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Temperature measurements in the maxillary sinus of rabbits

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SUMMARY

An experimental study was designed to investigate the temperature of the maxillary sinus before and after creation of nasoantral windows and in relation to different ambient temperatures. In 10 rabbits the natural ostium was enlarged (ostioplasty) and in 10 other animals a window was created far from the ostium (antrostomy). Six rabbits, in which no surgery was performed on the nasoantral wall, served as controls. The results show that before surgery, the temperature of the sinus is kept constant even when the external temperature changes. After ostioplasty or antrostomy, the capacity of air conditioning is significantly reduced and the sinus temperature changes in correlation to the environmental temperature.

INTRODUCTION

The main functions of the maxillary ostium are the ventilation, which occurs mainly by diffusion (Proetz, 1953; Doiteau, 1955; Negus, 1958; Aust and Drettner, 1971, 1974; Svanholm et al., 1981) and the drainage of secretions by mucocilliary transport (Proetz, 1953; Doiteau, 1955; Aust and Drettner, 1971, 1974). For these two functions, the size and the location of the ostium seem unfavourable, since it can easily become obstructed (Drettner, 1982; Melen et al., 1986; Plenk and Tschabitscher, 1986). Since the maxillary ostium has the same mucosal lining as the nasal turbinates (Zange, 1940), it is likely that its functions would also be similar to that of the turbinates, i.e. the conditioning of air entering the sinus and eventually, as postulated by Zange in 1940, the protection of the sinus from nocuous external influences and nasal secretions.

In order to investigate these function of the ostium, we designed an experimental study in which the temperature of the rabbit's maxillary sinus was measured under various external conditions. Additionally, nasoantral windows were created in different locations and the temperature measurements were repeated. This investigation gave us the opportunity to study the capacity of air-conditioning of the ostium and how it is affected by surgery of the nasoantral wall.

MATERIAL AND METHODS

Twenty-six adult New Zealand white rabbits of both sexes were purchased for this experiment. The animals were divided into three groups:

I. Unoperated control group (n=6);
II. Antrostomy group (n=10);
III. Ostioplasty group (n=10).

On the day of surgery (day 0), the rabbits of group II and III were anaesthetized with an intramuscular injection of 40 mg/kg ketamine hydrochloride, 10 mg/kg xylozine and 1 mg/kg acepromazine maleate. If necessary, half of the dose was repeated during the procedure. The nasal dorsum was shaved and disinfected. A paramedial incision of the skin was carried out and the periosteum incised. After elevation of the periosteum, the bone of the superior wall of one sinus was removed with a drill. Through the opening a temperature probe with a diameter of 3/16″ (Yellow Springs Instrument Co., Inc. Probe 402, Time Constant 3.2 sec) was placed into the sinus in order to measure the temperature within the sinus (Ts). The skin was hermetically sealed around the probe to prevent external air from entering the sinus and changing the values. A second probe with a diameter of 7/64″ (Yellow Springs Instrument Co., Probe 401, Time Constant 7.0 sec) was placed into the oesophagus for measurement of the body temperature (Tb).

The probes were connected to a Hewlett-Packard Temperature Module 78204 B and the results were recorded by reading the values from the display. This arrangement did not allow to record fast temperature changes (respiratory cycle). After an adaptation period of approximately one minute, the values came to a steady state. We recorded these values after three minutes, making sure that no more changes occurred during the last minute.

The first measurements were taken in the operating room with an external temperature of 25 °C. The animals where then placed into a cooled room with an external temperature of 10 °C and measurements were repeated in the same fashion.

Animals of group I didn't have any surgery and served as a control. The group III (ostioplasty) animals were then operated, with the sinus ostium widened anteriorly and inferiorly by sharp dissection and under microscopic view, creating a window of approximately 8 mm in diameter. In the antrostomy group (II), a window of the same size as in the ostioplasty group was created as far anteriorly from the sinus ostium as possible. Temperature measurements were repeated in the operating room and in the cooled room in the same way as described before. The incision was closed with 3-0 Nylon sutures, taking special care to close the periosteum hermetically.

Three month after the initial procedure (day 84), all the sinuses, including the contralateral sinuses of the animals of the surgical groups and both sinuses of the rabbits of the control group, were opened in the same way as on the day of surgery. Temperature measurements were taken as described before. After all procedures had been completed, the animals were sacrificed with an intravenous injection of an overdose of pentobarbital sodium and phenytoin sodium (Beuthanasia-D Special).

RESULTS

Day 0: Measurements before creation of nasoantral windows (Group II and III): At 25 °C external temperature, the sinus temperature (Ts) was 35.2 (± 0.7) °C. When placed into the cold room, Ts dropped 1.1 (± 0.96) °C to 34.1 (± 1.1) °C. This change of Ts was statistically significant in the two groups ($p<0.05$) (Figure 1a). As the body temperature (Tb) at the same time dropped 0.49 (± 0.33) °C from 38.9 (± 0.5) °C to 38.5 (± 0.5) °C, we analyzed the difference between the body and the sinus temperature in order to minimize the effects of Tb changes on Ts. These relative sinus temperature (Tb-s) increased from 3.7 °C at 25 °C external temperature to 4.5 °C in the cold room. This increase was statistically not significant in the two groups ($p<0.05$) (Figure 1b).

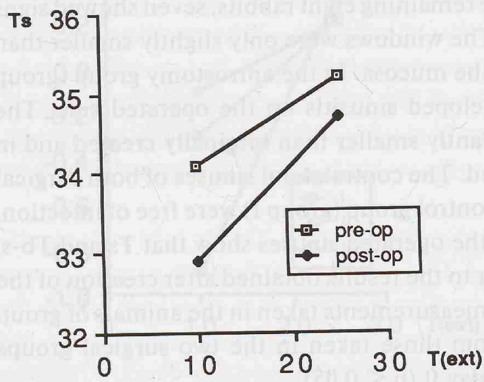

Figure 1a.
Pre- and postoperative sinus temperature.

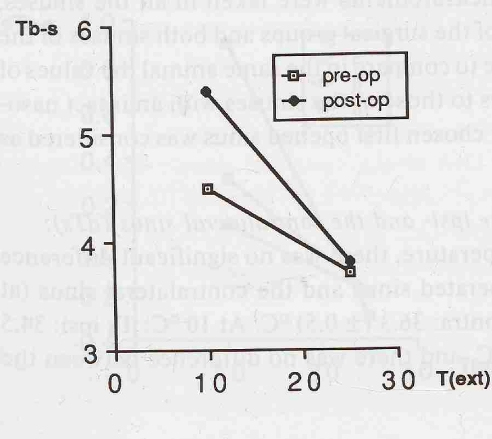

Figure 1b.
Pre- and postoperative relative sinus temperature.
Ts: Sinus temperature;
Tb-s: Difference between body temperature and Ts;
T(ext): Room temperature.

After creation of the windows at 25 °C external temperature, Ts was 34.7 (± 0.8) °C. When measured in the cold room, it dropped more than before creation of the window to 32.9 (± 1.7) °C (Figure 1a). The measurements of Tb were comparable to those before creation of the windows. Tb-s at 25 °C external temperature was 3.8 (± 0.9) °C. After exposure of the animals to cold environment, Tb-s increased significantly ($p < 0.05$) in both groups to 5.4 (± 1.8) °C (Figure 1b).
The comparison between the measurements taken before and after creation of nasoantral windows shows that Ts dropped more after creation of the window than before, when the rabbits were placed into the cooled room. These difference was statistically significant for the animals of group II, but not significant for the animals of group III ($p < 0.05$). Tb-s, which before creation of the window was not significantly different in the warm and cold rooms, was significant after creation of the window ($p < 0.05$).

Day 84:

During the three months of observation, two animals of the ostioplasty group (group III) died of septicemia. Of the remaining eight rabbits, seven showed signs of infection in the operated sinus. The windows were only slightly smaller than originally created due to edema of the mucosa. In the antrostomy group (group II), only one of the 10 rabbits developed sinusitis on the operated side. The windows in this group were significantly smaller than originally created and in three animals were completely closed. The contralateral sinuses of both surgical groups and all the 12 sinuses in the control group (group I) were free of infection.
The temperature measurements in the operated sinuses show that Ts and Tb-s, taken at 25 °C and 10 °C were similar to the results obtained after creation of the windows on the day of surgery. The measurements taken in the animals of group I, were statistically not different from those taken in the two surgical groups before creation of the windows on day 0 ($p < 0.05$).
Since on day 84 the temperature measurements were taken in all the sinuses, including the contralateral sinuses of the surgical groups and both sinuses of the control group (group I), we were able to compare in the same animal the values of the sinuses with nasoantral windows to those of the sinuses with an intact nasoantral wall (in group I the randomly chosen first opened sinus was considered as ipsilateral sinus).

Difference of temperature between the ipsi- and the contralateral sinus (dTs):

At 25 °C and at 10 °C external temperature, there was no significant difference between the temperature of the operated sinus and the contralateral sinus (at 25 °C: Ts ipsi: 36.5 (± 0.6) °C, Ts contra: 36.3 (± 0.5) °C. At 10 °C: Ts ipsi: 34.5 (± 1.1) °C, Ts contra: 34.9 (± 0.7) °C, and there was no difference between the three groups ($p < 0.05$).

When the animals were placed in environments ranging from warm to cold, dTs in group III changed significantly more in the ipsilateral sinus than in the contralateral sinus (dTs ipsi: 2.0 °C, dTs contra: 0.8 °C) ($p < 0.05$). These changes were not significant in the other groups (Figure 2a).

Difference of the relative sinus temperature between the ipsi- and contralateral sinus (dTb-s):
In a warm environment, there was no significant difference between the operated sinus and the control sinus (Tb-s ipsi: 2.8 (± 0.7) °C, Tb-s contra: 3.0 (± 0.7) °C. In the cold room, Tb-s of the ipsilateral sinus was 4.5 (± 0.9) °C and Tb-s of the contralateral sinus 4.2 (± 0.6) °C. dTb-s was significantly different only in group III when compared to group I ($p < 0.05$). There was no difference between the other groups ($p < 0.05$) (Figure 2b).

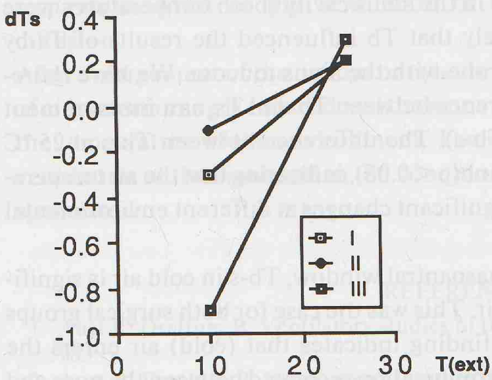

Figure 2a.
Difference between ipsi- and contralateral sinus temperature [dTs] (day 84).

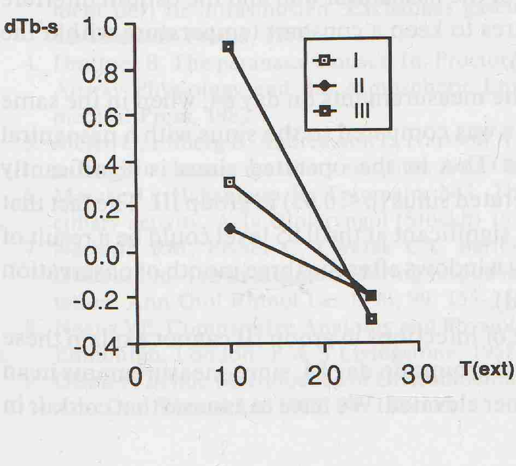

Figure 2b.
Difference between ipsi- and contralateral relative sinus temperature [dTb-s] (day 84).
I: Control group
II: Antrostomy group
III: Ostioplasty group
i: ipsilateral (operated)
c: contralateral (non-operated).

When the animals were moved from the warm in the cold environment, the increase of dTb-s was also only significant in group III ($p < 0.05$) (Figure 2b). If we exclude the rabbits in group II in which the nasoantral window was closed, then there is also a significant difference between group II and III ($p < 0.05$). This finding indicates that the sinus with an intact nasoantral wall and ostium was able to equilibrate the change of the external (respiratory) air temperature significantly better than the sinus with an enlarged ostium.

DISCUSSION

In the rabbit's maxillary sinus with an intact nasoantral wall and ostium, the temperature is significantly lower than the temperature of the body ($p < 0.05$). After the exposure of the animal to a cold environment, temperature measurements show that Ts is significantly lower than in warm air, whereas Tb is not ($p < 0.05$).

Since with our method it was not possible to separately measure the temperature of the mucosa and the air contained in the sinus cavity (both temperatures were measured simultaneously), it is likely that Tb influenced the results of Ts by direct contact of the temperature probe with the sinus mucosa. We have therefore analyzed the temperature difference between Tb and Ts, as a measurement of the relative sinus temperature (Tb-s). The difference between Tb-s at 25 °C and at 10 °C is statistically insignificant ($p < 0.05$), indicating that the air temperature in the sinus does not undergo significant changes at different environmental temperatures.

In sinuses with a surgically created nasoantral window, Tb-s in cold air is significantly different from Tb-s in warm air. This was the case for both surgical groups (antrostomy and ostioplasty). This finding indicates that (cold) air enters the sinus cavity more easily if a large communication is created between the nose and the sinus; either by enlarging of the ostium or by creation of a window far from the ostium. Both types of surgery of the nasoantral wall and the ostium interfere with the capacity of these structures to keep a constant temperature within the maxillary sinus (air-conditioning).

This conclusion is supported by the measurements on day 84, when in the same animal the normal maxillary sinus was compared to the sinus with a nasoantral window. These results show that Tb-s in the operated sinus is significantly different from Tb-s in the non-operated sinus ($p < 0.05$) in group III. The fact that in group II this difference was not significant at the 0.05 level could be a result of the reduced size of the antrostomy windows after the three month of observation (three windows completely closed).

The significantly higher incidence of infections in group III cannot explain these difference between the two surgical groups on day 84, since measurements in an infected site are expected to be rather elevated. We have to assume that cold air in the sinus is at least partially responsible for the infections and their course. From results of other studies (Takagi et al., 1969; Mercke et al., 1974; Proctor et al., 1977; Olson and Bende, 1985; Togias et al., 1988; Naclerio et al., 1990), it can be suspected that cold (and dry) air in the maxillary sinus reduces mucocilliary transport and in this way could be responsible for pathologic changes of the sinus. In our study, the temperature measurements were taken at relatively moderate external temperatures (10 °C and 25 °C). It is possible that at more extreme external temperatures which commonly occur in nature, these findings would be even more pronounced.

CONCLUSION

The temperature of the maxillary sinus in rabbits is kept constant even when the external temperature changes. The capacity to maintain a constant temperature depends on an intact nasoantral wall and maxillary ostium. The small size of the ostium allows only a very small amount of the sinus air to be exchanged during respiration. Most of the ventilation of the sinus is therefore achieved by diffusion.

After enlargement of the ostium or creation of a nasoantral window, the capacity of air conditioning is reduced and the sinus temperature changes in correlation to the temperature of the environment. The effects of such changes in the type of ventilation of the sinus and in the conditioning of the exchanged air can only be speculated.

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