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Nasal resistance measured by anterior rhinomanometry

Tokuji Unno, Yoshihiro Naitoh, Nobuo Sakamoto and Hiroshi Horikawa, Asahikawa, Japan

SUMMARY

The technique and principle of the active anterior rhinomanometry were justified by human examination and model experiment. The resistance values obtained from anterior method did not always agree with those from posterior one. Causes of the disagreement were considered to be distortion of the nostrils, air leakage from the apparatus and resistive component in the nasopharynx. These possibilities were demonstrated and analyzed in model experiments. The anterior rhinomanometry was concluded as a precise and convenient method to assess the conductivity of the nasal cavities.

INTRODUCTION

The active anterior rhinomanometry is now considered to be the most common and physiological technique because of its easy and harmless application to subjects tested. Almost no trouble is encountered in the measurement. But it measures the patency of one side of the nose at a time. Bilateral patency remains relatively constant in spite of unilateral fluctuation due to the nasal cycle. So the bilateral value is more suitable to assess the nasal condition of a subject. In anterior rhinomanometry the bilateral value is usually calculated by the same formula as the electrical resistance connected in parallel. The purpose of this paper is to justify the technique of the anterior rhinomanometry and to find out probable causes of discrepancies between anterior and posterior ones.

METHOD

25 female and 25 male subjects with only slight or no nasal obstruction were examined by anterior and posterior rhinomanometry. In anterior rhinomanometry, the pressure in the nasopharynx was conducted through a tube connected to a nostril by a nozzle. Pressure difference across the nasal cavities was thus recorded on the abscissa of an X-Y recorder. A Lilly type pneumotachograph applied to

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the other nostril by another nozzle ordinarily recorded flow changes on the ordinate of the recorder. In posterior rhinomanometry, the pressure in the pharynx was conducted through a disposable 2 ml syringe which was connected to a tube and held in the mouth. A mask for anesthesia connected to the pneumotachograph was pushed against the face around the nose with pressure conducting tube kept in place. Cautions were paid to prevent any distortions of the external nose and kinking of the tube. Comparisons of the values by two different methods were made at the pressure point of 50 Pascals (Pa) in expiration and that of – 50 Pa in inspiration because all subjects exceeded these points in both unilateral and bilateral nasal breathings without efforts. Calculation of the total resistance in anterior rhinomanometry was made by an equation

$$\frac{1}{R_n} = \frac{1}{R_r} + \frac{1}{R_l}$$

in which R_n meant the resistance of both nasal cavities, R_r that of right cavity and R_l that of left cavity.

Experimental models consisted of straight and Y-shaped metal pipes with side arms for pressure conduction. These pipes were connected and sealed by adhe-

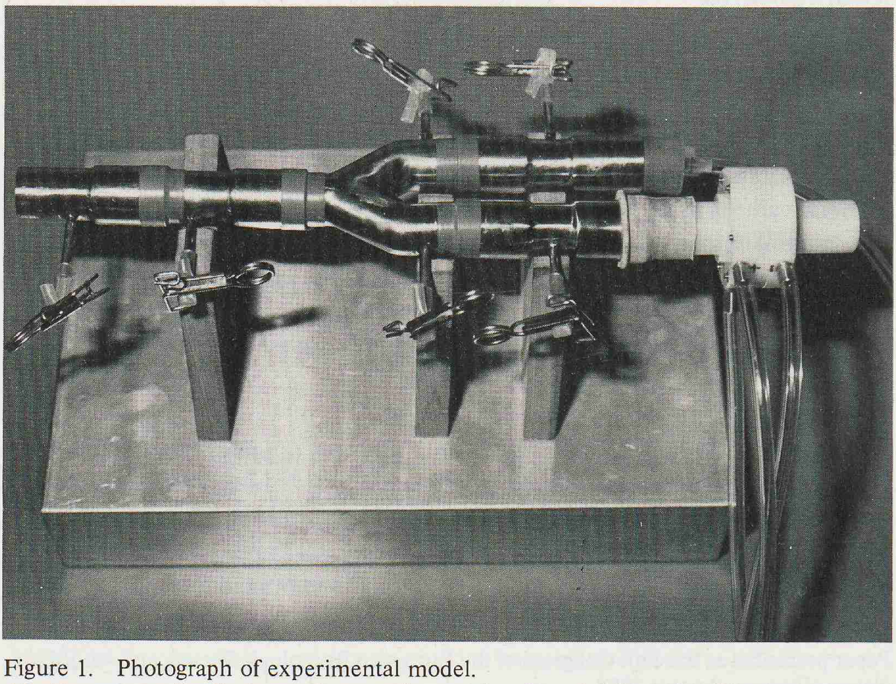

Figure 1. Photograph of experimental model.
All side arms are firmly clamped except the positions D and G (anterior rhinomanometry).

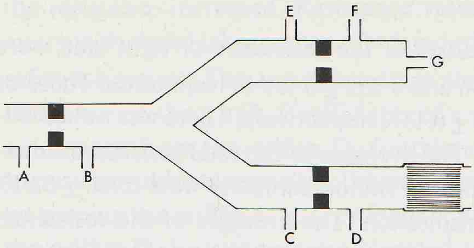

Figure 2.
Diagram of experimental setup for anterior rhinomanometry.

sive tape. The form of the connection was changed according to the method of measurement (Figure 1). A plastic disc with a hole at the center was firmly held at the predetermined position in the pipes. Size of the hole ranged from 3.5 to 10 mm in diameter. The orifices of the arms unnecessary to conduct the pressure were tightly clamped and only orifices suitable for the measurement were connected to the conducting tubes. The plastic discs were inserted in the parallel pipes between C and D and between E and F of the model to test various combinations of the resistance. Anterior rhinomanometry measures the pressure difference conducted from the orifices D and G (Figure 2). Posterior rhinomanometry measures that from the orifices B and G of the same model except an additional Y-shaped pipe connected (Figure 3). Ventilation through this series of pipes was made by a Harvard pump at various speeds with a tidal volume of 700 cm^3. Pressure and flow signals were led to a data recorder for computer analyses. Recorded data were digitalized at every 20 msec by an A–D converter and the resistance from each sample was then calculated by dividing pressure by instantaneous flow. Transitional parts from inspiration to expiration and vice versa were excluded to minimize the error due to the time lags of the transducers. Average resistance of an expiratory and inspiratory phase was calculated from the residual parts of the curves. The pressure and flow signals were also recorded on an X–Y recorder for manual calculation.

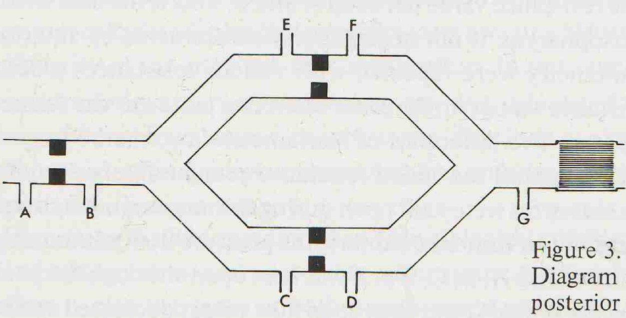

Figure 3.
Diagram of experimental setup for posterior rhinomanometry.

RESULTS

In the subjects tested, the mean values of the resistance of right side were 0.375 ± 0.171 Pa/cm^3/sec in expiration and 0.352 ± 0.159 in inspiration. Those of left side were 0.314 ± 0.136 and 0.304 ± 0.137, respectively. There was no statistical significance among these values. The averages of the total resistance calculated from the unilateral values by anterior rhinomanometry were 0.160 ± 0.053 in expiration and 0.157 ± 0.055 in inspiration. The averages of the resistance measured by posterior rhinomanometry were 0.143 ± 0.041 and 0.153 ± 0.048, respectively. The regression line between the two values was expressed by an equation $y = 0.75x + 0.034$ for expiration with a correlation coefficient (r) of 0.829 ($p < 0.01$) and $y = 0.71x + 0.036$ for inspiration with that of 0.794 ($p < 0.01$).

The results of the model experiment were as follows. Firstly, computerized mean values were used for the comparison. Calculated values by anterior rhinomanometry were approximately twice as high as the values by posterior rhinomanometry although both values were well correlated ($r = 0.99$ in both expiration and inspiration). Next, resistance values at the same pressure point were compared. Reference points were 50, 100, 150, 200, 250 and 300 Pa. The number of refered resistance varied from 11 to 28, but the values by two methods were almost equal with very high correlation coefficients ranged from 0.991 to 0.999.

Additional experiments were performed to clarify how the values measured by anterior and posterior rhinomanometry became different as observed in the subjects tested. In anterior rhinomanometry, pressure difference between G and B, C, E or F was almost zero because no flow existed among them during the measurement (Figure 2). Exchange of the pneumotachograph and pressure conducting orifices for each other pipe enabled to measure the resistance of the other side. Then the total resistance was calculated. In posterior rhinomanometry, pressure difference between B and C or E, and that between D and F of G were almost zero because no resistive components existed between them (Figure 3). The total resistance between B and G by posterior rhinomanometry was about the same as the calculated resistance by anterior rhinomanometry. The resistance between A and G by posterior rhinomanometry, however, became larger than the calculated one to the amount of the resistance value between A and B. This is the case when the resistance in the nasopharynx is not neglegible. Measurements by anterior and posterior rhinomanometry were repeated with various resistances placed between A and B. Resistance values at the same reference points as the former experiment were compared. The difference of resistance by two methods were exactly the same as the amount of the added resistance at any reference points. Next, the orifices of the side arms were kept open during the measurement to test the effects of leakage. In anterior rhinomanometry, the pressure flow relationship was not affected when the orifice A, B, C, E or F was kept open although the peak flow was reduced. When the orifice D was kept open flow values decreased and so the resistance increased. Resistance values measured by anterior rhinomanometry with such leakage were compared with those by posterior one at the same reference points. The regression lines slowly sloped because of the increased resistance on the x axis. Coefficients of x varied according to the amount of the air leakage from the orifice D. Correlation coefficients were extremely high. In posterior rhinomanometry, the pressure flow relationship was not so affected by keeping the orifice A, B, C or E open. But similar effects were observed when the orifice D, F or G was not clamped because of the reduced flow into the pneumotachograph.

DISCUSSION

As mentioned at the first part of this paper, the active anterior rhinomanometry measures only one side of the nose at a time. Unilateral resistance usually changes its value according to the nasal cycle. So the nasal conductivity of a subject is better estimated by the total resistance although the unilateral resistance itself has a meaning in its own value. Some investigators have the opinion that the recording measured by anterior rhinomanometry is a different entity from that by posterior rhinomanometry and that calculation of the total resistance from the former is not appropriate (Kortekangas, 1972; Solow et al., 1980; Berdel et al., 1983). Others use the unilateral resistance as the basis for calculation of the total resistance (McCaffrey et al., 1979; Clement et al., 1983; Jalowayski et al, 1983). The reference point to calculate the total resistance is still in dispute (Clement, 1984). Bachmann (1973) noted that pressure difference between the atmosphere and the nasopharynx is the same for each nasal cavity and that the total flow at the same pressure gradient is the sum of the air flow of both cavities. The same fact was also pointed out by Clement (1983). In our model experiment the pressure flow curves depicted on an X–Y recorder showed the same trace even if the speed and tidal volume were changed although the dimension of the curve was different according to the attained peak flow. In bilateral respiration the breathing air divides into both sides of the nasal cavities according to their grade of patency. In unilateral breathing at the same ventilatory speed and volume, the flow and pressure of that side increase compared with those in bilateral breathing. Resistance values calculated from increased flow and pressure also increase because of curvilinearity of the pressure flow relationship. In our computer analyses the total resistance by anterior rhinomanometry was calculated from the average resistance of the increased respiratory waves. This is an explanation of our data which show higher total resistance measured by anterior rhinomanometry than that by posterior rhinomanometry.

Assuming that the anatomical and physiological condition of the nose is the same in both unilateral and bilateral breathings, the relationship between pressure and flow is also the same in both breathings. Accordingly, calculation of the total resistance from the unilateral ones at an arbitrary same pressure point is theoretically correct. Comparisons of resistance values by anterior rhinomanometry with those by posterior rhinomanometry in the subjects showed relatively good correlation. But the values by one method do not always accord with those by the other method. Measurement errors in anterior rhinomanometry are mainly caused by the use of nozzles or adaptors unsuited for the application. Insertion of these apparatus into a nostril often brings about distortion of the other nostril, which affects the resistance of the distorted side. Adhesive tape technique is recommended (Clement, 1984). A piece of adhesive tape, the center of which is pierced by a thin pressure conducting tube, is patched to one nostril of a subject. The subject breathes through the mask applied around the nose and upon the conducting tube. In the present study two nozzles were used at both nostrils for pressure and flow recordings. The resistance values measured by anterior rhinomanometry using nozzles probably differ from the values measured by posterior rhinomanometry in breathing through a mask. Model experiments in the present study completely excluded the effect of distortion. Both resistance values well coincided with an extremely good correlation at any pressure points elected.

Probable factors to influence values beside the distortion were examined in other experiments. When some resistive components exist in the nasopharynx, the calculated resistance value in anterior rhinomanometry becomes smaller than the measured value in posterior rhinomanometry. In posterior rhinomanometry the total resistance values become different due to the experimental condition which includes or excludes this resistance. Anterior rhinomanometry always excludes the resistance in this position. The difference of the resistance in anterior and posterior rhinomanometry corresponds with the amount of this resistance. Schlenter (1982) reported effects of air leakage from the mask during respiration. Unexpectedly disturbed pressure flow curves often result from the air leakage. It was shown in our experiment that the leakage which reduced the air through a pneumotachograph led to an underestimation of the flow and so overestimation of the resistance.

In conclusion, the anterior rhinomanometry is a precise and convenient technique to assess the conductivity of the nose. The total nasal resistance in this method should be calculated from the unilateral resistance values measured at a certain pressure point. Flow point should not be used as reference. Use of average resistance is not suitable. Probable errors in the resistance measurement such as distortion of the nostril or leakage from the mask should carefully be checked all the time. Resistive component in the nasopharynx should be taken into consideration in comparison of anterior and posterior rhinomanometry.

ZUSAMMENFASSUNG

Die Technik und das Prinzip der aktiven anterioren Rhinomanometrie ist durch die Untersuchung am Menschen und das Modell-experiment als richtig nachgewiesen worden. Die Widerstandswerte, die man durch die anteriore Methode am Menschenkörper erlangte, kamen nicht immer überein mit denen, die man durch die posteriore bekam. Diese Uneinigkeit schien von der Verzerrung des Naseneingangs, der Luftsickerung aus dem Gerät oder von widerstehenden Komponenten in der Nasopharynx herzurühren. Dann wurde jeder mögliche Fall mit Hilfe vom Modellexperiment vielfach demonstriert und analysiert, so dass die anteriore Rhinomanometrie sich schliesslich als präzise und angemessene Methode bewiesen hat, die Nasendurchgängigkeit abzuschätzen.

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T. Unno, M.D.
Dept. of Otolaryngology
Asahikawa Medical School
Nishikagura 4-5-3-11
Asahikawa 078-11
Japan