Investigation of the blood flow in the maxillary sinus

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SUMMARY

Plethysmographic measurements of the blood flow in the mucosa of the human maxillary sinus was reported in 1974, but the errors of the method were not completely known. By measuring the absorption of the radioactive gas ^{133}Xe by the antral mucosa simultaneously with plethysmography a comparison between the two methods is possible. A good correlation between the two methods was found in the only subject investigated so far.

PLETHYSMOGRAPHY OF THE ANTRAL MUCOSA

A method for studying the blood flow of the mucosa in the maxillary sinus in living persons was reported in 1974 (Drettner and Aust) and this method could be used for quantitative measurements even if the magnitudes of all errors were not known. No quantitative measurements of human mucosal blood flow in the upper respiratory tract or in any human mucosa in vivo has been published before this study.

The method is a plethysmographic measurement based on the observation that pulse waves synchronous with the heart rate sometimes are recorded during pressure recordings from the maxillary sinus when the ostium is partially or totally obstructed. When similar recordings are performed in normal cases after nasal tamponade of the maxillary ostium, such pulse waves are almost always seen. The magnitude of the pulse waves can easily be measured quantitatively by calibration which is done by recording the pressure change during aspiration of a known volume of air from the measuring system and using Boyle's law. The height of the pulse waves shows the quantity of blood added to the maxillary mucosa by the effect of the systole of the heart. This is, however, not a blood flow measurement since it does not give the total blood flow of the mucosa.

Such a blood flow measurement can be performed when the jugular veins in the neck are compressed by applying pressure with two fingers on each side of the neck. During this compression, the recording rises and this rise is more pronounced during bilateral jugular compression than during compression only on

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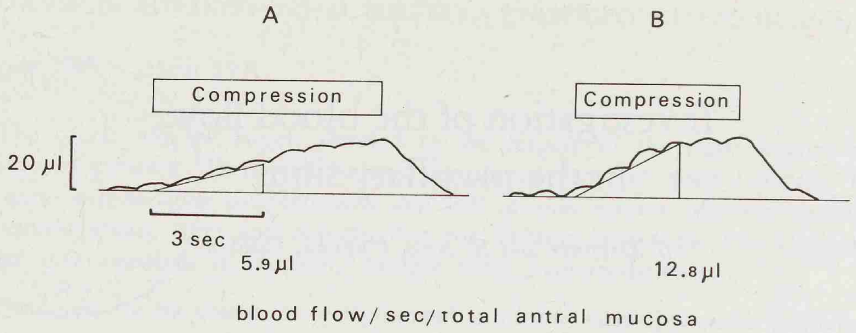

Figure 1. Plethysmography of the mucosa in the maxillary sinus during bilateral compression of the jugular veins before (A) and after (B) xenon study. The maxillary ostium was blocked by a tampon in the middle meatus.

one side. The slope of this rise during bilaterial compression gives the increase in volume per second which gives the blood flow per second for the whole antral mucosa. (Fig. 1).

The volume and the surface of the mucosa of the maxillar sinus can easily be measured roentgenographically (Aust and Helmius, 1974) and the blood flow per surface area of the mucosa can thus also be measured. A problem is to obtain a value of the thickness of the mucosa. According to the literature (Loring and Tenney, 1973) it is 125 μm. By using this value and transforming it to a common expression for blood flow, ml blood flow per 100 g tissue and minute, a value of 125 ml was obtained as a mean blood flow in seven subjects. (Drettner and Aust, 1974).

This plethysmographic measurement has certain errors which are difficult to evaluate. The effectiveness of the jugular compression is almost impossible to know. An outflow of blood to other vascular systems, for example to the vertebral veins, may occur during jugular compression but it seems that this error probably is small when the compression only lasts a few seconds. These two errors both work in the same direction implying that the value of the blood flow may be too low but they can hardly result in values which are too high. A back flow of blood in a retrograde direction from the compressed part of the jugular vein into the maxillary mucosa may occur since the veins have no valves. An overflow from other organs may also be possible, even if it seems likely that such an overflow is small. The magnitude of the errors caused by back flow or overflow of blood can not be measured with the reported method. These errors must be known in order to be able to use the method for studies of the blood flow during various physiological or pharmacological studies.

XENON ABSORPTION BY THE ANTRAL MUCOSA

Another method for study of the blood flow in the maxillary mucosa has therefore been worked out using xenon 133 which is a gamma radiating chemically

inert gas with a half life of 5.3 days. So far, we have only used xenon and plethysmography simultaneously in one person.

The ostium was blocked by tamponade and a cannula was introduced into the sinus. Plethysmography was done after verifying that the ostium was blocked. One ml gas containing eight μCi ^{133}Xe was then introduced through the cannula and the radioactivity measured by a natrium iodide crystal detector connected to a scaler and a semilogarithmic recorder. The measurement required approximately one hour.

RESULTS

It took 10-15 minutes before a decreasing radioactivity could be measured. (Fig. 2). This first period may be due to temperature differences and/or distribution to reach to the whole cavity as suggested by Elner and Nilsén (1970), when they studied gas exchange of the cell system of the ear. It may also be due to the time required for the gas to be absorbed by the mucosa before reaching the blood vessels. Xenon has a solubility in blood (and therefore probably also in tissues) which is about 6 times lower than that of nitrogen. After the first period the decrease in radioactivity from the maxillary sinus followed general physical laws and the blood flow could be measured from this result. Finally plethysmography was done again. The blood flow measured immediately after tamponade of the ostium with the plethysmographic technique was 0.13 $\mu l \cdot cm^{-2} \cdot s^{-1}$. (Fig. 1.). Calculation of the blood flow by xenon absorption gave a value of 0.28 $\mu l \cdot cm^{-2} \cdot s^{-1}$ and a new plethysmographic measurement immediately after the xenon study gave exactly the same value. (Fig. 1, table 1).

DISCUSSION

The only parameter which is unknown in the present investigation is the thick-

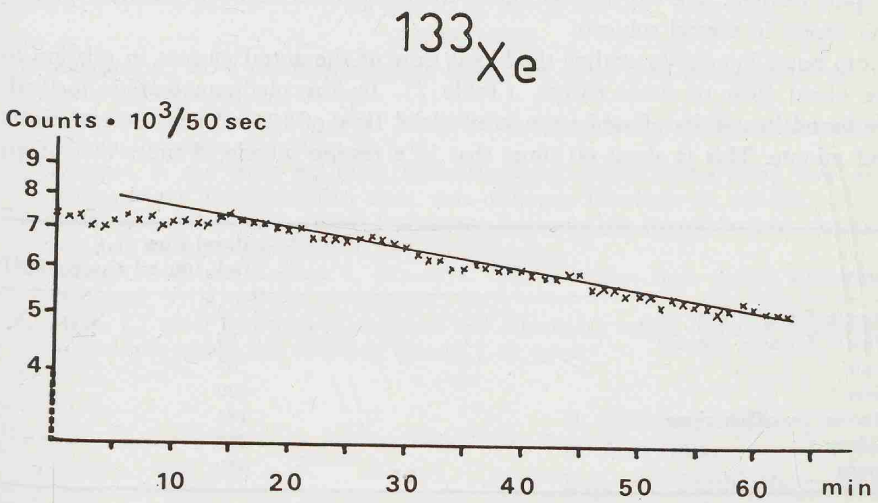

Figure 2. Recording of radioactivity from the maxillary sinus after introduction of ^{133}Xe in the sinus.

BLOOD FLOW OF THE ANTRAL MUCOSA		
	$\mu l \cdot cm^{-2} \cdot s^{-1}$	$ml \cdot 100\ cm^{-3} \cdot min^{-1}$
Plethysmography I	0.13	61
Xenon	0.28	135
Plethysmography II	0.28	135

Table 1. Results of blood flow measurements of the antral mucosa by plethysmography (twice) and ^{133}Xe in the same subject.

ness of the mucosa, but the results of both the methods are expressed in blood flow per surface area which makes the results independent of the thickness. However, if it is assumed that the thickness of the mucosa of the maxillary sinus has not changed during the procedures and if the thickness is estimated to be 125 μm, the blood flow calculated per 100 cm^3 tissue and minute is 61 ml according to the first plethysmographic measurement and 135 ml according to the xenon study and to the second plethysmographic measurement. Since the second measurement was done in close connection to the xenon study, and as considerable time passed between the first plethysmographic study and the xenon measurement it was, in this experiment, a good correlation between the two methods. The difference between the first and the second plethysmographic measurement may be due either to irritation, causing a more rapid blood flow or to increasing thickness of the mucosa or to an insufficient compression of the jugular veins at the first measurement.

It is thus possible to get a relatively good quantitative measurement of the blood flow of the mucosa of the maxillary sinus by the relatively simple plethysmographic method. We will be continuing the comparison between plethysmography and xenon in several subjects.

It can be of interest to analyse the blood flow of the antral mucosa in relation to the blood flow of other tissues. (Table 2). By the plethysmographic method, we found in a series of subjects a mean blood flow of 125 ml per 100 cm^3 tissue and minute. This is about 60 times that in a resting muscle, 4 times that of an

Tissue	Blood flow ($ml. \cdot 100\ g^{-1}$ tissue$\cdot min^{-1}$)
Muscle, forearm, rest	2
Muscle, forearm, exercise	30
Brain	65
Liver	100
Mucosa, maxillary sinus	125
Kidney	400
Lungs	450

Table 2. Blood flow in some human tissues according to textbooks in relation to the calculated blood flow of the mucosa of the maxillary sinus according to the present investigation.

active muscle, twice that of the brain and slightly more than that of the liver. Only the kidneys and the lungs have a greater blood flow.

Two other Swedish investigations published last year have shown a high blood flow in the nasal mucosa of cats. Malm (1974) found 130 ml per 100 g nasal mucosa and minute by catherisation of the draining vein, while Änggård (1974) presented figures indicating a total blood flow of about 120 ml, by the use of radioactive microspheres. Thus there is a high blood flow both in the nose and in the mucosa of the sinuses which seems to be of similar magnitude. However, the mucosal thickness in these human antral experiments was not known. All comparisons are therefore doubtful. We intend to reduce this doubt by measuring the mucosal thickness in cadavers.

ZUSAMMENFASSUNG

Plethysmografische Blutflussmessungen des menschlichen Kieferhöhlenschleimhautes wurden in 1974 publiziert, aber die Fehlerquellen der Methode waren nicht vollständig bekannt. Durch Messung der Absorption des radioaktiven Gases ^{133}Xe durch die Kieferhöhlenschleimhaut gleichzeitig mit Plethysmographie wurde ein Vergleich der beiden Methoden möglich. Eine gute Uebereinstimmung wurde in der bis jetzt einzige Probanden gefunden.

RÉSUMÉ

Les auteurs ont rapporté, en 1974, des mesures pléthysmographiques du flux sanguin au niveau de la muqueuse antrale chez l'homme; mais, les erreurs de la méthode n'avaient pu être totalement évaluées. Dans le présent travail, les auteurs rapportent les résultats d'une autre méthode qui consiste à mesurer l'absorption par la muqueuse antrale du Xenon ^{133}. Les deux méthodes ont été utilisées simultanément chez un même sujet et il apparaît qu'une bonne corrélation existe entre les résultats obtenus.

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