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Comparison of calculated nasal resistance from Röhrer's equation with measured resistance at ΔP150Pa*

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SUMMARY *Values of nasal resistance at ΔP150Pa have been recommended by the International Standardization Committee for clinical use. However, this point seems somewhat high for quiet nasal breathing. To determine the usefulness of calculated nasal resistance at ΔP150Pa from Röhrer's equation when transnasal pressure fails to reach the point, the values at ΔPl50Pa calculated from the method have been compared with actually measured nasal resistances at ΔPl50Pa by active anterior rhinomanometry with a nasal nozzle. The mean value of measured unilateral nasal resistance in 75 patients is 0.513±0.511 Pa/cm^3/s on expiration and 0.335±0.193Pa/cm^3/s on inspiration. The mean value of calculated nasal resistance from Röhrer's equation is 0.511±0.515Pa/cm^3/s on expiration and 0.337±0.207Pa/cm^3/s on inspiration. Correlations between measured and calculated nasal resistances have been assessed and are almost identical in both expiration and inspiration. Calculated nasal resistance at ΔP150Pa from Röhrer's equation seems to be suitable for evaluation when transnasal pressure fails to attain the point.*

Key words: nasal patency, nasal resistance, rhinomanometry, differential nasal pressure

INTRODUCTION

Rhinomanometry is a well-established method for objective evaluation of nasal patency. In recent years pneumotachographic systems have been used to determine nasal airflow ($\dot{V}$), which is measured simultaneously with transnasal differential pressure (ΔP). Nasal patency is represented as a ratio between nasal airflow and transnasal differential pressure as shown by the equation:

R (resistance) = $\Delta P / \dot{V}$ [*Equation 1*]

This equation indicates the relationship between differential pressure and flow under laminar flow conditions. However, even during quiet nasal breathing, the flow regimen is non-laminar, and the anomalous relationship between empirical measurement and Equation 1 is unresolved.

In an attempt to solve the problems associated with the inconsistency in calculating nasal resistance, several methods of expression of nasal patency were reported all over the world (Ingelstedt et al., 1969; Postema et al., 1980; Eichler and Lenz, 1985; Ohki and Hasegawa, 1986). Consequently, an internation-

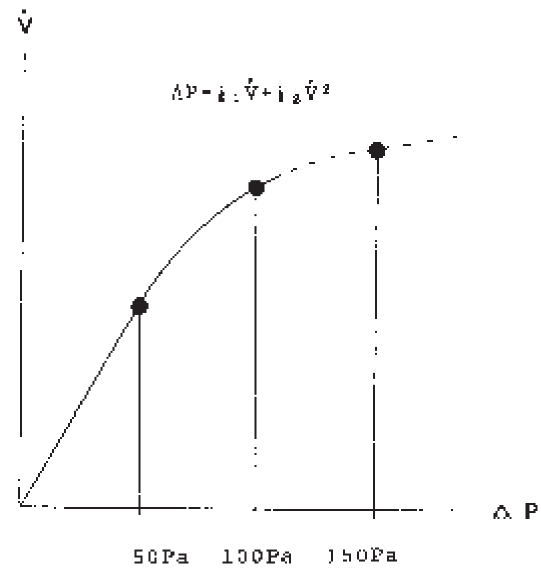

Figure 1. The pressure/flow curve can be expressed as an equation proposed by Röhrer ($\Delta P = k_1\dot{V} + k_2\dot{V}^2$). When coefficients k_1 and k_2 of the equation are obtained from the pressure/flow curve, we can estimate nasal resistance at any point whether the curve attains the predetermined point or not, for instance 50 Pa, 100 Pa and 150 Pa.

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al committee was established to recommend standardized methods of measurement and expression of rhinomanometric results (Kern, 1977, 1981; Clement, 1984). Although the Committee recommended employment of nasal resistance at ΔP150Pa for evaluation, transnasal differential pressure fails to reach the level of even ΔP150Pa in 24% of adult Caucasians (Naito et al., 1989a); therefore, attainment of ΔP150Pa seems high in resting nasal breathing.

The pressure/flow curve can be expressed by means of the equation proposed by Röhrer (1915):

$$\Delta P = k_1\dot{V} + k_2\dot{V}^2 \text{ [\textit{Equation 2}]}$$

Where k_1 is the coefficient of laminar flow and k_2 is the coefficient of turbulent flow. When k_1 and k_2 are estimated, nasal resistance at ΔP150Pa can be calculated, although the differential pressure may fail to reach ΔP150Pa as shown in Figure 1. To determine the usefulness of the calculated nasal resistance from Röhrer's equation we have compared the nasal resistances at ΔP150Pa actually measured and calculated from Equation 2.

MATERIAL AND METHODS

Seventy-five consecutive patients with nasal disease visiting our institution (aged 16-78 years; mean: 46.2 years; 59 men and 16 women) were assessed in this study.

Unilateral nasal resistances were measured by active anterior rhinomanometry with a nasal nozzle using the Rhinorheograph MPR-2100 (manufactured by Nihon Kohden, Tokyo, Japan) during quiet breathing through the nose. Only values of nasal resistance that reached the point of ΔP150Pa either on expiration or inspiration were employed. Coefficient values of k_1 and k_2 from the pressure/flow curve were processed by computer (programme NI-101 written by Naito et al. [1993]) connected with the Rhinorheograph. Values of airflow were arithmetically calculated from Equation 2, when k_1, k_2 and ΔPa (equalling 150 Pa in this study) of Equation 2 were determined. Then, the calculated nasal resistance at ΔP150Pa from Equation 1 was obtained from the estimated value of airflow and compared with the actually measured resistance at the same point.

Coefficients of correlation between measured and calculated nasal resistances at ΔP150Pa were assessed and unpaired t-test of the correlation lines were evaluated for statistical analysis.

RESULTS

In 75 Japanese patients, 100 out of 150 (66.7%) measurements of unilateral nasal resistances reached the level of ΔP150Pa on expiration and 115 measurements (76.7%) on inspiration. The mean value of k_1 was 3.04±3.98 and k_2 was 3.83±2.99 on expiration, and k_1 was 1.84±4.76 and k_2 was 3.70±2.28 on inspiration, respectively.

The mean value of the measured unilateral nasal resistance was 0.513±0.511 Pa/cm^3/s on expiration and 0.335±0.193 Pa/cm^3/s on inspiration. The mean value of the calculated nasal resistance from Equation 2 was 0.511±0.515 Pa/cm^3/s on expiration and 0.337±0.207 Pa/cm^3/s on inspiration.

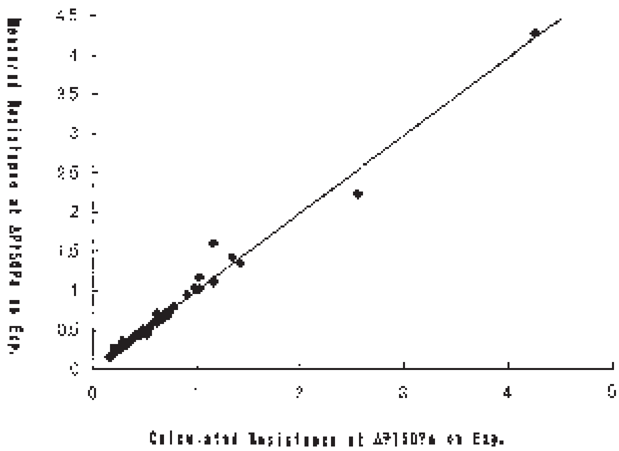

Figure 2. Relationship between calculated nasal resistance at ΔP150Pa and measured resistance at the same point on expiration, and the correlation line (y = 0.99x + 0.01; r=0.993; p<0.0001).

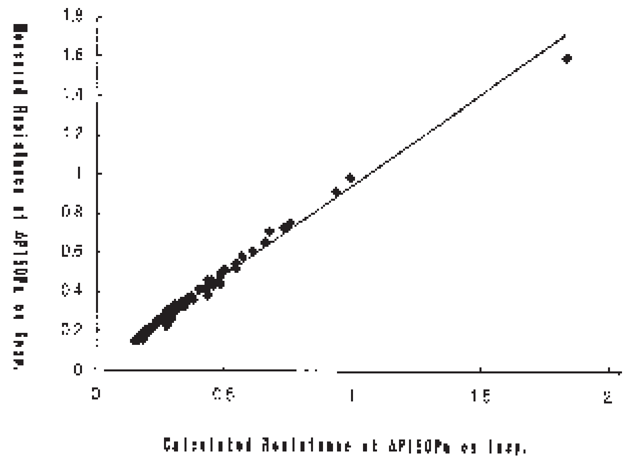

Figure 3. Relationship between calculated nasal resistance at ΔP150Pa and measured resistance at the same point on inspiration, and the correlation line (y = 0.93x + 0.02; r=0.994; p<0.0001).

Correlation between calculated nasal resistance at ΔP150Pa and measured resistance at the same point on expiration was demonstrated as (Figure 2; r=0.993, p<0.0001):

$$mR = 0.99cR + 0.01 \text{ [\textit{Equation 3}]}$$

On inspiration as (Figure 3; r=0.994, p<0.0001):

$$mR = 0.93cR + 0.02 \text{ [\textit{Equation 4}]}$$

where *mR* is measured resistance and *cR* is calculated from Equation 2. Calculated and measured nasal resistances at ΔP150Pa were almost identical in both expiration and inspiration.

DISCUSSION

Rhinomanometry – which provides an objective assessment of nasal patency – is well established, but there still remain problems. We have attempted to solve the problems concerning equipment (Naito et al., 1991), measurement methods (Naito et al., 1990), expressions of patency (Naito et al., 1995), relationships between objective assessment and subjective perception of nasal obstruction (Naito et al., 1988, 1989b) and racial differences (Ohki et al., 1991). In general, pneumotachographic systems have been widely used to obtain nasal airflow and differential pressure of quiet nasal breathing simultaneously. Alternating airflow through the nose is considered to be non-laminar (Butler, 1960; Eichler and Lenz, 1985; Naito et al., 1989c) even under resting condition, while nasal resistance – commonly calculated from Equation 1 – applies to laminar flow. This anomaly between empirical measurement and this equation remains subject to discussion, despite the efforts of many researchers.

Some investigators (Solomon et al., 1985; Ingelstedt et al., 1969) have measured nasal resistance at a flow point of 0.5 l/s (500 cm^3/s), but many subjects with obstructions do not attain this flow level. Other groups (Postema et al., 1980; Connell, 1982) have measured resistance at $\Delta P1.5cmH_20$ (150Pa). Some researchers regard this point as too high for evaluation. Ohki and Hasegawa (1986) have found ΔP100Pa more suitable for the Japanese adult population.

In an attempt to avoid problems associated with predetermined pressure and/or airflow coordinates, we measured nasal resistance from Equation 1 at peak flow during resting nasal breathing (Naito et al., 1989). Cole et al. (1986) computed nasal resistance from averaged consecutive 50-Hz pressure and flow values (time-averaged method). We found that the time-averaged (30-Hz) value of resistance almost completely coincided with the value from Equation 1 at peak flow, and values of nasal resistance at ΔP150Pa were smaller than those obtained from the former (superior) methods (Naito et al., 1993). Resistance values at ΔP75Pa must be much smaller than those calculated from the former methods.

Alternatively, Naitoh and Unno (1988) estimated the area under the pressure/flow curve (integrated nasal patency) and Broms et al. (1982) measured angles at which the curves crossed circles at predetermined radii. This variety of methods and equations complicated investigations and troubled users of rhinomanometry. Thus, an international committee was established to recommend standardized methods of measurement and expression of rhinomanometric results (Kern, 1977, 1981; Clement 1984). The Committee recommended employment of nasal resistance at ΔP150Pa (Clement, 1984).

However, transnasal pressure fails to attain the level of ΔP150Pa in 24% of adult Caucasians (Naito et al., 1989) and also in Japanese (Naito et al., 1993). Bilateral transnasal pressures reach ΔP150Pa in only half of normal Caucasian subjects examined during spontaneous resting nasal breathing (Cole and Havas, 1986). In the present study of Japanese subjects, 33.3% on expiration and 25.3% on inspiration failed to reach the point. However, international comparison and discussion of rhinomanometric data actually require nasal resistance at ΔP150Pa, irrespective of it being considered right or wrong at present. How do we obtain nasal resistance at ΔP150Pa as recommended by the Standardization Committee when differential pressures fail to reach the point? Hyperventilation is required in many Japanese and Caucasian subjects to obtain nasal resistance at ΔP150Pa (Naito et al., 1989, 1993), but this is neither quiet nasal breathing nor physiologically normal. On the other hand, the pressure/flow curve can be demonstrated by Röhrer's equation (Equation 2), and nasal resistance at any point on the pressure/flow curve can be estimated when the equation is employed. In this paper we have compared calculated nasal resistances at ΔP150Pa from Equation 2 with the actually measured values at the same point to determine the usefulness. Calculated values of nasal resistance were almost identical with measured resistances on both expiration and inspiration. According to the results of this study, we consider the calculated nasal resistances at ΔP150Pa from Equation 2 to be comparable to the actual measurements of resistance, and worth employing for clinical evaluation in situations when transnasal pressures fail to reach ΔP150Pa. Furthermore, once coefficients k_1 and k_2 of Röhrer's equation are obtained from the pressure/flow curve, we can estimate nasal resistance at any predetermined points, whether the curve attains the point or not, for instance ΔP50Pa, ΔP75Pa, ΔP100Pa and ΔP150Pa. We believe that our proposal will end the discussion concerning the question which point on the pressure/flow curve is most suitable to evaluate.

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