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The effect of breath holding, hyperventilation, and exercise on nasal resistance

Makoto Hasegawa and Eugene B. Kern, Rochester, U.S.A.

SUMMARY

A group of 51 patients was studied by a technique of active posterior rhinomanometry that assessed he influence of breath holding, hyperventilation, and exercise on nasal resistance. Breath holding of 30 seconds or longer produced a decrease in nasal resistance in most of the subjects tested. Hyperventilation had variable effects on nasal resistance, and exercise consistently decreased nasal resistance. These observations are consistent with the proposed effect of chemoreceptor stimulation on nasal airway resistance.

In 1923, Tatum found a decrease in the nasal blood flow in dogs which was induced by breath holding. After cervical sympathectomy, the dogs did not show any changes in nasal blood flow during either breath holding or rebreathing studies. By regularing the capacitance vessels in the nasal mucosa, the autonomic nervous system can alter the cross sectional area of the nasal airway and thereby affect nasal resistance. In 1964 and 1969, Rundcrantz detailed the effect of head position on nasal resistance, and Salman and associates in 1971 studied the influence of cold and warm air on nasal resistance. In 1969, Takagi and associates analyzed the effects of carbon dioxide breathing on nasal resistance. They found that nasal resistance was markedly decreased during carbon dioxide breathing and considered that this was due to the peripheral vasoconstrictive action of carbon dioxide on the nasal mucosal vessels. In 1976, Hasegawa and co-workers observed the effect of breath holding in 15 normal adults and found that they all showed marked decrease in nasal resistance after breath holding.

Since nasal resistance can be affected by many nonpathologic factors, such as the nasal cycle, head position, humidity and temperature of the inspired air, we quantitated the physiologic influence of breath holding, hyperventilation, and exercise on nasal resistance in 51 normal adults, utilizing the technique of active posterior rhinomanometry.

METHODS

The active posterior rhinomanometric procedures that have been used for clinical investigations at the Mayo Clinic during the past six years were utilized (Kern, 1973; Hasegawa and Kern, 1978).

The study involved 27 females (mean age 25 years and range 14 to 47) and 24 males (mean age 24 years and range 14 to 44) who had rhinoscopically normal noses and no history of nasal or paranasal sinus disease. Examination followed an acclimatization period of about 30 minutes. The subjects were examined in the sitting position while quietly breathing room air at 21 °C. The relative humidity varied from about 25 ±5% (October through April) to 35 ±5% (May through September).

A tightly fitting "mask flowmeter" was placed over the patient's face and secured with an elastic strap (Figure 1). Nasal airflow was measured by recording the pressure drop across two pneumotachograph screens with a differential gas pressure transducer (Model 270 Hewlett-Packard). The pressure drop across these screens was found to be linearly related to airflow.

This strain-gauge, with one input in the mask and the other in the mouth, measured the transnasal pressure or the pressure drop between the mask and the nasopharynx. (The transnasal pressure constitutes the driving pressure for nasal airflow.) A constant bias airflow was used to reduce instrumental dead space.

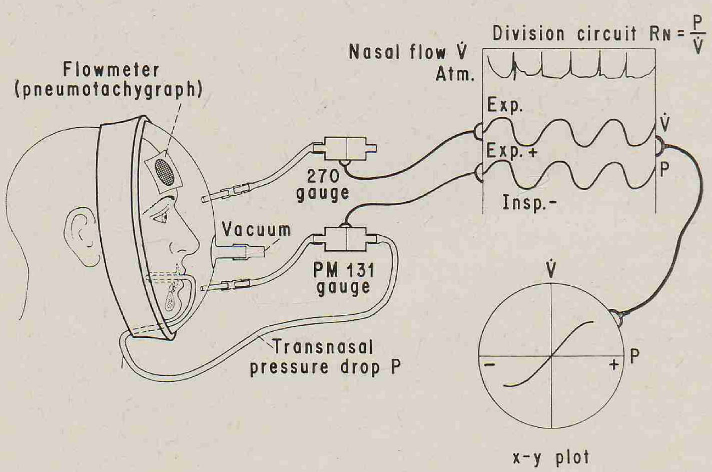

Figure 1. Schematic diagram of active posterior rhinomanometry. Inputs into face mask flowmeter are connected to gauges that measure nasal air flow and transnasal pressure. Output of gauges enters an amplifier, and responses may be read out on recording paper. With this information, nasal resistance can be calculated, or computerized division circuit can be used to calculate simultaneous nasal resistance. Another output may be led into an oscilloscope so that pressure-flow relationship may be visualized as S-shaped curve resulting from changes during inspiration and expiration.

Transnasal pressure and nasal airflow were recorded continuously (Hewlett-Packard-Thermal-Tip model 7414A). Transnasal pressure and flow were displayed on the X and Y axes of an oscilloscope (Tektronics, type 564B storage oscilloscope) so that the pressure-flow relationship was visualized during inspiration and expiration, resulting in an S-shaped curve. Using transnasal pressure and flow, nasal resistance was calculated. From a computerized division circuit, nasal resistance was recorded simultaneously with the transnasal pressure-flow curves.

Only subjects who could relax the soft palate and breathe quietly so as to produce undistorted pressure-flow curves on the storage oscilloscope were included in this study. Two subjects were unable to relax the soft palate adequately and were excluded from the study. To avoid obstructing the mouthpiece, the subject was asked to place his tongue between the upper and lower teeth against the buccal mucosa of the cheek. This also facilitated relaxation of the soft palate.

Nasal resistance was calculated by dividing transnasal pressure by the nasal flow rate. The value for nasal airway resistance was the mean of four breaths calculated at the peak inspiratory pressure and flow rates during quiet respiration.

Because of the variable breathing patterns of the subjects, it was decided to utilize a fixed reference point from which to calculate nasal resistance. Four consecutive flow rate curves before and after each procedure were observed, and the lowest peak flow rate was used as the fixed reference point.

Breath-Holding Test. With the patient sitting in a chair breathing quietly using the "mask flowmeter," baseline pressure and flow curves were obtained and nasal resistance was calculated before breath holding. The patient then held his breath for 20 seconds, and nasal resistance was then calculated from the pressure-flow curves that were obtained immediately after breathing was resumed. A 15-minute interval elapsed to allow the subject to return to a resting state, and the subject again held his breath for as long as possible, after which the pressure and flow recordings were obtained and the nasal resistance was calculated. During this breath-holding test, the patient first took three deep breaths and then held his breath at the peak of the inhalation of the fourth breath.

Hyperventilation Test. After the breath-holding test was completed, a 15-minute rest period allowed the subject to return to a resting state. Pressure and flow recordings were then obtained, and the nasal resistance was calculated. The subject hyperventilated for 30 seconds, after which nasal pressure and flow studies were obtained and nasal resistance was calculated. Some of the patients also hyperventilated for 60 seconds, and test results were recorded.

Exercise Test. After the hyperventilation test, a 15-minute rest period was imposed. Resting pressure-flow studies were obtained and nasal resistance was calculated. The subject then exercised by stepping up and down on a small step for a 3-minute period. After the exercise, the nasal pressure-flow curve was obtained and nasal resistance was calculated.

RESULTS AND COMMENT

Nasal resistance was measured in 51 subjects (24 males and 27 females) before and after each of the following activities: 20-second breath holding, long breath holding, hyperventilation, and exercise. In addition, 27 subjects (9 males and 18 females) were evaluated before and after hyperventilation of 60 seconds. Percentiles (25th, 50th, and 75th) are shown (Table 1). Statistically significant changes were found in each case (Table 2). However, the magnitude of these cases in which the change exceeded the estimated 90th percentile for normals was 5.9% for 20-second breath holding, 11.8% for long breath holding, 15.7% for 30-second hyperventilation, 14.8% for 60-second hyperventilation, and 66.7% for exercise.

The magnitude of change in nasal resistance (Hasegawa et al., in press) occurring in normals was not associated with age (Spearman two-sided rank correlation) and dit not differ between males and females (two-sided rank-sum

Table 1. Nasal resistances before and after breathing activities.

	breath holding				hyperventilation					
	20-second		long		30-second		60-second		exercise	
percentile	before	after	before	after	before	after	before	after	before	after
25th	0.9	1.0	1.0	0.8	1.1	1.1	1.1	1.2	1.0	0.5
50th	1.3	1.3	1.2	1.0	1.4	1.6	1.6	1.6	1.4	0.7
75th	2.0	2.1	2.0	1.6	2.2	2.9	2.3	2.7	2.0	1.0

Table 2. Changes* in nasal resistance after breathing activities.

percentiles	20-s breath holding	long breath holding	hyper-ventilation	60-s hyper-ventilation	exercise
25th	−4.2	−27.0	−6.6	−4.0	−57.0
50th	6.3	−15.8	7.7	6.7	−48.9
75th	18.0	− 5.2	21.9	20.4	−34.2
fraction showing decrease in nasal resistance (*P* level)	11/38 (0.008)	36/38 (<0.001)	14/43 (0.017)	7/23 (NS)	51/51 (<0.001)
% exceeding $P_{.90} = 39.7$	5.9	11.8	15.7	14.8	66.7

$$* \ \Delta \text{ resistance} = \frac{\text{after} - \text{before}}{\text{before}}$$

test). The same was true for each of the above activities except for changes occurring after exercise, in which males and females differed significantly ($P<0.02$). The median percent change for males was 39.4% compared with 54.6% for females. The mean number of breaths was 38.9 ± 10.86 among subjects hyperventilating for 30 seconds compared with 69.5 ± 11.15 among those hyperventilating for 60 seconds.

Breath Holding. Comparison of the nasal resistance before and after breath holding revealed that after breath holding for 20 seconds, the nasal resistance increased in 27 paitents, decreased in 11 paitents, and remained unchanged in 13. The Pa_{CO_2} increased with breath holding and, at the same time, venous return may have been interrupted by an increase in intrathoracic pressure – an effect similar to that seen after compression of the jugular veins, producing an increase in nasal resistance. According to Williams (1970), Van Dishoeck showed that moderate compression of the jugular veins in the neck produces moderate congestion of the turbinates, with a resultant increase in the resistance to air flow in a normal nose. With breath holding of only 20 seconds, the Pa_{CO_2} probably increased only moderately; therefore, the increased intrathoracic pressure increases the nasal resistance by interruption of venous return and negates the moderate effects of vasoconstriction induced by the increased Pa_{CO_2}.

When the patients held their breath as long as possible in our study, the nasal resistance decreased in 36 subjects, increased in 2, and remained the same in 13. As the Pa_{CO_2} increases with breath holding, venous return is interrupted; however, vasoconstriction of the nasal mucosa occurs because of chemoreceptor stimulation. In this situation, the increase in Pa_{CO_2} is greater than that during the 20-second breath holding, and the chemoreceptor stimulation with its vasoconstriction effects via the sympathetic nerves and resultant decreased nasal resistance predominates over the increased intrathoracic pressure and interrupted venous return.

Hyperventilation. In our study, in the 30-second test, nasal resistance increased in 29 patients, decreased in 14, and remained the same in 8. In the 60-second test, nasal resistance increased in 16 patients, decreased in 7, and remained the same in 4. Some workers believe that nasal resistance increases with hyperventilation because of vasodilation of the nasal vessels. The blood vessels of the nasal mucosa are innervated by sympathetic nerves arising from the superior cervical ganglion and parasympathetic nerves arising from the sphenopalatine ganglion. This may be important physiologically in that, when one system (parasympathetic) predominates, the nose produces vasodilation with increased restitance to nasal airflow while the other system (sympathetic) causes vasoconstriction and lessens the resistance to airflow through the nose.

Exercise. After the 3 minutes of exercise, a decrease in nasal resistance was observed in all of the 51 patients. Generally, a respiratory peak point is easily observable during peak inspiration, but during exercise, different inspiratory peak points are observed; therefore, a fixed point in different subjects was impossible to locate because of the different amplitudes. Thus, the lowest peak was chosen as the reference point. Richerson and Seebohm (1968) suggested that the decrease in nasal resistance was due to an increase in Pa_{CO_2}. They thought there was a stimulation of the chemoreceptors, and the decrease in nasal resistance was due to vasoconstriction and subsequent increase in patency of the nasal airways. Richerson and Seebohm stated that the effects of exercise continue for approximately 30 minutes.

CONCLUSIONS

It is a well-known and indisputable fact that a number of physiologic phenomena can affect the moment-to-moment resistance to airflow through the nose. Rundcrantz (1964, 1969) showed that position changes of normal persons produced a slight change in nasal resistance, while in an allergic population, these same changes in position did produce significant changes in nasal resistance. We think that breath holding, hyperventilation, and exercise cause changes in Pa_{O_2} and Pa_{CO_2} in the blood, affecting the chemoreceptors which in turn affect the autonomic nervous system, producing alterations in nasal blood flow and consequently changes in nasal resistance. This is supported by the work of McCaffrey and Kern (in press, a, b) which has shown that in the dog and in man an increase in Pa_{CO_2} or a decrease in Pa_{O_2} produces a significant reduction in nasal airway resistance, which is dependent upon an intact sympathetic nervous supply to the nasal mucosa.

RESUME

L'influence de l'apnée, de l'hyperventilation et de l'exercice sur la résistance nasale mesurée par une technique de rhinomanométrie postérieure active est étudiée dans un groupe de 51 patients. Une apnée de 30 secondes ou plus détermine une diminution de la résistance nasale chez la majorité des sujets testés. L'hyperventilation a des effets variables et l'exercice provoque une diminution de la résistance nasale. Ces observations sont compatibles avec l'intervention de chémorécepteurs dont la stimulation agit sur la résistance nasale.

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Makoto Hasegawa, M.D.
Eugene B. Kern, M.D.
Mayo Clinic and Mayo Foundation
200 First Street SW
Rochester, Mn. 55901, U.S.A.