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The influence of climatic factors on the nasal mucosa of rats

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SUMMARY

The influence of indoor climate on goblet cells and intraepithelial glands of nasal mucosa was analysed. A cold and heat adapted group of twenty rats were compared with a neutral adapted group after eight weeks of climatic exposure. There was a decrease of density of the goblet cells and the intrapeithelial glands in cold adapted rats. It is suggested that the adaptive changes of the mucous membranes of the rats may be correlated with the increased ventilation rate in the cold.

INTRODUCTION

People exposed to air conditioned environments frequently suffer from upper respiratory symptoms such as the common cold or dryness of the nose. Kroeling evaluated 23 parameters of nasal dysfunction and noted a significant difference in those people respiring conditioned air over those breathing natural air.

The way in which climatic factors such as temperature and humidity influence the nasal mucosa is not well understood. To evaluate these conditions, more systematic animal research is needed. The rat seems to be a suitable animal model as many nasal parameters including physiological cycles, morphologic structures and nerve supply are remarkably similar to man (Cauna, 1975).

The effect of hot and cold climate on the nasal mucosa of the rat was analyzed histologically. Specifically studied were epithelial structures including goblet cells and endothelial glands and subepithelial structures such as secretory glands, vessels and subepithelial tissue thickness.

To include all these parameters, we found it best to look at coronal sections of the nasal septum.

MATERIAL AND METHODS

Outbred female rats (Iva:SIV), which were 160 g at the onset of climatic exposure were divided in three groups. These groups were exposed for a period of eight weeks to the following climates: Groupe 1 (cold adapted = CA), (n = 20) at air temperature, T_a 7° C, 80% relative humidity (RH), wet-bulb temperature, T_{wb} 5,5° C, water vapour pressure, e 0.80 kPa; group 2 (normal adapted = NA), (n = 10) at T_a 21° C, 60% RH, T_{wb} 16.0° C, e 1.48 kPa: group 3 (heat adapted = HA), (n = 20) at T_a 30°-32° C, 30% RH, T_{wb} 10.0° C, e 1.33 kPa. Body weights were

taken daily and food consumption was measured. After eight weeks the animals were killed and the heads were worked up for histology. After fixation in Heidenheim-Susa and decalcification in 5% trichloracetic acid the heads were embedded in paraffin and dissected in 5 micron fine coronal sections in series. Each tenth section was stained with HE and each eleventh with AB-PAS. On the AB-PAS stained sections the goblet cells and the intraepithelial glands were recognized by a deep blue-violet colour.

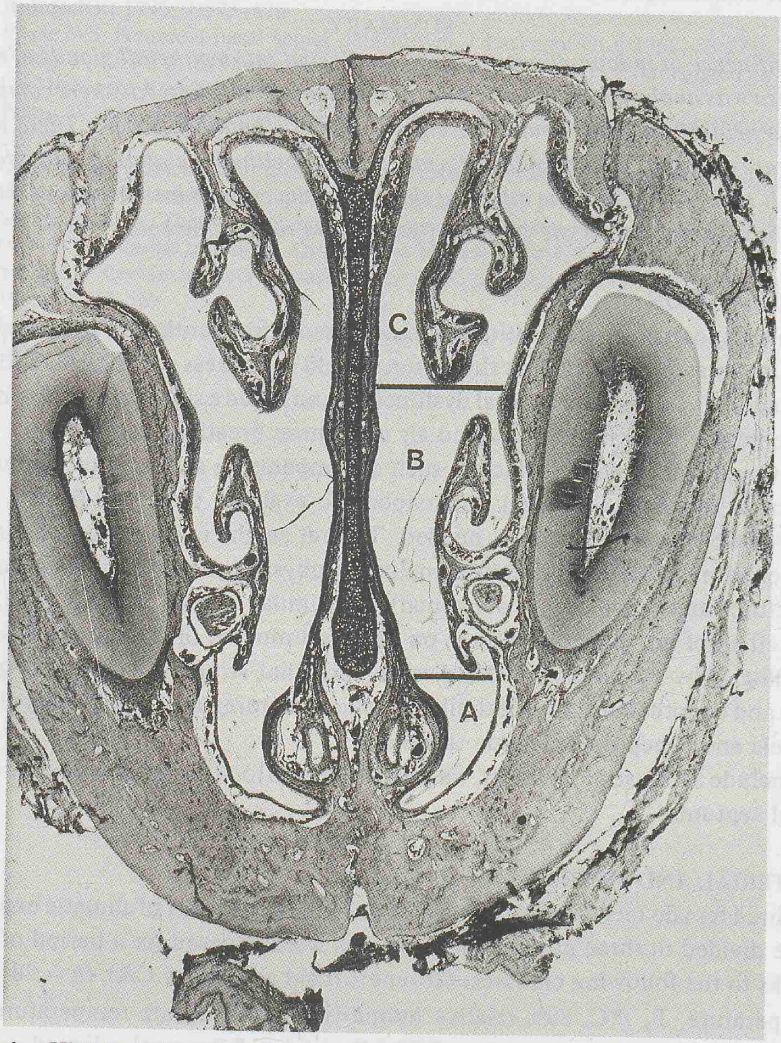

Figure 1. Histological cross-section through the head of a rat. The septum and the remaining surface of the nasal cavity respectively are subdivided into region A (basal), B (medial) and C (apical).

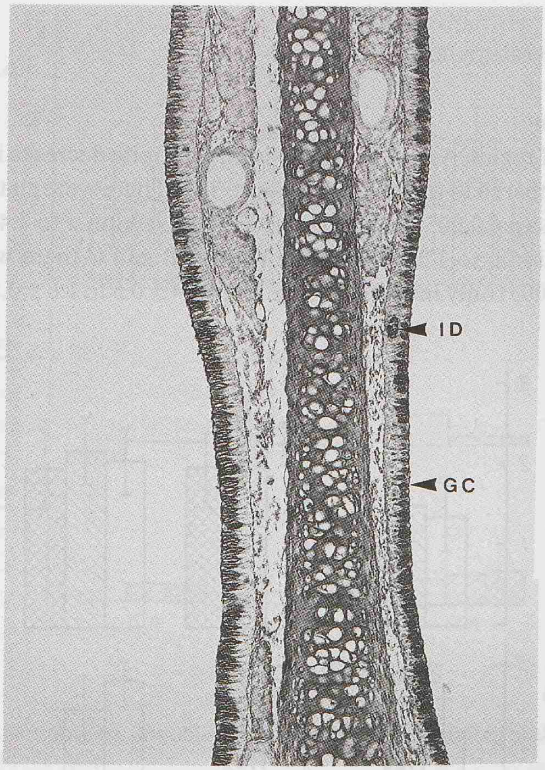

Figure 2. Cross-section of the septum of the rat region B. GC = goblet cell, IG = intraepithelial gland.

A light microscopical evaluation of the respiratory epithelium and subepithelium was carried out in the nasal cavity at three different levels from the nostril (section a, b, c), corresponding to the sections I, III and IV described by Hebel and Stromberg (1975). The relative density of the goblet cells in the areas of the nasal septum and the nasal cavity respectively were divided into three regions: Region A (basal), region B (medial), and region C (apical) (Figure 1). The goblet cells (Figure 2) were scored in the following manner: Many = 3 points, medium = 2 points, some = 1 point, none = 0 points. For each region the mean and standard deviation ($x \pm SD$) were calculated and graphically demonstrated. For statistical analysis the Student t-test was used.

The number of intraepithelial glands (Figure 2) of the total septal mucosa were counted per section, because of their totally irregular localization over the septum and their scarcity throughout the remaining mucosa of the nasal cavity. The average score was also shown graphically.

RESULTS

A. EPITHELIAL STRUCTURES

1. Goblet cells

a. Nasal septum

In section a-c of region A the CA-rats showed a definite decrease in the density of goblet cells compared to the NA-rats (Figure 3A). There were statistically significant differences ($p<0.005$), e.g. from 2.3 ± 0.5 in section a to 1.4 ± 0.9 and from 2.6 ± 0.5 in section b to 1.5 ± 0.8. In the regions B and C there was a significant decrease ($p<0.005$) only in section a, e.g. from 2.4 ± 0.5 to 1.6 ± 0.8 in region C. In

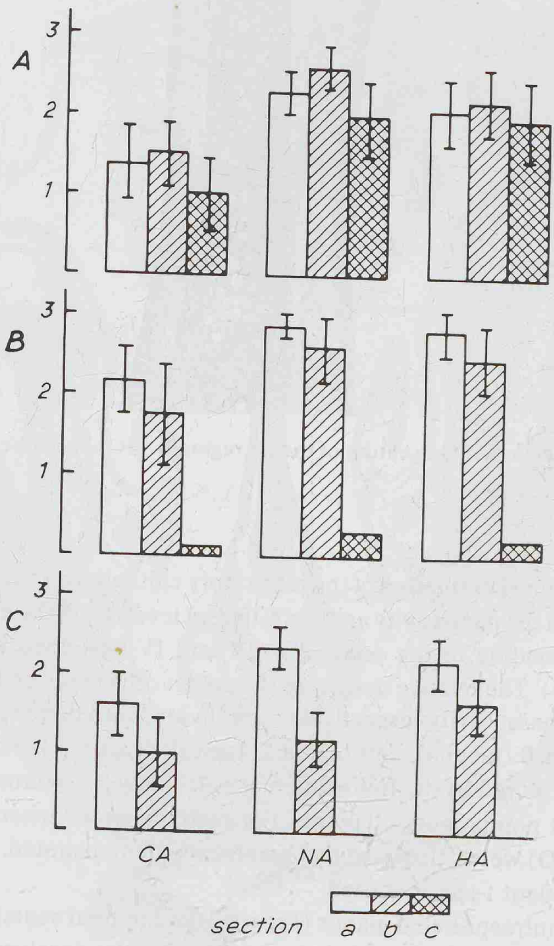

Figure 3. Relative numbers of goblet cells in the septum of the rat in the regions A-C and at 3 different distances (a-c) from the nostril. CA = cold adapted (7° C, 80% RH), NA = normal adapted (21° C, 60% RH) and HA = heat adapted (30° C-32° C, 30% RH) group.

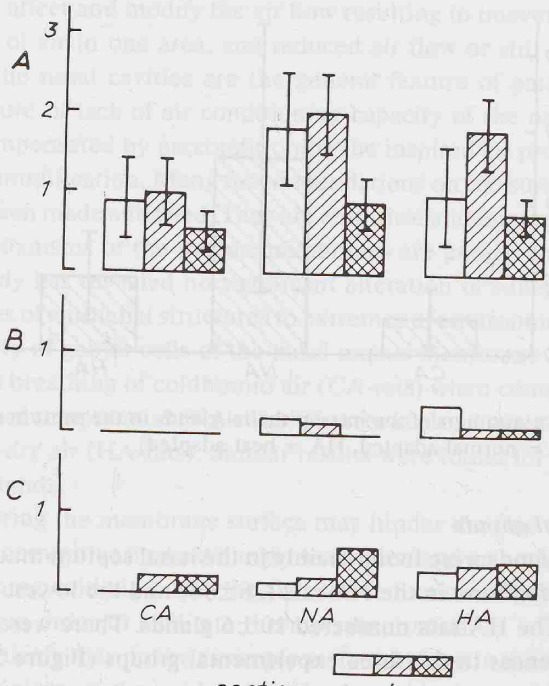

Figure 4. Relative numbers of goblet cells of the nasal cavity (excluding the septum), regions A–C, distances a–c.

the remaining sections of the CA-rats there was no significant decrease in the density of goblet cells.

The HA-rats also exhibited a tendency towards a decreasing density of goblet cells compared to the NA-rats but this was not statistically significant (Figure 3A–C). In section a of region A there was a relative density of 2.1 ± 0.8 to 2.3 ± 0.5 at the NA-rats. A slight increase (1.4 ± 0.7 of the NA-rats to 1.7 ± 0.7) was noticed in section b of region C (Figure 3C).

b. Nasal cavity

In the CA-rats there was also found in region A of the nasal cavity a decrease of the numbers of goblet cells in section a–c compared to the NA-rats (Figure 4A). There was a significant difference ($p < 0.01$) in section a and b e.g., from 1.8 ± 0.5 to 0.9 ± 0.5 in section a of the NA-rats. In HA-rats there was a trend towards a decrease in the numbers of goblet cells in region A compared to NA-rats. In the posterior and upper areas of the nasal cavity, only a few goblet cells were present because of the wide distribution of olfactory epithelium, and therefore these have not been evaluated in these areas (Figure 4B–C).

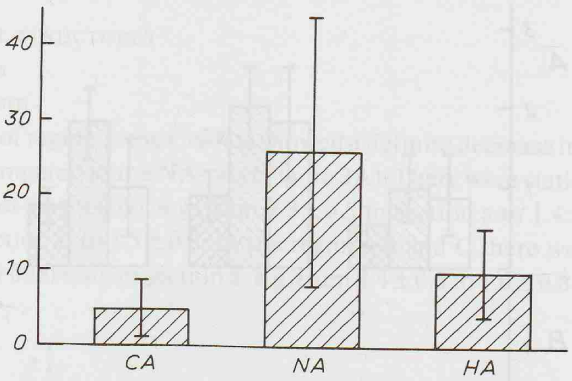

Figure 5. Relative numbers of the intraepithelial glands in the septum of the rat (CA = cold adapted, NA = normal adapted, HA = heat adapted).

2. Intraepithelial glands

Intraepithelial glands were found mainly in the nasal septum mucosa. The highest numbers were found in the NA-rats (26 ± 18) and the lowest in the CA-rats (5 ± 4 glands). The HA-rats numbered 10 ± 6 glands. There were no significant statistical differences in the three experimental groups (Figure 5).

B. SUBEPITHELIAL STRUCTURES

Secretory glands, vessels and subepithelial tissue thickness of the nasal septum and nasal cavity showed no significant alterations.

DISCUSSION

Recommendations on indoor climate for man are based on thermal sensation and degrees of comfort ratings of healthy persons (Ashrae, 1972). Complaints such as "dryness" or "stuffiness" of the nose, or more complex feelings of unpleasantness summarized as "sick building syndrome" (Finnegan et al., 1984) have been insufficiently studied by the rhinologist. Of relevant interest to the rhinologist however are the two main air conditioning functions of the nasopharyngeal mucus membranes - the surface fluid evaporation for water vapour saturation, and the warming of the inspiratory air at body temperature.

The evaporation rate increases with forced convection during breathing. The convection depends on speed of air flow and air flow patterns. The faster the air flow and the more turbulent the flow pattern is the closer will be the contact and the steeper will the gradient between the surface of the membrane and the inspired air.

It appears that the efficiency of the thermoevaporation of the nasal mucus membranes depends on the structure of the intranasal cavities. Deformities of

mutilations will affect and modify the air flow resulting in uneven flow patterns with impinging of air in one area, and reduced air flow or still air in another. Alterations of the nasal cavities are the general feature of patients. In these persons the failure of lack of air conditioning capacity of the naso-pharyngeal tract may be compensated by preconditioning the inspired air probably by both warming and humidification. Many recommendations on the suitable condition of the air have been made and tried. They are empirical and improperly argued as long as the mechanisms of the mucus membranes are poorly understood.

The present study has revealed no significant alteration of subepithelial structures but changes of epithelial structures to extremes of environmental temperatures. The density of goblet cells of the nasal mucus membrane had decreased after continuous breathing of coldhumid air (CA-rats) when compared with the density at standard temperature (NA-rats). There was also a slight decrease after breathing warm-dry air (HA-rats). Similar results were found for the density of intraepithelial glands.

The mucus covering the membrane surface may hinder the free evaporation of the fluid and the convective heat exchange. As the demand on both is particularly high with breathing cold air it may be that the reduction of goblet cells is an adaptive change in order to facilitate thermotranspiration.

The situation certainly may not be as simple as that. At least in the rat a metabolic adaptation takes place in the cold and in the heat at temperatures below and above the thermoneutral zone which is between 28° to 29° C. This metabolic adaptation implies increased metabolic rate or oxygen consumption. Increased oxygen demand results in increased breathing and ventilation rates. This puts more demand on the thermoevaporative function of the mucus membranes. The metabolic rate of CA-rats was increased by about 50% on the increase of food intake (Hart, 1971) of the HA-rats only moderately. It is suggested that the adaptive changes of the mucus membranes of the rats may be correlated with the ventilation rate. A high ventilation rate would lead to a reduction of mucus producing goblet cells. If this is correct the only slight decrease of goblet cells in the HA-rats could be explained.

This interpretation of the results is supported by previous investigations. Applying intermittant exposure of 4–6 hours daily at 0° C for several weeks, Gusic et al. (1964) noticed an early decline and later a normalization of the density of goblet cells. The authors reported the same effect when the experiment was repeated at an exposure temperature of 40° C. When rats were exposed continuously for four weeks at −18° C there was a total absence of goblet cells combined with metaplasia of the epithelium and hyperplasia of connective tissue (Gusic et al., 1984). After exposure of rats to a temperature of 32° C for a period of many weeks Riesenfeld observed complete atrophy of the non-olfactory turbinate. An effect of nasal air flow velocity on goblet cells was described by

Hilding (1932) in rabbits. After closing one nostril the goblet cell population has increased on the closed side and decreased on the open side of the nasal cavity. This was confirmed by Morgensen and Tos (1978).
In conclusion, nasal complaints, for example "dryness of the nose" may not only be caused by the indoor-climate with its temperature and humidity exclusively, but possibly also by air flow speed and frequency of ventilation. Therefore it should be the task of the rhinologist to look for, and correct, deformities within the nasal cavity which cause a disturbance of normal ventilation.

ZUSAMMENFASSUNG

Es wurde das Adaptationsverhalten von Becherzellen und intra-epithelialen Drüsen der Nasenschleimhaut auf klimatische Einflüsse untersucht. Zwei Gruppen von Ratten wurden je einmal kalt-feuchtem und warm-trockenem Raumklima ausgesetzt und mit einer Kontrollgruppe nach acht Wochen verglichen. Es zeigt sich, dass bei den kalt-feucht adaptierten Ratten die Dichte der Becherzellen und intraepithelialen Drüsen abnahm. Ein direkter Zusammenhang mit einer vermehrten Nasenventilation wird diskutiert.

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