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Measurement of velocity of air flow in the sinus maxillaris

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SUMMARY

Anemometry with the hot wire and hot film technique previously described, enables the rhinologist to record slow and rapidly changing air flow in the maxillary sinus. The advantages and disadvantages of this method are considered. Anemometry together with manometry may be designated sinumetry and used as a diagnostic procedure following sinuscopy in chronic maxillary sinus disease. The value of the function from velocity of time allows the estimation of flow-volume in the sinus. Furthermore, the method is useful to evaluate the optimal therapy to restore ventilation in the case of an obstructed ostium demonstrated before and after surgical opening in the inferior meatus.

In two previous papers (Müsebeck and Rosenberg, 1978 a, b) had been reported a remarkable hitherto unknown air flow in the maxillary sinus in direct relation with the respiratory cycle. The technique is based on the principles of hot wire anemometry. An air flow velocity of about 5 cm/s during normal breathing and up to 24 cm/s during forced breathing has been recorded in the maxillary antrum when the ostium is patent. In chronic sinusitis it is reduced if the ostium is partially or completely obstructed. In the course of diagnostic procedure we perform the sinumetry (anemometry and manometry) following sinuscopy (1978 c). The details of hot wire anemometry have been described previously. The top of the probe is heated to a temperature of about 120° Celsius. The principle of measurement is based on a loss of heat if there is an air flow.

The aims of this paper are to consider the advantages and disadvantages of anemometry in the maxillary sinus, to investigate the flow volume per minute, to asses the circulation of air stream and finally to hopefully use it as a tool in evaluating clinical progress.

The *advantages* of hot wire anemometry:

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1. The method permits the recording of the low but rapidly changing air flow we expect in the sinus.
2. The probes are small enough to put through the cannula of a 4 mm trocar used for sinuscopy.
3. The probes can be placed under direct visual control with the Hopkin's-Optic either near the ostium, in the center of the sinus or at one of the recessus.
4. It is useful for measurements in the nose and the sinus.

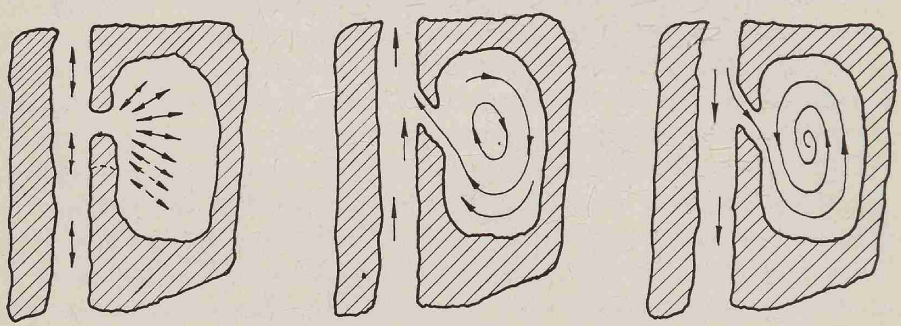
The disadvantages:

1. No commercial equipment available for measurements in the sinus.
2. Equipment should be fairly well calibrated for measurements.
3. The probe is dependent on the temperature.
4. The top of the probe can be mechanically damaged.

With the velocity value (mean value $c = 5$ cm/s) we can ascertain not only the relation of sinus resistance to pressure/volume ($R_s = P/V$) but also the value of air exchange (flow volume per minute = V_{min}) following the formula

$$V_{min} = c \times A$$

A is supposed to be a mean ostial cross-sectional area about 2,35 mm^2 (diameter of 2.4 mm) (Aust and Drettner, 1974b).
The estimated value of flow volume varies about 10–20 ml/min. The sinus contains an air capacity of 15 ml. Therefore, the exchange needs only one minute.



a straight angled ostium diffusion with oscillated movement

b inspiration: principle of water vacuum pump oblique angled ostium, circulation or turbulence

c exspiration: injector effect

Figure 1. The influence of the angle of the ostium on the air flow in the sinus.

Aust and Drettner (1974c) had been observed 90% Oxygen-exchange in a time of 1–20 minutes dependent on the size of the ostium.
Several factors may have influence on the great variations of air exchange and had to be considered like (Figure 1):

1. Period change of the respiratory cycle with short peaks of velocity.
2. Gap of velocity from ostium to the center of the sinus.
3. Border stream in the recessus.
4. Oscillated movements of air (Badré and Guillerm, 1960) (Figure 1a).
5. Circulation of air (Figure 1b and c).

Factor 4 is more observed in straight angled ostium, factor 5 in oblique angled ostium with injector-effect (Müsebeck and Rosenberg, 1978).
For the examination of the direction of air stream in the sinus the hot wire probe was covered with a hood passing air only in one direction (Figure 2).

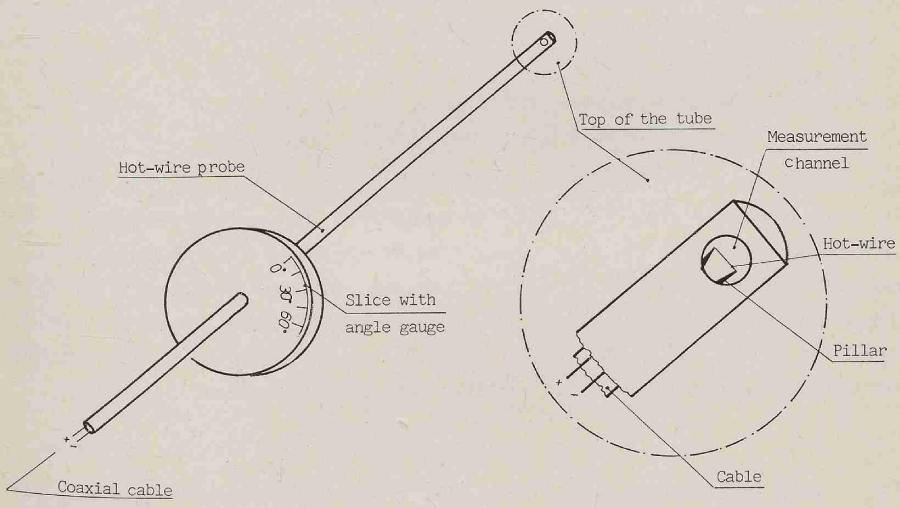


Figure 2. A covered hot-wire-probe for the examination of the direction of air stream in the sinus.

After axial converting to 90° no recordings could be observed. This directed anemometry is demonstrated in Figure 3. In this example, there is a completely obstructed ostium. The probe is introduced through the anterior wall of sinus. After placing of a second cannula through the inferior meatus only minimal flow occured. After a surgical opening in the inferior meatus (under local anesthesia) of about 1 cm diameter the air flow rises in the sinus to normal values. The recordings disappeared on the converted side of probe as expected. This example demonstrated the use of the probe as a mean of evaluating the efficacy of ventilator procedures. It is one modus how large the inferior meatal

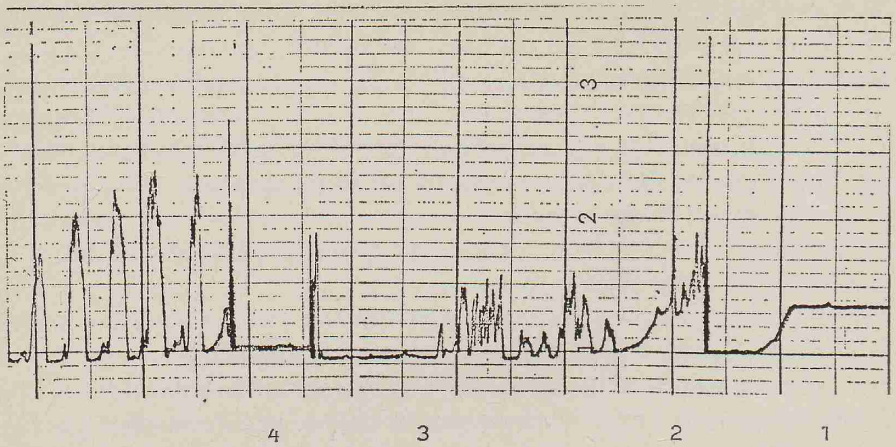


Figure 3. Control of surgical therapy for restoring ventilation in the sinus.
1 First probe (through anterior wall) registrating obstructed ostium.
2 Second probe placed through inferior meatus.
3 Minimal flow, disappeared after converted probe.
4 Returned probe registrating normal flow values after surgery.

antrostomy should be for optimal ventilation. No recordings could be observed in large openings after Caldwell-Luc approach, because the velocity is diminished according to the above mentioned formula $V = c \times A$. A small surgical ostium is more adapted for ventilation, because a directed air stream is possible. These and other research efforts with anemometry can be extended to determine the ventilation conditions of natural and operated ostiae or to detect correlations between ventilation and the restitution of diseased membrane.

ZUSAMMENFASSUNG

Die früher beschriebene Hitzdraht- und Heissfilm-Anemometrie ermöglicht dem Rhinologen, die schwachen und rasch wechselnden Luftströmungen in der Kieferhöhle zu messen. Die Vor- und Nachteile dieser Methode werden aufgeführt. Anemometrie und Manometrie werden als Sinumetrie bezeichnet, die für die Diagnostik der chronischen Sinusitis nach der Sinuskopie angewandt werden. Die zeitliche Aufzeichnung des Geschwindigkeitswertes erlaubt die Ermittlung des Minutenvolumens. Fernerhin ist die Methode zur Kontrolle für eine optimale Therapie brauchbar, wenn bei verschlossenem Ostium die Belüftung wiederherzustellen ist. Das wird an einem Beispiel vor und nach chirurgischer Eröffnung zum unteren Nasengang gezeigt.

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