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Blood flow and pulse amplitude in the mucosa of the human maxillary sinus in relation to body posture

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SUMMARY

The paranasal sinuses are non-collapsable ventilated gas pockets without any known function. They should, however, be adequately ventilated to stay healthy. Persons lying in a recumbent body position compared to persons sitting or standing upright have reduced antral mucosal blood flow, a reduction of 35%, and a congested mucosa which reduces both the mucosal gas exchange and the perostial ventilation, creating a more anaerobic antral gas mixture facilitating pathogenic bacterial growth and reduced ciliary activity. It is, therefore, recommendable for patients with sinusitis to treat themselves or be treated in an upright or semi-recumbent body position.

INTRODUCTION

The maxillary sinus together with the other paranasal sinuses are, according to Rahn and VanLiew (1955), non-collapsable ventilated gas pockets. In spite of many investigations and speculations their function is still unknown. As long as they are adequately ventilated they generally remain healthy but when the ventilation is insufficient there are disturbances such as inflammation, pain and a feeling of fullness.

The gas transport of the paranasal sinuses takes place mainly by ventilation through their ostia but also by gas exchange through their mucosal lining. The perostial ventilation is dependent on ostial patency and nasal breathing. The mucosal ventilation is dependent on mucosal blood flow and to some extent on the mucosal thickness. The gas diffusion from the sinus cavity to the blood in the mucosa and from the mucosal blood to the sinus cavity is mainly perfusion-limited.

Winslow et al. (1934) found that thickness of the mucosa in the upper airways varied with changed body position. Persons lying down had thicker nasal mucosa than persons sitting up. Jonson and Rundcrantz (1969) studied the pressure in the bulb of the internal jugular vein and registered variations from 0.5 to 15 cm H_2O according to changes in the body position of the investigated persons. Aust and Drettner (1974) found that the diameter of the maxillary ostium was reduced when patients changed their position from sitting to recumbent, and Ivarsson et al. (1984) registered that this change in ostial diameter could be reduced by the administration of phenylpropanolamine nose drops. The volume changes of the respiratory mucosa in the upper airways is partly a result of variations in mucosal venous blood content caused by the lack of valves in the cervical and cranial veins and partly the result of the regulation of the autonomous nervous system on the arterial shunts and the venous sinusoids in the antral mucosa (Malm, 1974; Änggård, 1974). Not only the blood contents but also the blood flow in the antral mucosa are influenced by the body position.

When using radioactive Xenon, Bende (1983) found a reduction of the nasal blood flow when his investigated persons changed body position from sitting to recumbent.

The blood flow in the mucosa of the upper airways has been studied by means of various methods. Bende (1983) used, as mentioned above, radioactive Xenon, Kumlien (1984) investigated antral mucosal blood flow in rabbit with "fluorescein flowmetry" and microspheres tagged with ^{86}RbCl. The blood flow of the human maxillary mucosa was studied by Drettner and Aust (1974) using plethysmography and by Aust et al. (1978) using radioactive Xenon.

The aim of this investigation was to study changes in the maxillary blood flow in relation to variation of body position. This is an interesting question since it is known that gas exchange, both through the ostium and in the mucosa, is important for the normal healthy paranasal sinus and both pathways for ventilation are dependent on the mucosal blood content and flow.

METHOD AND MATERIAL

The variations in antral blood flow were registered as pressure changes in the investigated, experimentally occluded, sinus with a manometer EMT 33 (Elema Schönander) connected to an amplifier EMT 31 (Elema Schönander) and a Mingograph 32 (Elema Schönander). The manometer was connected by means of a thin plastic tubing, with an inner diameter of 0.8 mm, to a cannula with an inner diameter of 1.2 mm. After anaesthesia with Xylocain spray the cannula was introduced into the maxillary sinus through the lower nasal meatus as in antral lavage (Figure 1).

The mucosal blood flow was measured with plethysmography, the method we find simplest to use in humans. When the jugular veins bilaterally are compressed a pressure rise in the maxillary sinus can be registered and expressed in relation to the time of the compression. The blood flow was expressed as mm^3 blood/cm^3 sinus volume/min.

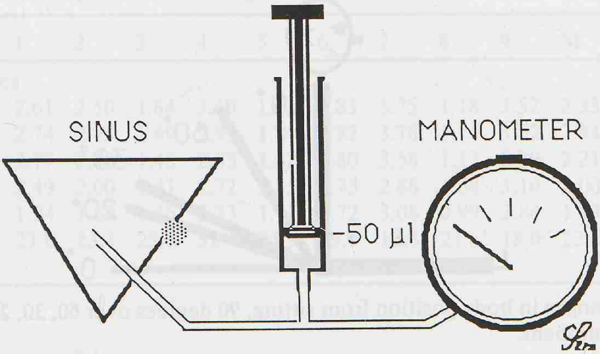

Figure 1. Equipment used for determination of the volume of the maxillary sinus.

The volume of the investigated sinus was calculated according to Boyle's law. A volume of 50 mm^3 of air was introduced into the occluded sinus, the pressure rise was registered and the volume of the sinus could be calculated (Ingelstedt et al., 1969; Aust and Helmius, 1974).

$P \times V = P^1 \times V^1$ P = initial sinus pressure.

V = sinus volume + manometrical system volume.

P^1 = Antral pressure after insufflation of 50 microliters of air.

V^1 = Sinus volume minus + manometrical system volume – 50 microliters.

The pressure rise caused by the insufflation of the 50 microliters of air does not compress the mucosa enough to cause any important error of the measurements. The experiments concerning pulse amplitude were performed in nine healthy volunteers, six women and three men aged 24 to 47 years. In the experiments with plethysmography, eight (five women and three men) participated.

PROCEDURE OF THE EXPERIMENTS

The experiment started with a thorough history and investigation of the person entering the study regarding nasal and antral disorders. If the person was found healthy she/he was placed sitting on a couch with an adjustable head end in a semi-recumbent position. The lateral wall of the lower nasal meatus was anaesthetised with Xylocain® dental spray and punctured with a cannula connected to the manometer system. Through the cannula introduced into the sinus the variations of antral pressure generated by nasal respiration were recorded. If there were respiratory pressure variations the ostium was patent.

The next step in the procedure was to close the ostium with Spongostan® moistened in Xylocain® gel. When no respiratory pressure variations could be recorded but pulse waves were registered instead, the ostium was registered as closed.

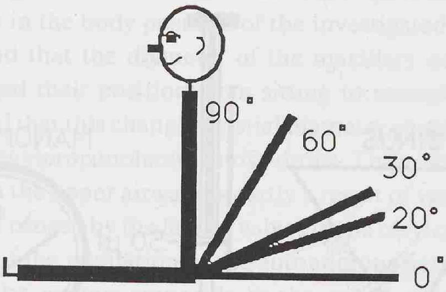

Figure 2. Changes in body position from sitting, 90 degrees over 60, 30, 20 to 0 degrees, recumbent.

When the ostium was occluded with sponge the amplitude of the pulse waves were registered with the person sitting on the couch in a body position of 90°, 60°, 30°, 20°, from horizontal and in recumbency, 0° (Figure 2). Registrations were made both when the body position was changed from recumbent to sitting and from sitting to recumbent, but the measurements were made from sitting to recumbent.

After a 5 minutes pause, the investigation was continued with plethysmographic studies with compression of the jugular veins bilaterally for 10 seconds with the body in the same positions as in the pulse wave recordings.

The series of experiments ended with the insufflation of 50 mm^3 of air through the cannula into the closed sinus for calculation of the antral volume from the pressure rise according to Boyle's law.

RESULTS

Antral pulse amplitude

In all investigated sinuses the pulse amplitude was reduced when the investigated person changed body position from sitting up (90° from horizontal) to recumbent (0°). From 90° to 60° no change occurred (Table 1), from 60° to 30° there was a decrease of 5%, from 30° to 20° another 9% and from 20° to 0° the registered reduction was still another 7%. The total change of pulse amplitude in the investigated sinus was 21% when the investigated person changed position from sitting to recumbent (Figure 3).

Antral blood flow

The results of the plethysmographic studies of the antral blood flow showed similar reduction of the flow when the investigated person changed position from sitting to recumbent (Table 2).

Table 1. Pulse amplitude (mm H_2O) in relation to body posture.

Case no.	1	2	3	4	5	6	7	8	9	M	%	Δ%
position degrees												
90	2.61	2.50	1.84	3.10	1.65	0.83	3.75	1.18	3.52	2.33	100	0
60	2.74	2.75	1.49	2.91	1.81	0.82	3.78	1.14	3.62	2.34	100	0
30	2.77	2.40	1.48	2.85	1.62	0.80	3.58	1.13	3.30	2.21	95	− 5
20	2.49	2.00	1.41	2.72	1.55	0.75	2.88	1.08	3.10	2.00	86	−14
0	1.94	1.68	1.46	2.33	1.41	0.72	3.08	0.99	2.84	1.83	79	−21
sinus volume cm^3	23.0	23.4	22.6	31.4	23.9	19.6	16.8	21.6	18.0	22.8		

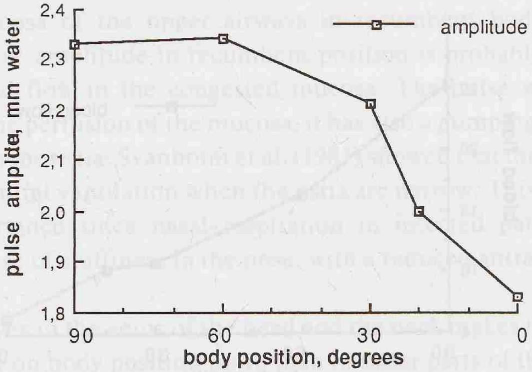

Figure 3. Relation between antral pulse amplitude and body position.

The change of body position from 90° to 60° resulted in a reduction of blood flow of 17%, the change from 60° to 30° another 10%, from 30° to 20° only 1% and from 20° to 0° an additional 7%, altogether being a 35% reduction (Table 2, Figure 4). The mean sinus volume in the first investigation was 22.8 cm^3 and in the second 22.7 cm^3

DISCUSSION

The paranasal sinuses are ventilated non-collapsable cavities without known function. However, they must be adequately ventilated both through their ostia and through their mucosa to remain healthy. The ventilation is important both for the gas composition in the sinus cavity and for the oxygen/carbon dioxide content in the mucosal tissues. Reduced ventilation results in increased antral carbon dioxide and reduced oxygen concentration (Svanholm et al., 1981). The gas mixture in the sinus cavity should differ as little as possible from normal air to avoid anaerobic conditions. Poor ventilation facilitates pathogenic bacterial growth. Both the perostial and the mucosal gas exchange are dependent on blood flow and blood content, regulating the thickness of the mucosa, in the antral mucosal lining.

Table 2. Mucosal blood flow (mm^3/min per cm^3 sinus volume/min) in relation to body posture.

Case no.	1	2	3	4	5	6	7	8	M	%	Δ%
position degrees											
90	32.1	15.6	29.0	27.5	22.8	26.1	12.6	11.7	22.2	100	0
60	30.9	14.2	21.0	20.2	18.0	25.5	11.5	6.7	18.5	83	−17
30	27.9	13.9	18.7	17.3	14.4	21.1	10.4	6.4	16.3	73	−27
20	25.8	12.6	17.6	17.9	13.2	23.9	12.1	6.0	16.1	72	−28
0	24.8	10.1	19.9	17.3	9.0	20.5	8.7	5.6	14.5	65	−35
sinus volume cm^3	23.0	18.0	27.6	31.4	23.9	16.8	21.6	19.6	22.7		

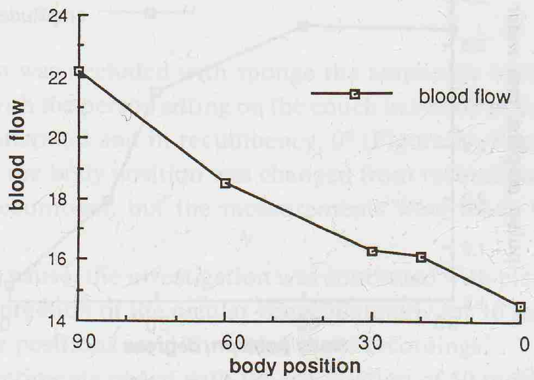

Figure 4. Mucosal blood flow (mm^3/min per cm^3 sinus volume) in relation to body posture.

This investigation, together with Bende's, shows that the blood flow in the mucosa of the upper airways has a pronounced variation depending on alteration in body posture.

Authors such as Winslow, Jonson and Rundcrantz have shown that the nasal cavity becomes less patent when patients are leaning backwards from sitting, the same phenomenon has been shown in the maxillary ostium by Rantanen and Kortekangas (1971) and by Aust and Drettner (1975).

This investigation shows that in spite of what could be expected, the blood flow and the pulse amplitude in the antral mucosa is reduced when the investigated person changes body position from sitting to recumbent. It is known that the systolic blood pressure in the head rises more than the diastolic in recumbent position, and logically, since the driving pressure is increased, one would also expect the blood flow and probably also the pulse amplitude to increase instead of decrease, as seen in this investigation.

The anatomy of the blood vessels in the upper airways is, however, very complicated with its shunts, anastomoses and sinusoides. Rundcrantz and Jonson have shown that this type of mucosa has an ability and tendency to become thicker the lower the head is located in relation to the right atrium of the heart. In their experiments they found a congestion in the mucosa of the nose and the Eustachian tube in recumbent position compared with sitting. This congestion, a result of increased hydrostatic pressure in the venous system of the head, reduces the venous blood flow, thus making it more difficult for the arterial blood to pass through the nasal and antral mucosa, resulting in a reduced blood flow.

It has been observed in space medicine that astronauts get swollen faces in gravitation-less situations. This could be explained by lack of negative venous pressure between the facial venous pressure and the thoracic. This results in a congestion of the facial veins, similar to what is observed in the mucosa of the respiratory mucosa of the upper airways in recumbent body position. The decrease in pulse amplitude in recumbent position is probably a result of the decreased blood flow in the congested mucosa. The pulse wave is not only important for the perfusion of the mucosa, it has also a pumping effect on the air passing through the ostia. Svanholm et al. (1981) showed that the pulse waves are important for antral ventilation when the ostia are narrow. This phenomenon is of great importance since nasal respiration in infected patients is already impaired because of stuffiness in the nose, with a reduced antral ventilation as a consequence.

The lack of valves in the veins of the head and the neck makes the venous blood flow dependent on body position more than in other parts of the body. Recumbent position of the upper part of the body results in congestion of the cranial tissues and a reduced blood flow which reduces the gas exchange over the mucosal vessels and narrows the ostial canal thus forming, as a result of the poor antral ventilation, a more anaerobic condition in the sinus with increased possibilities for pathogenic bacterial growth (Aust and Drettner, 1974). Furthermore, reduced oxygen tension in the paranasal sinuses is harmful to ciliary activity and for the mucociliary clearance (Naumann, 1963). The reduced blood flow in patients with sinusitis lying in bed in a recumbent position might also lower the immune activity (Herberhold, 1982), thus further delaying the healing process of sinusitis.

Our study of blood flow and pulse amplitude in the human paranasal sinuses supports the recommendations from Rundcrantz and others when they suggested that patients with upper respiratory infectious diseases should be treated in a sitting or semi-recumbent position. The investigation shows little difference in mucosal congestion and pulse amplitude when a person changes his body posture from 90° to 60° from horizontal (Falck, 1989). Patients suffering from nasal blockage and/or sinusitis should be treated in a comfortable semi-recumbent position.

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