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Computer averaged nasal resistance

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SUMMARY

Nasal resistances were measured before and after decongestion of the nasal mucosa by posterior rhinomanometry with a head-out body plethysmograph in 95 adults referred to our nasal airflow laboratory. These resistances were calculated by a time averaging method (1), the equation $R=\Delta P/\dot{V}$ *at* ΔP *1.0 cm* H_2O *(2) and* $R=\Delta P/\dot{V}$ *at the point of peak flow (3), and the results were compared.*

Correspondence between resistances from the time averaging method and those from the equation $R=\Delta P/\dot{V}$ *at* $\Delta 1.0$ *cm* H_2O*, the equation* $R=\Delta P/0.83\dot{V}^{1.33}$ *was obtained with statistical significance (*$P<0.001$*) and it is suggested that the value of resistance from the time averaging method represents transitional airflow.*

At resistances <3.5 *cm* $H_2O/L/sec$*, the time averaging method and the equation* $R=\Delta P/\dot{V}$ *at* $\Delta 1.0$ *cm* H_2O *and at peak flow produced almost identical values. At resistances* >3.5 *cm* $H_2O/L/sec$*, the time averaging method produced values equivalent to those from the equation* $R=\Delta P/\dot{V}$ *at peak flow but values from the equation* $R=\Delta P/\dot{V}$ *at* ΔP *1.0 cm* H_2O *different from the former two methods.*

The results suggest that nasal resistances from the time averaging method and the equation $R=\Delta P/\dot{V}$ *at the point of peak flow are appropriate expression of nasal patency.*

INTRODUCTION

Rhinomanometry is widely employed for assessment of nasal patency, but there are several different methods and means of expression which complicate comparison of results of individual investigators. In recent years, most workers in this field have employed pneumotachographic systems to determine nasal airflow ($\dot{V}$) which they measure simultaneously with transnasal differential pressure (ΔP). Nasal patency is expressed in terms of nasal resistance (R) or conductance (C) and is represented a ratio between transnasal differential pressure and airflow:

$$R = \Delta P / \dot{V} \quad (1)$$

$$C = \dot{V} / \Delta P \quad (2)$$

These equations describe the relationship between differential pressure and flow under laminar flow conditions. However, non-laminar conditions prevail during much of the quiet nasal breathing cycle (Butler, 1960) and the disagreement between empirical measurement and these equations is unresolved.
Fisher (1960) suggested that the equation describing nasal resistance under turbulent flow could be:

$$R = \Delta P / \dot{V}^{n} \quad (3)$$

(n: coefficient of non-laminar flow)

and he found the mean value of the coefficient n be 1.85. Dallimore and Eccles (1977) and Eichler and Lenz (1985) recommended using $n=2$ to represent the coefficient of turbulent flow. Cole et al. (1980) computed nasal resistances from averaged consective 50 Hz pressure and flow values to obtain a representative value for resistance (time averaging method).
In this communication we have compared nasal resistances from the time averaging method with values from other common methods of calculation e.g. resistance values from equation (1) and equation (3) at ΔP 1.0 cm H_2O (=100 Pa) and at the point of peak flow.

MATERIALS AND METHODS

Subjects

The nasal resistances of 95 adults (aged 17–63 with a mean age of 33 years, 64 males and 31 females) referred to our nasal airflow laboratory for assessment of nasal obstruction were tested by posterior rhinomanometry before and after decongestion (0.1% xylometazoline hydrochloride nasal spray) of the nasal mucosa.

Nasal resistance

Respiratory airflow was detected by a head-out displacement type plethysmograph (Niinimaa et al., 1979). Transnasal differential pressure was obtained through a fine tube (8F infant feeding tube) inserted along the floor of one nasal cavity to the nasopharynx. Pressure and airflow signals were sensed by reluctance transducers (Validyne MP45 and DP103) and their electrical analogues were digitized at 50 Hz by the A/D converter of a programmed IBN/PC microcomputer. Consecutive digitized values were stored in the computer memory and several respiratory variables, which included time averaged resistance, were computed on completion of chosen sequences of breaths.
In addition, nasal resistances at ΔP 1.0 cm H_2O (=100 Pa) and at peak flow were obtained from the pressure/flow curve on the screen of an *X-Y* storage oscilloscope by direct measurement.

Resistances were compared as follows:

1. Resistance from the time averaging method;
2. Inspiratory resistance from equation (1) [$R=\Delta P/\dot{V}$] at ΔP 1.0 cm H_2O ($\fallingdotseq$100 Pa);
3. Inspiratory resistance from equation (1) at the point of peak flow;
4. Inspiratory resistance from equation (3) [$R=\Delta P/\dot{V}^2$] at Δ1.0 cm H_2O ($\fallingdotseq$100 Pa).

RESULTS

In 69 (24%) of 286 measurements in 95 subjects, transnasal pressure failed to reach the level of Δ1.0 cm H_2O ($\fallingdotseq$100 Pa) during spontaneous resting nasal breathing. In subjects breathing through the combined nostrils after decongestion of the mucosa the failure rate was higher (31%).

Plots of 96 measurements showed the regression of resistance values from equation (1) [$R=\Delta P/\dot{V}$] at the point of peak flow on those from the time averaging method to be very close to the line of identity (Figure 1), i.e. resistances derived from each method had similar values. Comparisons between nasal resistances from equation (1) at ΔP 1.0 cm H_2O ($\fallingdotseq$100 Pa) and the former two methods are demonstrated in Figure 2 and Figure 3 respectively. At resistance values below 3.5 cm H_2O/L/sec (which is greater than that of a healthy nose (2.0$\pm$0.5 cm H_2O/L/sec) during quiet nasal breathing), all three methods gave almost identical values, thus it seems unimportant which of the methods is

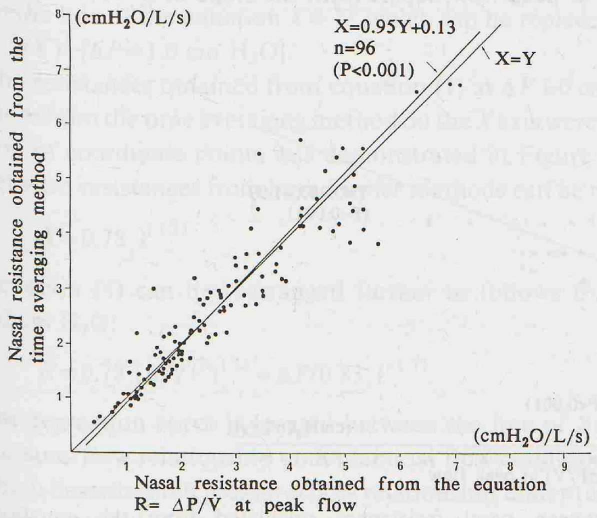

Figure 1. Relationship between nasal resistances calculated from the time averaging method and from the equation $R=\Delta P/V\AE$ at the peak flow point, and the correlation line ($X=0.95\ Y+0.13$).

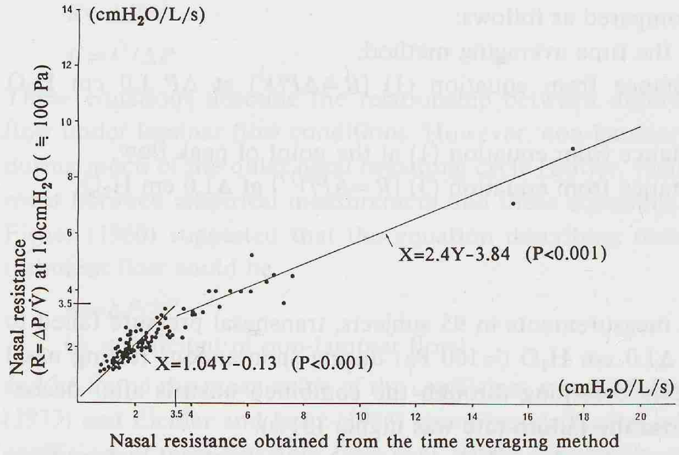

Figure 2. Relationship between nasal resistances calculated from the time averaging method and from the equation $R=\Delta P/V$Æ at ΔP 1.0 cm H_2O (≒100 Pa), and the correlation lines ($Y=0.96\ X+0.13$, $X\leqq 3.5$ cm H_2O/L/sec, $Y\leqq 3.5$ cm H_2O/L/sec and $Y=0.41\ X+1.58$, $X>3.5$ cm H_2O/L/sec, $Y>3.5$ cm H_2O/L/sec).

employed at resistances below 3.5 cm H_2O/L/sec. At resistances > 3.5 cm H_2O/L/sec, although results from the time averaging method agree with those from equation (1) at the point of peak flow, the regression of resistance values from equation (1) at Δ1.0 cm H_2O on those from the time averaging method and equation (1) at the point of peak flow depart from the slope of $X=Y$.

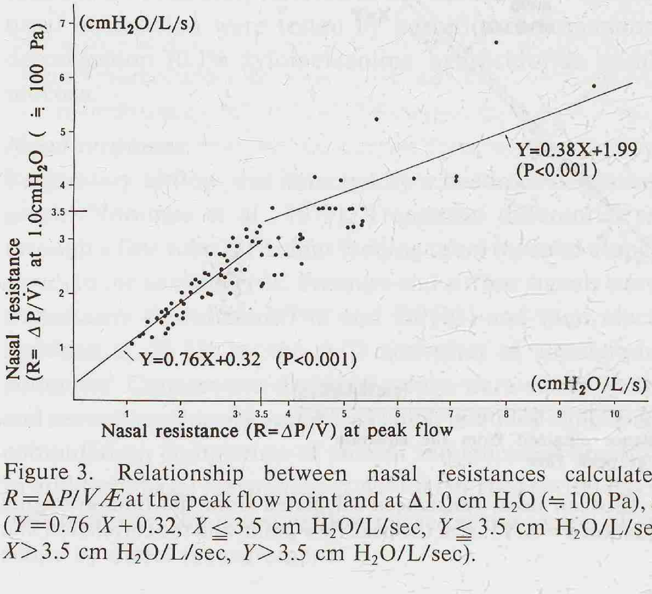

Figure 3. Relationship between nasal resistances calculated from the equation $R=\Delta P/V$Æ at the peak flow point and at Δ1.0 cm H_2O (≒100 Pa), and the correlation lines ($Y=0.76\ X+0.32$, $X\leqq 3.5$ cm H_2O/L/sec, $Y\leqq 3.5$ cm H_2O/L/sec and $Y=0.38\ X+1.99$, $X>3.5$ cm H_2O/L/sec, $Y>3.5$ cm H_2O/L/sec).

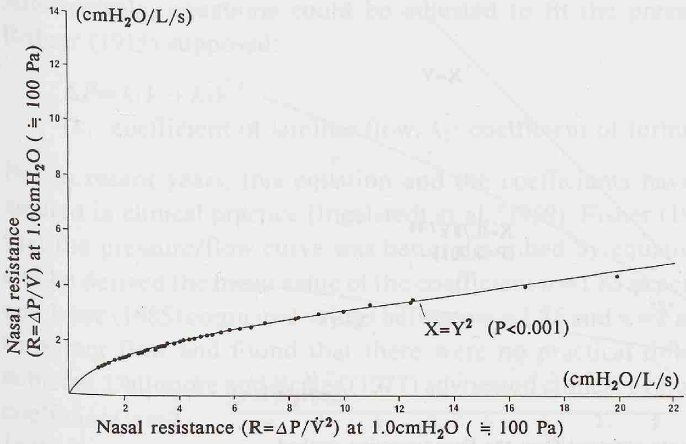

Figure 4. Relationship between nasal resistances calculated from the equation $R=\Delta P/ V$Æ at ΔP 1.0 cm H_2O (≒100 Pa) and from the equation $P=\Delta P/ V$Æ^2 at ΔP 1.0 cm H_2O, and the regression curve ($X=Y^2$).

As shown in Figure 4, nasal resistances calculated from equation (1) (which describes the pressure/flow relationship under laminar flow conditions at ΔP 1.0 cm H_2O) are plotted on the Y axis and resistances from equation (3) (which describs the pressure/flow relationship under turbulent flow conditions at ΔP 1.0 cm H_2O) are plotted on X axis respectively. These data points lay exactly on the line of the equation $X=Y^2$ which can be replaced the equation $1.0/\dot{V}^2=(1.0/\dot{V})^2$ [$\Delta P=1.0$ cm H_2O].

The resistances obtained from equation (1) at ΔP 1.0 cm H_2O on the Y axis and those from the time averaging method on the X axis were plotted and the distribution of coordinate points was demonstrated in Figure 5. The regression curve between resistances from both former methods can be represented by equation:

$$X=0.78\ Y^{1.33} \qquad (4)$$

Equation (4) can be rearranged further as follows if ΔP of Y is assumed as 1.0 cm H_2O:

$$R=0.78\ (\Delta P/\dot{V})^{1.33}=\Delta P/0.83\ \dot{V}^{1.33} \qquad (5)$$

The regression curve is located between the line of $X=Y$ which describes the pressure/flow relationship under laminar flow conditions and the line of $X=Y^2$ which describes the pressure/flow relationship under turbulent flow conditions. It appears therefore that nasal resistance obtained from the time averaging method has a value equivalent to that calculated by using a coefficient for transitional airflow.

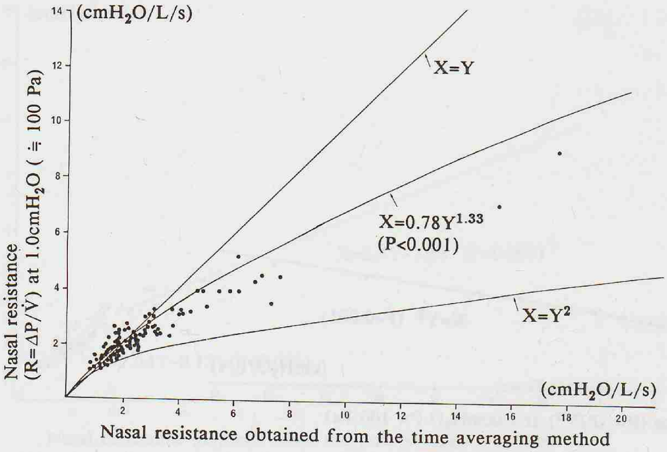

Figure 5. Relationship between nasal resistances calculated from the time averaging method and from the equation $R=\Delta P/ V$Æ at ΔP 1.0 cm H_2O (≒100 Pa), and the regression curve ($X=0.78\ Y^{1.33}$).

DISCUSSION

Many authors agree that laminar flow conditions are unlikely to prevail in the nasal conduits throughout even resting breaths (Butler, 1960; Eichler and Lenz, 1985) but nasal resistance is usually calculated from equation (1), even though this equation represents the pressure/flow relationship under laminar flow conditions. Discrepancy between empirical measurement and the equation is unresolved.

Solomon et al. (1965) and Ingelstedt et al. (1969) measured nasal resistance at a transnasal flow of 0.5 l/sec but many obstructed subjects do not attain this flow level. Postema et al. (1980), Connell (1982) and Eichler and Lenz (1985) measured resistance at a transnasal pressure of 1.5 cm H_2O (≒150 Pa) but Ohki and Hasegawa (1986) found ΔP 1.0 cm H_2O (≒100 Pa) more suitable for a Japanese population. According to Cole and Havas (1986) transnasal pressures reach 1.5 cm H_2O (≒150 Pa) in only a half of normal subjects during spontaneous resting breaths. Even in occidental subjects, 24% of 285 measurements did not reach the point of ΔP 1.0 cm H_2O in our present study. In order to obtain nasal resistances by these methods voluntary hyperventilation is required in many cases.

In attempts to avoid problems associated with predetermined pressure and/or flow coordinates, Naito et al. (1985) made measurement of nasal resistance at peak flow during resting nasal breathing, Cole et al. (1980) computed nasal resistance from averaged consecutive 50 Hz pressure and flow values (time averaging method), and Broms et al. (1982) measured angles at which the curves crossed circles at appropriately fixed radii.

Alternatively, equations could be adjusted to fit the pressure/flow curve as Röhrer (1915) supposed:

$$\Delta P = k_1 \dot{V} + k_2 \dot{V}^2 \quad (6)$$

(k_1: coefficient of laminar flow, k_2: coefficient of turbulent flow)

But in recent years, this equation and the coefficients have not been widely applied in clinical practice (Ingelstedt et al., 1969). Fisher (1969) demonstrated that the pressure/flow curve was better described by equation (3) [$R = \Delta P / \dot{V}^n$] and he derived the mean value of the coefficient $n = 1.85$ experimentally. Eichler and Lenz (1985) compared values between $n = 1.85$ and $n = 2$ as representative of turbulent flow and found that there were no practical differences in human subjects. Dallimore and Eccles (1977) advocated clinical evaluation by use of the coefficient $n = 2$.

In this presentation we have compared nasal resistances from the time averaging method with values from other common methods of calculation (e.g. equation (1) [$R = \Delta P / \dot{V}$] at ΔP 1.0 cm H_2O and at the point of peak flow and equation (3) [$R = \Delta P / \dot{V}^2$] at ΔP 1.0 cm H_2O. Those observations have shown agreement between resistances from the time averaging method and resistances from equation (1) at ΔP 1.0 cm H_2O, and the equation $R = 0.83\ \Delta P / \dot{V}^{1.33}$ to achieve high statistical significance. Nasal resistance from the time averaging method and is an average of measurements at 50 Hz during quiet nasal breathing and is an equable complex constructed from all airflow characteristics i.e. laminar, transitional and turbulent. It is suggested that resistance from the method represents transitional airflow. Richerson and Seebohm (1968) claimed that the coefficient n was 1.5 for the human nose and they thought the characteristics of airflow through the nose were transitional.

At resistances < 3.5 cm H_2O/L/sec, the three methods, time averaging, equation (1) at ΔP 1.0 cm H_2O and at the point of peak flow producted almost identical values. Thus it may be unimportant which of these resistance methods are employed for nasal resistances within the normal range or those which exceed it moderately. Furthermore, results from the time averaging method agree with those from equation (1) at the point of peak flow at resistances > 3.5 cm H_2O/L/sec. However resistances from equation (1) at 1.0 cm H_2O differed from values obtained by the former two methods of calculation. Equation (1) represents a linear pressure/flow relationship under laminar flow conditions but the empirical pressure/flow curve reveals different values since most airflow through the nose is transitional and/or turbulent. At all levels resistances from equation (1) at peak flow showed good agreement with those from the time averaging method, which might be explained by the fact that throughout much of each phase in quiet nasal breathing near peak flow prevails. In addition, neither method, the time averaging method or equation (1) at the point of peak flow requires the pressure/flow curve to pass through pre-determined points of either pressure or flow. It was felt these advantages make both methods useful and convenient.

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