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The relationship between body posture and pressure in occluded maxillary sinus of man

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SUMMARY

One of the most common symptoms in sinusitis is pain over the infected cavity increasing when the patient is bending forward or lying down. It is commonly thought that this increase in pain is a result of increased pressure in the paranasal cavities when bending forward.

In this investigation we have found that changing the body position from sitting to recumbent or even to "head between knees" gives a manometrical pressure rise in the sinus that is too small to cause a pressure-mediated pain. The pain is probably caused by a dilation in the blood vessels of the infected mucosa when the patient is bending forward or lying down.

INTRODUCTION

One of the most common symptoms in sinusitis, inflammation of the paranasal cavities, is antral pain, increasing when the patient is lying down or bending forwards. This phenomenon has been discussed and studied by many authors and it has been suggested that the increased pain is a result of increasing antral pressure caused by increased blood content in the mucosa of the upper airways in a person in a semi-recumbent or recumbent position compared with a person sitting straight up or standing. Winslow et al. (1934) found that nasal mucosa increases in volume when his investigated persons changed position from sitting to recumbent. Jonson and Rundcrantz (1969) registered pressure changes in the bulb of the jugular vein in connection with changes of body posture. They found that the pressure in the jugular bulb rose when the investigated subject changed from sitting to recumbent as much as when the neck was compressed with an inflatable cuff with a pressure of 25 mm Hg. The pressure variations in the bulb in their experiments were 0.5 to 15 cm H_2O.

Rhinomanometry and investigations of the patency of the Eustachian tube (Rundcrantz, 1969) showed that changing body position from upright to recumbent causes an increase in mucosal volume, thus reducing the passage of air. Additional experiments by Rundcrantz (1969) also showed that in persons with nasal allergy or inflamed mucosa the swelling is more pronounced than in healthy individuals.

Studies of the effect of changes in body position on patency of the maxillary ostium were performed by Rantanen and Kortekangas (1971) and Aust and Drettner (1975). They found the same type of variations in size of the ostial lumen as was found in the nasal cavity and Eustachian tube by earlier investigators.

Aust et al. (1981) studied the correlation between antral pressure and antral pain in healthy and infected patients and found that a positive pressure of 400 cm of H_2O or a negative pressure of 110 cm of H_2O was needed to produce pain in human maxillary sinuses.

The aim of this investigation is to obtain more knowledge about the relationship in the paranasal sinuses between pressure and body position.

Furthermore, the relationship between antral pressure and antral pain in sinusitis will be discussed.

MATERIAL AND METHOD

Nine healthy volunteers, six women and three men aged 24–46 years, participated in this study.

For the registration of pressure variations in the investigated paranasal sinuses, a manometer EMT 33 (Elema Schönander) connected to a cannula with a plastic tube 800 mm of length and with an inner diameter of 0.8 mm was used (Figure 1). The inner diameter of the cannula was 1.2 mm. The signals from the manometer were amplified in an EMT 31 (Elema Schönander) amplifier and recorded with a Mingograph 32 (Elema Schönander).

Before the measurements of pressure variations in human maxillary sinuses, a series of tests concerning the validity and reliability of the manometer equipment were performed in model experiments and these experiments showed that the precision in measurements was high and that the different registrations of pressure varied less than 1% regardless of pressure or antral volume in the range in which we were working.

Calculation of antral volume

All studies were performed in experimentally occluded maxillary sinuses.

The volume of the investigated sinus was calculated according to Boyle's law in the following manner: Into the investigated, experimentally occluded sinus, 50 microliters of air were insufflated with a syringe and a cannula introduced into the maxillary sinus through the lower nasal meatus and the increase in antral

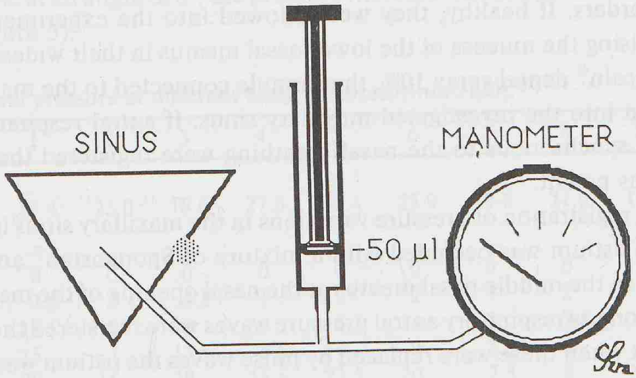

Figure 1. Equipment for measuring the volume of the maxillary sinus.

pressure was recorded. The initial pressure and the pressure rise, together with the volume of the insufflated air and the volume of the manometer system, makes calculation of the antral volume possible when used according to Boyle's law (Ingelstedt et al., 1967).

$$P \times V = P_1 \times V_1$$

P = Initial antral pressure.
V = Sinus volume + manometrical system volume.
P_1 = Antral pressure after insufflation of 50 microliters of air.
V_1 = Sinus volume + manometrical system volume minus 50 microliters of air.

Calculation of the volume of the antral mucosa

Aust and Helmius (1974) performed experimental studies with X-ray and contrast medium injections into maxillary sinuses of dry skulls. From these experiments they constructed a formula in which length, width and height of the sinus measured on the X-ray pictures in two projections gave both sinus volume and area of the antral mucosa.

In their study, they compared different hypothetically formed maxillary sinuses with known volumes and found that variations of the different sinus dimensions gave only small variations in the calculated mucosal area. They therefore approximated an ideal sinus form in which they estimated the mucosal area from the sinus volume and multiplied this area by 0.4 mm, being the thickness of the antral mucosa given by Tos (1979), thus getting an estimation of the volume of the antral mucosal lining.

Procedure of the experiments

The subjects participating in the study were thoroughly investigated regarding sinus disorders. If healthy, they were allowed into the experiments and after anaesthetising the mucosa of the lower nasal meatus in their widest nasal cavity with Xylocain® dental spray 10%, the cannula connected to the manometer was introduced into the investigated maxillary sinus. If antral respiratory pressure variations synchronous to the nasal breathing were registered the ostium was regarded as patent.

To enable registration of pressure variations in the maxillary sinus in our experiments the ostium was occluded with a mixture of Spongostan® and Xylocain® gel placed in the middle nasal meatus at the nasal opening of the maxillary ostial canal. As long as respiratory antral pressure waves were registered the ostium was patent, but when these were replaced by pulse waves the ostium was regarded to be closed.

With the ostium occluded and volume of the investigated sinus known, the antral pressure variations were recorded when the body position of the investigated persons was changed from sitting (90°) via 60°, 30°, 20° to 0° recumbent position (Figure 2).

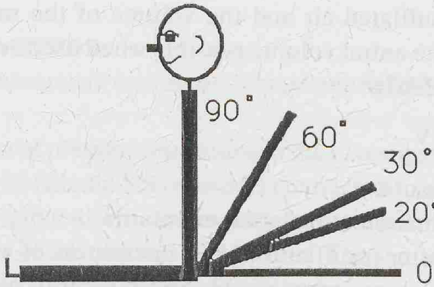

Figure 2. Body posture changes from sitting, 90° over 60°, 30°, 20° to recumbent 0°.

The measurements were made both with the person standing and sitting. Furthermore, three of the persons were investigated when bending forward from standing to "head between knees".

The investigated subject rested for two minutes between measurements on each step, to obtain steady state before each registration.

RESULTS

Changing position from 90° to 60° from horizontal gave an increase of the mean antral pressure of 2 mm H_2O. At an angle of 30° the mean pressure rise was 6 mm H_2O. When the investigated person was leaning further backwards to 20° the antral pressure was increased to 9 mm H_2O and when the subject was lying recumbent, i.e. at an angle of 0°, the pressure increase was as much as 17 mm H_2O (Table 1, Figure 3).

Table 1. Antral pressure at different body positions (mm H_2O).

case no.	1	2	3	4	5	6	7	8	9	M
sinus volume cm^3	23.4	23.0	18.0	27.6	31.4	23.9	19.6	21.6	16.8	22.8
position										
90°	0	0	0	0	0	0	0	0	0	0
60°	2.5	3	4.5	1	2	2	1	2	1	2
30°	12	6	10	4	8.5	4	3	2.5	6	6
20°	15	7	13.5	8.5	14	9	3.5	5	7	9
0°	20	15	28	15.5	23.5	20	7.5	8	19	17
forward bent position (−90°)							26.0	29.5	35.5	30.3

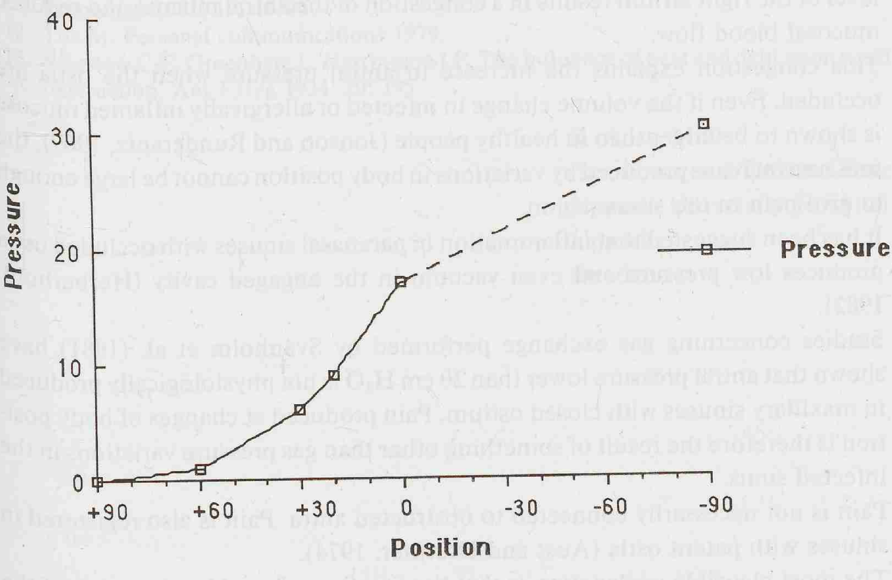

Figure 3. Relation between body position and antral pressure, mm H_2O (−90°, forward bent position).

This pressure rise corresponds to an increase of the mucosal volume of about 2%. When the investigated person was sitting up to 90° at the end of the experiments the antral pressure returned to the initial level almost immediately.

In three of the investigated subjects the antral pressure was measured when the person bent forwards to "head between knees" in standing position. The pressure rise from vertical to the forward position was just above 30 mm H_2O (Table 1). The sinus volume in the investigated persons varied from 16.8 to 31.4 cm^3. These volumes are relatively large compared to those found by Aust and Helmius (1974).

DISCUSSION

As seen by earlier investigators (Winslow et al., 1934; Jonson and Rundcrantz, 1969) the blood pressure and mucosal volume in the upper respiratory airways are increased when the body position is changed from upright to semi-recumbent, recumbent or bent forward. This investigation shows that this is also valid for the mucosa of the paranasal sinuses or at least for the mucosa of the maxillary sinus. The increase in mucosal volume is moderate and the increase in pressure is of the same magnitude that was found by Jonson and Rundcrantz in the jugular vein in corresponding experiments.

The stasis of the neck and head veins when the head is lowered to or below the level of the right atrium results in a congestion of the antral mucosa and reduced mucosal blood flow.

This congestion explains the increase in antral pressure when the ostia are occluded. Even if the volume change in infected or allergically inflamed mucosa is shown to be larger than in healthy people (Jonson and Rundcrantz, 1969), the pressure increase produced by variations in body position cannot be large enough to give pain in the sinus region.

It has been suggested that inflammation in paranasal sinuses with occluded ostia produces low pressure and even vacuum in the engaged cavity (Herberhold, 1982).

Studies concerning gas exchange performed by Svanholm et al. (1981) have shown that antral pressure lower than 20 cm H_2O is not physiologically produced in maxillary sinuses with closed ostium. Pain produced at changes of body position is therefore the result of something other than gas pressure variations in the infected sinus.

Pain is not necessarily connected to obstructed antra. Pain is also registered in sinuses with patent ostia (Aust and Drettner, 1974).

The most plausible explanation is that the pain is produced by extension of the vessels in the infected mucosa, a result of congestion and pressure rise in the mucosal veins hindering the arterial blood flow (Herberhold, 1982).

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