Aspects on the function of the paranasal sinuses on the conditioning of the respiratory air

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SUMMARY

Results obtained recently concerning the oxygen exchange of the human maxillary sinus are used for an approximate calculation of the daily exchange of water vapour between the paranasal sinuses and the inspiratory air. The results of these calculations are related to the daily supply of humidity from the upper respiratory airways obtained from the measurements performed by Ingelstedt, 1956. This comparison shows that the contribution in humidity from the paranasal sinuses is only 1.5% of the total net supply of water vapour from the upper respiratory airways. Even if the role is considerably greater than supposed by Proetz in 1953, it is of course still too small to be able to explain the function of the paranasal sinuses in man.

MANY hypotheses concerning the function of the paranasal sinuses have been discussed (Table 1), but so far it has not been possible to find any function which would explain why man has paranasal sinuses.

The role for the conditioning of the respiratory air has been discussed more thoroughly than the other functions in Table 1. Proetz (1953) calculated theoretically from the pressure variations in the sinuses during respiration that only about 1/1000 of the volume of the sinuses was exchanged during each breath. With an approximate total volume of the paranasal sinuses of 50 ml, only 0.05 ml from the paranasal sinuses would thus be added to the tidal volume of 500 ml, corresponding to 0.01%. The conditioning effect is higher since the air from the sinuses has a temperature of about 36° C, and is principally saturated by vapour giving an absolute humidity of 42 g/m^3, while the ambiant air (20° C, 50% r.h.) can be assumed to have an absolute humidity of 9 g/m^3. The humidity supplied to the inspirated air from the paranasal sinuses would thus, according to the calculation by Proetz, be about 0.05% of the total humidity.

Since Proetz made his calculations new facts about the conditioning of air in the respiratory tract have been presented (Ingelstedt, 1965; Toremalm, 1960). Furthermore, the exchange of air from the paranasal sinuses is better understood (Aust and Drettner, 1974; Aust, 1974). It seems likely that these observations

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Table 1.

Hypotheses concerning the function of the paranasal sinuses

1. *Respiratory*
   a. Air-conditioning of the inspiratory air by keeping warm humid air.
   b. Pressure equilibration during breathing and at higher pressure changes.
2. *Vocal*
   a. Resonance
   b. Sound protection between the vocal organ and the ears.
3. *Olfactory*
   a. Contributing for olfaction in animals.
   b. Reservoir of air used as reference at new olfactory stimuli.
4. *Static*
   Reduced weight of the facial bones.
5. *Thermal*
   Thermal protection for the skull base.
6. *Dead space*

may change the previous assumptions concerning the air-conditioning function caused by the paranasal sinuses. By comparing these results it would be possible to gain new information concerning the role of the paranasal sinuses in the conditioning of the respiratory air. Since the humidity seems to be of greater importance for the conditioning than the temperature, the calculations have been devoted only to the humidity but are also relevante for the temperature.

Exchange of humidity from the paranasal sinuses

If it is assumed that the number of molecules of water vapour passing the ostium per minute is J and V is the volume of the maxillary sinus (16 ml as a mean), R the gas constant, and T the temperature (°K), the following equation is obtained

$$J = \frac{V}{RT} Q_2 (p - p') \qquad (1)$$

where Q_2 is an expression for the exchange of water vapour through the ostium, p is the partial pressure of the water vapour in the maxillary sinus and p' the same in the nasal cavity. The temperature in the maxillary sinus is about 36° C and, since it can be assumed that it is saturated with vapour, the partial pressure for vapour is 45 torr. If the expiratory air has the same temperature and humidity, and the inspiratory air has a temperature of 20° C and 50 r.h. (i.e. 9 torr vapour pressure), the mean partial pressure for water vapour in the nasal cavity will be 27 torr. Even if water vapour is not an ideal gas equation (1) can still be used, and after solving it becomes

$$J = Q_2 \cdot 1.5 \cdot 10^{-5} \text{ mol} \qquad (2)$$

The results of oxygen exchange experiments, through the ostium of the maxillary ostium in man (Aust, 1974), were expressed as the exponent of the exponential

function illustrating the increase in pO_2 of the maxillary sinus after exchanging the gas for nitrogen. This exponent was determined in 18 normal subjects. The mean of this exponent Q_2 was about 1.0 1/min.
The exponent Q_2 is proportional to the diffusion coefficient for the gas considered. Since the diffusion coefficient for oxygen and water vapour are approximately the same, $Q_2 \sim 1.0$ 1/min. Equation (2) now becomes,

$$J = 1.5 \cdot 10^{-5} \text{ mol/min} \qquad (4)$$

This corresponds to 0.3 mg H_2O/min.

With a tidal volume of 500 ml and a respiratory frequency of 16 per minute, the minute respiratory volume will be 8 l. Half of that, i.e. 4 l, will pass through each nasal cavity. The quantity of water vapour added to the inspiratory air from each maxillary sinus will thus be 0.07 mg H_2O/l air or 0.07 g/m^3. From both maxillary sinuses 0.14 g H_2O will thus be added to each m^3 of respiratory air. It can be assumed that the quantity of water vapour reaching the respiratory air from the other paranasal sinuses will be of the same magnitude, i.e. from all sinuses 0.3 g H_2O/m^3. The daily respiratory volume is about 15 m^3, which means that the water vapour added to the respiratory air from the paranasal sinuses per 24 hours is 4.5 g.

Supply of humidity in the upper respiratory airways

Ingelstedt (1956) measured the subglottic temperature and humidity in humans and found that under ordinary room conditions the 24 hour respiratory volume contains about 100 g H_2O. During nasal respiration 430 g H_2O is added from the mucous membranes in the upper air passage, principally the nose (Toremalm, 1960)), while saturation at body temperature (= 660 g) is achieved from the zone below the larynx. During expiration about 130 g of water is condensed chiefly in the nose since the nasal mucosa has a temperature of 3°-4° C below that of body temperature. The net loss of water vapour from the upper respiratory airways is thus about 300 g per 24 hours.
The proportion of this net loss coming from the paranasal sinuses is

$$\frac{4.5 \cdot 100}{300} = 1.5\%.$$

This is the role the paranasal sinuses play in the humidification of the respiratory air in relation to the whole net supply of water vapour from the upper respiratory airways.

DISCUSSION

The calculations for the estimation of the air-conditioning function of the paranasal sinuses only concerns the water vapour, which, however, seems to be of the greatest importance. There are several approximations in the calculations, which only concern the maxillary sinus, while the effect of the other paranasal sinuses is estimated. Water vapour is not an ideal gas physically and transformation of results obtained during measurements of the oxygen exchange may thus be open for discussion.

The calculations have given the result that only 1.5% of the total net supply of water vapour to the respiratory air comes from the paranasal sinuses. This is too small to be of great importance and it is not sufficient to explain the function of the paranasal sinuses in man. However, it is greater than supposed from the calculations made by Proetz (1953) when the role only was considered to be 0.05% or even less.

The results concerning the daily exchange of water vapour from the upper respiratory airway are based only on the conditions of normal room temperature and humidity. It is not possible to calculate the role of the paranasal sinuses in the conditioning of the respiratory air in other climatic situations, since no studies of the exchange from the paranasal sinuses other than under room conditions have been performed. If it is assumed that the quantity of water vapour coming from the paranasal sinuses in cold climates is not changed very much, the total effect of the paranasal sinuses will not be considerably altered, since even if the water added to the inspiratory air with each breath is greater in cold climates, the condensation in the upper respiratory airways is also greater and the net supply of water vapour from the upper respiratory airways seems thus to be of the same order of magnitude as under room conditions.

ZUSAMMENFASSUNG

Unsere Untersuchungen über den Sauerstoffaustausch im menschlichen Sinus maxillaris werden für approximative Berechnungen der quantitativen Wasserdampfaustausches von Nasennebenhöhlen in Bezug auf die Inspirationsluft herangezogen. Die Ergebnisse dieser Berechnungen wurden mit anderen Untersuchungen über die Feuchtigkeitszufuhr aus dem oberen Respirationstrakt verglichen (Ingelstedt, 1956). Dieser Vergleich zeigt, dass die Nasennebenhöhlen nur 1,5% zur totalen Feuchtigkeitszufuhr aus dem oberen Respirationstrakt beitragen. Ihr Anteil ist also wesentlich bedeutender als Proetz, 1953 vermutete, trotzdem ist er zu gering, um eine Aussage über die Funktion der Nasennebenhöhlen des Menschen machen zu können.

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