

PRESSURE RECORDINGS IN THE MAXILLARY SINUS

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The pressure in the paranasal sinuses has been measured for various purposes.

The function of the paranasal sinuses

The first experiments in this field were made in order to study the function of the sinuses. **Braune and Clasen** (1876) measured the pressure in the maxillary sinus in a cadaver while a person was breathing into a tube sealed into the trachea. **Proetz** (1932) connected one water manometer to a needle introduced into the antrum and another to a needle held midway in the nasal fossa in living persons. From these investigations and from model experiments Proetz found that the pressure in the maxillary sinus was identical with that in the nasal cavity when the ostium was patent. With a narrow ostium there was a time-lag between the fluctuations in the sinus and the nasal fossa but the peak pressures were still the same. The fluctuation in pressure between inspiration and expiration amounted to about 10 mm H₂O, i.e. 1/1026 of an atmosphere. According to Boyle's law the exchange of air during one respiratory cycle is only 1/1026 of the air content in the sinuses. The hypothesis of the sinuses as a reservoir for warm and humid air which is utilized on inspiration, was therefore rejected by Proetz.

"Vacuum headache"

Another indication for measurements of the pressure in the paranasal sinuses arose when **Sluder** (1927) described the vacuum frontal headache. **Söderberg** (1934) measured the pressure in the frontal sinus during external operations for acute and chronic frontal sinusitis and found a positive pressure of between 10 and 66 mm H₂O. A negative pressure in the frontal sinus was found after aseptic occlusion of the nasofrontal duct in cats, but when this operation was combined with the instillation of Lugol's solution in the frontal sinus, the pressure became positive as a result of the inflammation and transudation. **Ballenger and Ballenger** (1952) found in experiments on dogs that occlusion of the nasofrontal duct gave a decrease of the pressure in the frontal sinus as frequently as an increase. These results were confirmed by **Doiteau** (1955) who also showed that an increase of the pressure was combined with an obvious transudation in the frontal sinus.

Air exchange in the sinuses

The exchange of air in the paranasal sinuses was also studied by **Doiteau** (1955). By measurements of the pressure and analysis of the gas content in

the frontal sinus in dogs, he showed that diffusion through the ostium and the mucosa was more important for the exchange of air in the sinus than the ventilation caused by changes in pressure during the respiratory cycle. **Flottes et al.** (1959) showed that the diffusion could be accelerated by sonic vibrations, which finding was utilized in aerosol treatments.

Pathophysiology of the ostium

Proetz (1932) and **Kerekes** (1934) analysed in model experiments and in patients various changes that may occur in the respiratory fluctuations of the maxillary sinus when the ostium or nasal cavity narrows. Kerekes found that respiratory fluctuations were usually present in normal sinuses but lacking in cases with sinusitis. Proetz and Kerekes also showed that the ostium sometimes functioned as a valve. In the evaluation of the results with sonic aerosols in sinusitis **Riu et al.** (1960) studied the permeability of the maxillary ostium by measuring the fluctuations in pressure of the sinus during respiration. After treatment with sonic or ordinary aerosols in various types of sinusitis the ostium was patent in 20 cases, partially obstructed in 3 and closed in 10 cases. The permeability before the treatment was not stated.

A study of the pathophysiology of the maxillary ostium has just been started in Uppsala. Pressure recordings are performed simultaneously from the maxillary sinus and nasal cavity. Two identical pressure transducers are used. One is connected to a needle which is introduced through the inferior meatus into the maxillary sinus after spraying the nasal mucosa with Xylocain without exadrine (R). The other is fitted to a narrow catheter which is placed with its tip in the region of the maxillary ostium. The transducers are connected to two amplifiers, and a direct writing apparatus is used for the recordings.

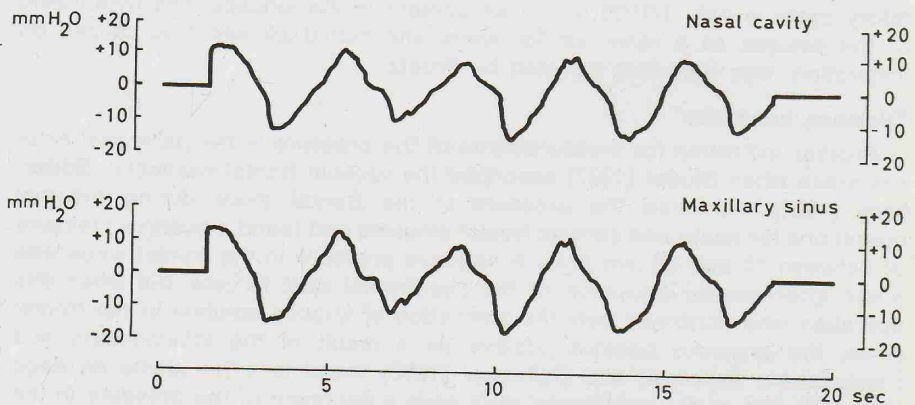


Fig. 1. Simultaneous recordings of the pressure in the nasal cavity and the maxillary sinus during forced breathing. Identical recordings showing a patent maxillary ostium. Normal sinus.

With a patent ostium the changes in pressure in the maxillary sinus and the nasal cavity are almost identical during ordinary and forced breathing (Fig. 1). When respiratory fluctuations are lacking in the maxillary sinus (Fig. 2)

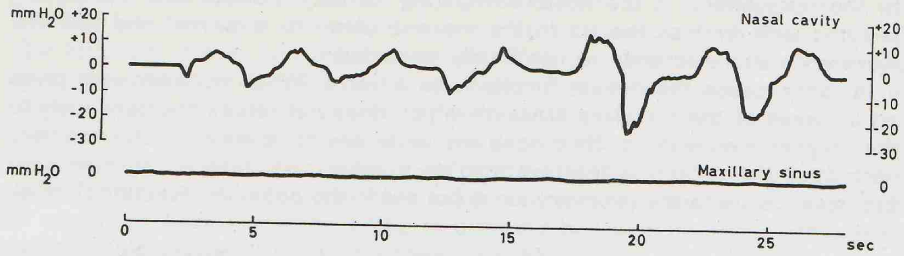


Fig. 2. Pressure recordings in the nasal cavity and maxillary sinus. No respiratory fluctuations are seen in the sinus, probably indicating an obstructed ostium. Chronic sinusitis.

the ostium may be obstructed, but similar recordings will also be made if the opening of the needle is situated in mucosa, polyps or mucus. Sometimes when the ostium is obstructed at first, it opens after blowing of the nose or sniffing. The pressure changes recorded from the maxillary sinus may be very small in comparison with the changes in the nasal cavity. According to **Proetz** (1932), such a result does not occur with a partially obstructed ostium. Model experiments have shown that water in the tube leading to the needle gives a decrease of the amplitude in the recording, and a discrepancy in amplitude between the recordings from the maxillary sinus and nasal cavity may then be due to an artifact.

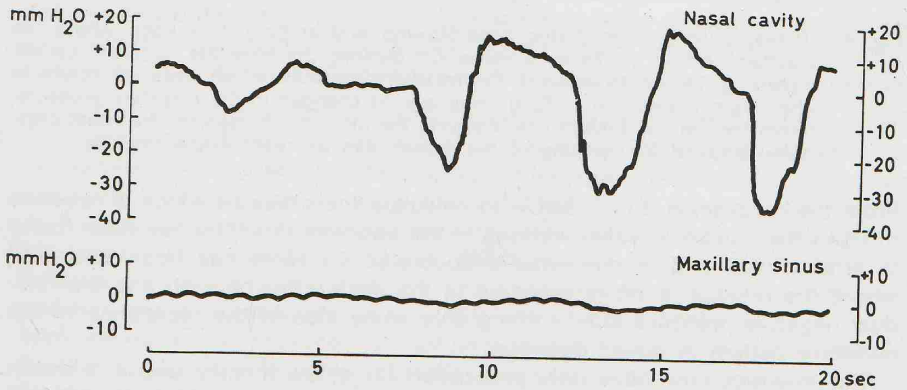


Fig. 3. Pulsations with the same rate as the heart in the maxillary recording. On forced breathing small respiratory fluctuations are present in the maxillary recording with a time-lag in relation to the fluctuations in the nasal cavity. Acute sinusitis.

Pulse waves in the maxillary recordings with the same rate as the heart are sometimes seen when respiratory fluctuations on ordinary breathing are absent in the sinus (Fig. 3). These pulsations may disappear when the needle is withdrawn a few millimeters. Small respiratory fluctuations superimposed on the pulse waves during forced respiration and with a time-lag in relation

to the fluctuations in the nasal cavity (Fig. 3) may indicate that the needle is lying with part of the tip in the mucosa close to a vessel and that the maxillary ostium at least is not totally occluded.

In some cases the ostium functions as a valve. When nose-blowing gives an increase of the maxillary pressure which does not return spontaneously to the original level while sniffing does not cause any fluctuations in the maxillary recording, the ostium is then working as a valve permitting air to flow from the nasal cavity to the maxillary sinus but not in the opposite direction (Fig. 4).

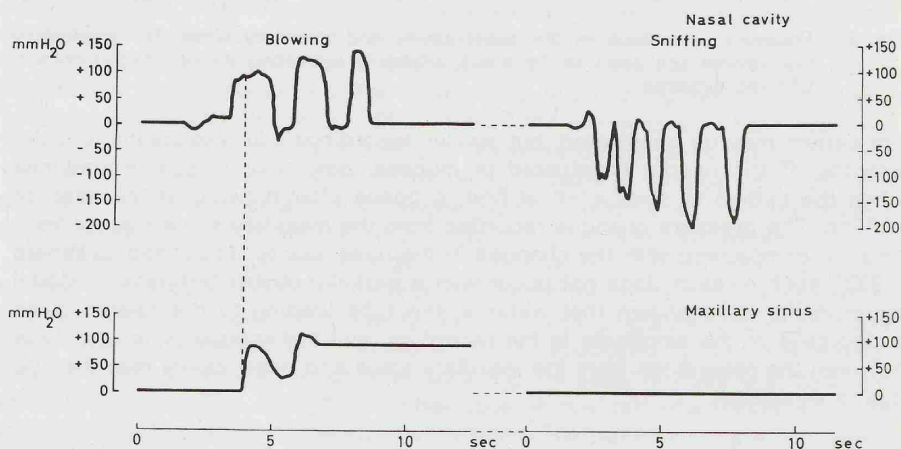


Fig. 4. Pressure recordings during nose-blowing and sniffing in a case where the maxillary ostium works as a valve. On blowing the nose the maxillary ostium opens, giving an increase in the maxillary pressure which does not return to the original level. On sniffing there are no changes in the maxillary pressure. From the vertical broken line, showing the moment of opening, the nasal pressure required for opening of the ostium can be read. Acute sinusitis.

From the recordings it is possible to calculate the pressure which is required to open the ostium. A valve working in the opposite direction has been found in other cases and in one case a double-acting valve has been observed where the residual positive pressure in the sinus after blowing and the residual negative pressure after sniffing give some idea of the resistance of the maxillary ostium in either direction.

The investigations have only proceeded for a few months and it is therefore too early to draw any conclusions about the occurrence of these different disturbances in the permeability of the maxillary ostium in various rhinological diseases. It is obvious however, that the maxillary ostium has been occluded in most of the investigated cases of acute and chronic sinusitis and nasal polyps.

The initial pressure in the maxillary sinus immediately after puncture has been measured in most patients. Values between -20 mm H_2O and $+30$ mm H_2O have been recorded in sinuses with an occluded ostium. In sinuses where the ostium works as a valve the initial pressure is usually positive in cases where the valve opens on blowing and negative in those where it opens on sniffing.

Irrigation has been performed by slow elevation of a bottle containing an isotonic solution, and the pressure required to overcome the resistance of the maxillary ostium has been measured. This has varied between 3 cm H₂O and more than 120 cm H₂O, with low values in cases with a patent ostium. In acute rhinogenous sinusitis the irrigation pressure shows a tendency to decline when the inflammation subsides but in chronic sinusitis it appears to remain high. During the elevation of the bottle there is a time-lag in the pressure obtained in the maxillary sinus, and this time-lag will obviously be a source of error when the bottle is elevated by hand. To reduce this error a bottle elevator with a uniform speed will be built.

The physiology and pathophysiology of the maxillary ostium warrant further investigations as a complement to the studies of the anatomy of the ostium performed by several authors (**Myerson**, 1932; van **Alyea**, 1936; **Simon**, 1939). It is hoped that pressure recordings in the maxillary sinus in normal persons and in patients with inflammatory or allergic diseases of the nose and paranasal sinuses will provide information as to how often and to what degree the maxillary ostium is occluded, and what effect disturbed permeability of the ostium may have on the clinical course of various nasal diseases, especially sinusitis.

ENREGISTREMENTS DE PRESSION DANS LE SINUS MAXILLAIRE

Les mesures de pression dans les sinus nasaux sur l'homme et l'animal ont été appliquées pour étudier la fonction des sinus nasaux, pour analyser scientifiquement la céphalalgie à vide, pour étudier l'échange d'air des sinus nasaux et pour examiner la pathophysologie des orifices des sinus nasaux.

L'auteur présente le résultat préliminaire d'un examen avec enregistrement de pression simultané dans le nez et le sinus maxillaire après ponction de ce dernier. Des variations de pression identiques pendant la respiration démontrent que l'orifice du sinus maxillaire est ouvert tandis qu'un manque de fluctuations dans le sinus maxillaire se produit entre autres lorsque l'orifice est fermé. Un orifice fermé dès le début s'ouvre quelquefois après s'être mouché ou avoir aspiré par le nez. Les variations de pression respiratoires qui sont moins prononcées dans l'enregistrement provenant du sinus maxillaire que dans celui provenant du nez se présentent comme un artifice quand il y a du liquide dans le tuyau raccordé à l'aiguille à ponction. Le pouls peut-être parfois observé dans l'enregistrement provenant du sinus maxillaire. L'orifice du sinus maxillaire fonctionne quelquefois comme une soupape, ce qui permet de mesurer sur les courbes d'enregistrement la sur- ou dépression nécessitée dans le nez pour surmonter la résistance dans l'orifice. La pression initiale dans le sinus maxillaire immédiatement après la ponction est souvent positive dans le cas où l'orifice permet le passage seulement lorsqu'on se mouche et négative dans le cas où l'orifice s'ouvre seulement en aspirant par le nez. La pression nécessaire pour le rinçage du sinus maxillaire montre une tendance décroissante au cours d'une sinusite rhinogène aigue en voie de guérison, tandis qu'elle reste élevée en cas de sinusite chronique.

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