocation it is not necessary to determine the actual nasal resistance.

The positive reactions without increased resistance elicited amongst the control group show that the subjective reactions of sneezing, itching of eyes and nose, and increased nasal secretion are insufficient criteria for the evaluation of a nasal provocation test.

Upon completion of our studies, we were suprised at the PAR results, for this instrument is a known method of measuring nasal resistance (Van Dishoeck, 1973). Several questions arise. Why did the initial PAR values of the control group differ from the pollinosis group, whereas the Siregnost measurements of the same subjects, only a few minutes prior, did not show any significant differences? Indeed, one would not expect a difference in nasal resistance between control and pollinosis subjects, when they are asymptomatic and measured out of the pollen season.

To exclude an irritation effect of the swabs on the nasal mucosa, we measured resistance prior to insertion of the swabs, after the neutral solution, and only then did

we proceed with pollen concentrations. Should the irritation effect have been significant, one would expect a rise in the control group's nasal resistance for measurements taken with both instruments, yet once again only the PAR readings gave this increase.

Although both methods measure the change in pressure produced by an external airflow introduced into the nose, the oscillating flow of 0.84 l/min is hardly perceptible whereas that of the PAR uses a much stronger flow of 15 l/min. Thus the latter could produce alterations in the tone of soft palate and epipharynx (Bachmann, 1972) and with repeated measurements of each nostril the sensitivity to the superimposed strong flow would gradually increase. This could explain the increased PAR resistance at the end of provocation of the control subjects. One question remains: if this increase in tone does occur, why do the oscillatory resistances of the same subjects, measured shortly before the PAR reading, not show this gradual increase in resistance?

Perhaps the PAR method is more sensitive in reflecting the real changes in the nasal airways; yet if this is so, the sensitivity is such that the nasal resistance of the control subjects rises significantly during provocation. Thus all cases provoked and measured with PAR would be positive—not an efficient diagnostic method when the aim is to clarify those cases where history, skin test, and possibly RAST do not fit together in a clear presentation of allergy.

We did statistical analysis to compare results of two different methods. The PAR method, however, uses an empirical scale to determine positive reactions; for example, initial values of 20–40 mm H₂O must increase to a minimum of 60 mm H₂O before the provocation is declared positive (Van Dishoeck, 1973). Therefore, they would not consider the control group's increase from 21 mm H₂O (0 value) to 28 mm H₂O (10^{-1} value) as being a positive reaction.

Our investigations show that the oscillation method can be used not only to measure nasal resistance at any one point in time, but that the method lends itself to the recording of change in resistance during nasal provocation. In comparison with passive anterior rhinomanometry, it appears to be superior. The oscillation method is a simple and effective way of measuring nasal resistance and is especially suitable for use with young children.

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