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The relationship of skin temperature to the nasal cycle in normal subjects*

M. Preece, R. Eccles

Common Cold and Nasal Research Centre, Department of Physiology, University of Wales College of Cardiff, United Kingdom

SUMMARY *Nasal airway resistance and skin temperature at the cheek, nose and forearm were measured at 30-min intervals over a period of 7 h in six healthy subjects (age 22–25 years). Right and left skin temperature measurements were made with an infrared thermometer, and right and left nasal airway resistance was measured by active posterior rhinomanometry. Three of the six subjects exhibited what has previously been described as a nasal cycle with spontaneous reciprocal changes in nasal airway resistance. There was a highly significant negative correlation between right and left nasal airway resistance in these subjects (r=–0.64 to –0.78). In contrast to the nasal airway resistance the right and left skin temperatures had highly significant positive correlations (r=0.74 to 0.93), which demonstrates that the skin temperature changes on each side of the body occurred in parallel with no evidence of a reciprocal relationship. The results indicate that in normal healthy subjects there is no relationship between nasal airway resistance and skin temperature despite the fact that both are controlled by sympathetic vasoconstrictor nerves.*

Key words: nasal cycle, skin temperature, nasal airway resistance

INTRODUCTION

The "nasal cycle" has been well documented in humans and animals; a phenomenon characterized by oscillations in unilateral nasal airway resistance with a reciprocal relationship between the two nasal passages (Kayser, 1895; Lillie, 1923; Heetderks, 1927; Stoksted, 1953). The oscillations in nasal airway resistance are regulated by changes in volume of the nasal venous erectile tissue. The blood flow to the skin and the filling of nasal venous erectile tissue are regulated by sympathetic vasoconstrictor nerves. Section of the cervical sympathetic nerve causes ipsilateral cutaneous vasodilation and ipsilateral nasal congestion (Stoksted and Thomsen, 1953; Eccles, 1978).

The "nasal cycle" is an example of autonomic asymmetry and there is some evidence that other functions may exhibit similar asymmetry in autonomic tone. Oscillations in axillary sweating in phase with changes in nasal resistance have been reported by Leclerc et al. (1987), and Kennedy et al. (1986) demonstrated that the catecholamine levels in blood taken from the right and left arms varied in phase with the nasal cycle. Asymmetric changes in skin blood flow of neonates have been observed which indicate that the two sides of the body are under separate autonomic control and capable of independent activity (Nelligan and Strang, 1952). Autonomic asymmetry is well established in the control of nasal airway resistance, but evidence for this type of autonomic activity in other organs such as skin is less convincing. Recent studies by Gilbert (1989) reported that there was no evidence for oscillations in facial skin temperature related to spontaneous reciprocal changes in nasal airway resistance. However, only facial skin temperature was recorded and this was measured by thermocouples taped to the skin, potentially causing local irritation and associated changes in blood flow.

In the present study we have measured skin temperature by means of an infrared thermometer which avoids direct skin contact. We have also measured skin temperature at the cheek, nose and forearm with simultaneous measurement of nasal airway resistance.

MATERIAL AND METHODS

Nasal resistance and skin temperature measurements were performed on six healthy subjects (4 female and 2 male, ages 22-25). Volunteers were recruited from the local

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student and laboratory staff population by poster advertisement. Subjects were screened by questionnaire and clinical examination to confirm their general and nasal fitness. Those with systemic pathology were excluded, as were those with mechanical nasal obstruction due to polyps or a deviated nasal septum. Evidence of an infective, allergic or vasomotor rhinitis was also a criterion for exclusion.

Skin temperature measurement was carried out using an infrared thermometer (Linear Laboratories, Model No. C-1600M). This device avoided the need for direct contact with the skin and thus the effects of local irritation and inflammation on skin temperature were minimized. Temperature readings were taken from each cheek, lateral surface of the nose, and palmar surface of the forearm. Readings from the cheek were from a point on the skin 3 cm below the midpoint between the prominence of the zygoma and the nose. Readings from the nose were from the midpoint of the upper margin of the lower lateral cartilage. These landmarks were gently marked with felt pen to enable consecutive measurements to be taken from the same area of skin. A mean of three readings was used from each site.

Nasal resistance was measured on each side of the nose separately using active posterior rhinomanometry (Mercury Electronics NR6 rhinomanometer with BBC microcomputer). The equipment was calibrated each day for pressure using a sloping paraffin-filled manometer (Type 504 manometer; Airflow Developments Ltd.) and for flow using a rotameter (Fisher 2000, Fisher Controls Ltd.). Resistance measurements were made on one side of the nose whilst the other nostril was occluded with Blenderm adhesive tape. Great care was taken not to disturb the shape of the measured side nostril and the airflow through it.

For each nostril, three runs of four resistance measurements were made using an inspiratory reference pressure of 150 Pa (Clement, 1984). The subject was allowed to reposition the mask between runs. The mean of these four measurements was calculated. If the calculated coefficient of variation of the means from three runs was greater than 20%, then the readings were continued until three consecutive runs (i.e., 12 breaths) gave a value less than 20%. The nasal resistance value used in analysis was thus the mean of 12 consecutive inspirations. Total nasal resistance was calculated from the equation:

$$\frac{1}{\text{total NAR}} = \frac{1}{\text{left NAR}} + \frac{1}{\text{right NAR}}$$

Prior to any readings being taken the subject was allowed to acclimatize to the laboratory temperature for a period of 30 min. (The average daily laboratory temperature ranged from 18.5 °C to 20.5 °C). During this time the questionnaire was completed by the subject as well as clinical examination and rhinomanometry instruction by the investigator. Measurements of skin temperature and nasal resistance were repeated at 30-min intervals over a period of seven hours (15 readings). On each occasion skin temperature readings were taken before nasal resistance measurements. During the course of the experiment the subjects remained in the laboratory. They were provided with a snack lunch and non-caffeinated drinks.

Graphs of the time course of changes in nasal resistance and skin temperature were plotted. Correlation coefficients were calculated relating changes in nasal resistance and skin temperature between right and left sides. The correlation between nasal resistance and skin temperature (cheek and nose) was also analysed. Analysis was carried out on both pooled, normalized data and those obtained from individual subjects. Pooling of the individual data was achieved by taking the maximum value obtained at each particular site as 100%. Readings taken from this site during the period of the experiment were then related to this highest value. Values from right and left were considered separately.

RESULTS

Spontaneous changes in nasal airway resistance with a definite reciprocal relationship between the right and left nasal passages were observed in three of the six subjects. A graph illustrating reciprocal oscillations in nasal airway resistance in one subject (No. 4) is shown in Figure 1A. The

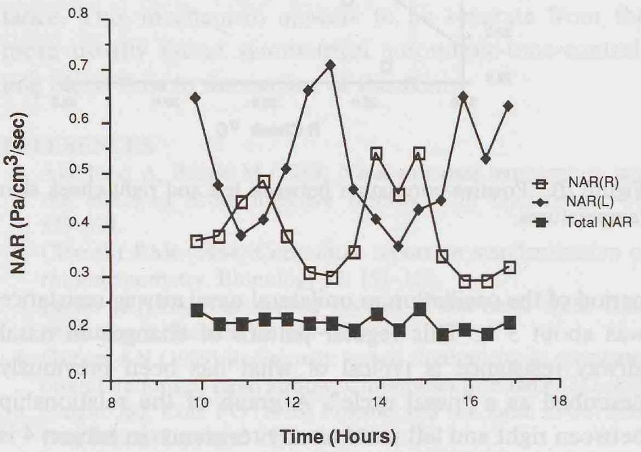

Figure 1A. Reciprocal changes in nasal resistance (NAR) over a period of seven hours.

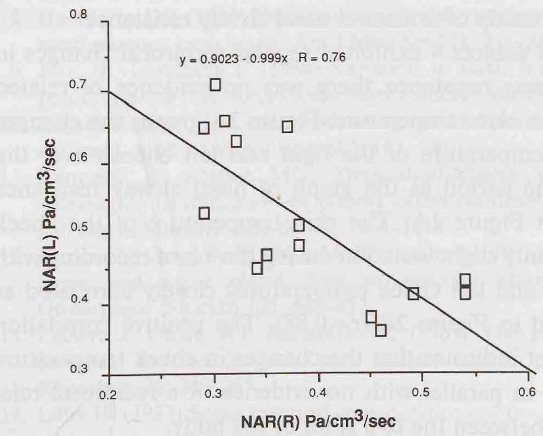

Figure 1B. Negative correlation between the left and right nasal airway resistances.

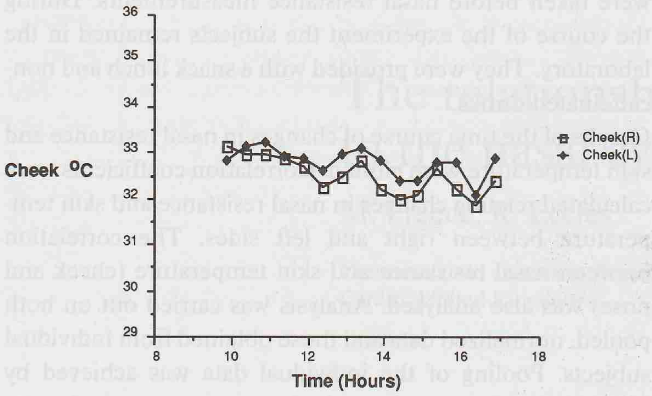

Figure 2B. Parallel changes in cheek skin temperature over a period of seven hours..

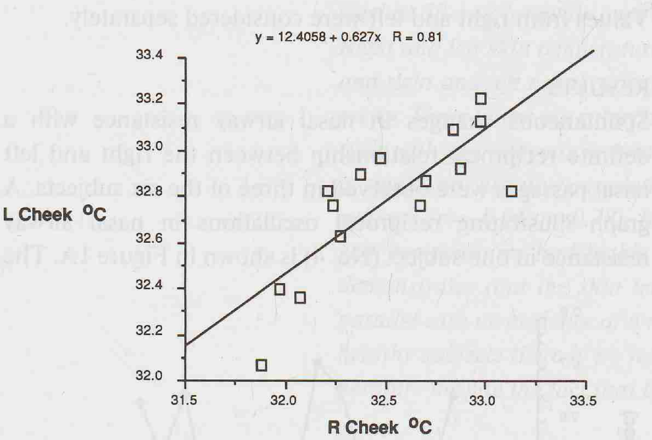

Figure 2B. Positive correlation between left and right cheek skin temperatures.

period of the oscillation in unilateral nasal airway resistance was about 3 h. This regular pattern of changes in nasal airway resistance is typical of what has been previously described as a "nasal cycle". A graph of the relationship between right and left nasal airway resistance in subject 4 is illustrated in Figure 1B, which shows that there was a negative correlation between the right and left nasal airway resistance ($r=-0.76$) as would be expected from the reciprocal relationship of unilateral nasal airway resistance.

Although subject 4 exhibited regular reciprocal changes in nasal airway resistance there was no evidence of related changes in skin temperature. Figure 2A graphs the changes in skin temperature of the right and left cheeks over the same time period as the graph of nasal airway resistance shown in Figure 1A. The skin temperature of the cheek showed only slight variation during the 7 h of recording with the right and left cheek temperatures closely correlated as illustrated in Figure 2B ($r=0.88$). The positive correlation coefficient indicates that the changes in cheek temperature occurred in parallel with no evidence of a reciprocal relationship between the two sides of the body.

The results for all the subjects are summarized in Table 1, which lists the correlation coefficients for the right and left nasal airway resistances and right and left skin temperatures. From the table it is apparent that subjects 1, 4 and 5 exhibited a reciprocal relationship between right and left nasal airway resistance with negative correlation coefficients of −0.78, −0.76 and −0.64, respectively. Subjects 2, 3 and 6 did not have any significant correlation between the right and left nasal resistance measurements.

In contrast to the nasal airway resistance the right and left skin temperatures for cheek and nose had highly significant positive correlations in every case, with a range from 0.71 to 0.98. The right and left arm temperatures had highly significant positive correlation coefficients in four of the subjects. The pooled data for the six subjects are given in Table 1, which shows that for the skin temperature measurements there was a highly significant positive correlation (range 0.63 to 0.93) between right and left cheek, nasal and arm temperatures whereas the pooled data for right and left nasal airway resistance did not show any correlation ($r=-0.08$). Nasal airway resistance and nasal skin temperature did not appear to be related. A significant correlation was found on only one side in one of the six subjects (Table 2).

Table 1. Correlations between left and right nasal airway resistance, and skin temperature (cheek, nose and arm; ***: $p<0.001$; **: $p<0.01$; * $p<0.05$; (ns): $p>0.05$).

Subject	left NAR/ right NAR	left cheek/ right cheek	left nose/ right nose	left arm/ right arm
1	−0.78***	0.85***	0.71**	0.88***
2	0.2 (ns)	0.84***	0.94***	0.95***
3	−0.27 (ns)	0.76***	0.94***	0.012*
4	−0.76**	0.81***	0.94***	0.88***
5	−0.64**	0.93***	0.98***	−0.17 (ns)
6	−0.11 (ns)	0.95***	0.97***	0.81***
pooled data	−0.08 (ns)	0.91***	0.93***	0.74***

Table 2. Correlations between nasal airway resistance and nasal skin temperature (* $p<0.05$; (ns): $p>0.05$)

subject	right NAR/nose	left NAR/nose
1	0.42 (ns)	0.42 (ns)
2	−0.26 (ns)	0.61*
3	−0.41 (ns)	0.46 (ns)
4	0.36 (ns)	−0.3 (ns)
5	−0.24 (ns)	−0.23 (ns)
6	−0.05 (ns)	0.33 (ns)

DISCUSSION

The present study shows evidence of a reciprocal arrangement in the spontaneous changes in nasal resistance of the two nasal cavities in half of the subjects studied. This is somewhat lower than other workers have found (Heetderks, 1927; Hasegawa and Kern, 1977; Gilbert, 1989). An attempt has been made to analyse the presence and degree of reciprocity on an objective basis rather than the subjective visual assessment that has made the interpretation of previous studies difficult. In common with Gilbert's study, when reciprocity is present it is with a high negative correlation; almost an all-or-nothing phenomenon.

This study does not provide any further clues as to why reciprocal changes in nasal airway resistance should be found in one subject and not another. Conditions during the experiment were maintained as stable as practical in the surroundings of a laboratory. Variations in temperature and humidity have been thought to be causes of variation in the period of nasal cycles in the past (Hasegawa and Kern, 1977; Juto and Lundberg, 1984). Each experiment was carried out after a period of rest and acclimatization, however it is possible that subjects were psychologically stressed to different extents by the procedure, resulting in suppression of any spontaneous changes in nasal airway resistance. Posture has a well-documented effect on nasal resistance (Haight and Cole, 1989). Lateral recumbency causes congestion of the lowermost nasal cavity with decongestion of the uppermost, such that the total nasal resistance remains constant. Shifts in posture during the course of an experiment and the changes in nasal resistance caused by these might give the appearance of spontaneous reciprocal changes. However, Cole and Haight (1986) maintain that the spontaneous changes of the nasal cycle are independent of positional changes, although they may be masked by them.

The present study does not show whether the reciprocal changes in nasal airway resistance are a constant feature in a given subject. It might be that a longer period of observation would have shown the disappearance of reciprocity or indeed its appearance in a subject with no initial evidence of such change. Repeat studies of nasal resistance in the same subject are few, but seem to show that the presence or absence of a "cycle" is not a constant feature. It may be that the presence or abscence of a nasal resistance reciprocity is itself dependent on an underlying circadian rhythm.

No attempt has been made in this study to assess the presence of an inherent rhythm in the spontaneous changes in nasal resistance - a true nasal cycle. In previous studies analysis has relied on visual inspection and extrapolation. Gilbert (1989) used autocorrelation analysis in an attempt to allow a more objective assessment. This method is limited by the length of observation; an experiment lasting 8 h could be expected to detect a cycle with a period of oscillation of between 20 min and 2 h with reasonable confidence. Oscillatory periods longer than this would be detected with less reliability. Previous studies claim to have detected cycles with a period of osscillation outside of this range (Heetderks (1927): 50 min to 4 h; Hasegawa and Kern (1977): 60 min to 6 h). The reciprocal changes in sympathetic tone resulting in the variation in nasal resistance seem to be confined to the nose. There does not appear to be a similar reciprocal arrangement in the sympathetic outflow to the skin of the cheek, nose or forearm as evidenced by the lack of correlation between the changes in nasal airway resistance and skin temperature. Whilst there are spontaneous changes in skin temperature, these are strongly positively-correlated between right and left indicating a parallel relationship. Similar results were obtained by Gilbert (1989) who showed significant nasal airway reciprocity in 5 out of 9 subjects, but no significant correlation between nasal airway resistance and facial skin temperature.

Changes in nasal resistance might be expected to be associated with changes in temperature within the nasal cavity due to an increase or decrease in the cooling effect of the airflow. In this study there did not appear to be any correlation between the external temperature of the nose and nasal airway resistance. When nasal mucosal temperature has been measured by direct means by other workers, a similar lack of correlation with nasal airway resistance has been found (Akerlund and Bende, 1989). Similarly, it appears that the blood flow through the superficial nasal mucosa, which might influence mucosal temperature, is largely independent of the state of the deeper-lying capacitance vessels that determine the nasal airway resistance (Kurita et al., 1988). It may be that the reciprocal sympathetic tone to the nose is limited to the control of the capacitance vessels; the superficial nasal mucosa being under the influence of the more usually found arrangement of a symmetrical sympathetic tone and parallel changes in sympathetic activity.

In summary, this study provides some evidence for a control mechanism which can in a reciprocal fashion influence specifically the nasal capacitance vessels and nasal airway resistance. This mechanism appears to be separate from the more usually found symmetrical autonomic-tone-controlling blood flow to the surface of the skin.

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Dr. M. Preece
Common Cold and Nasal Research Centre
Department of Physiology
University of Wales College of Cardiff
Cardiff CF1 1SS
United Kingdom