Rhinology, 22, 269-280, 1984

The nose as an indicating organ of vegetative controlling mechanisms

H. Simon, Leoben and H. Schmidt-Kloiber, Graz, Austria

SUMMARY

Long-term examinations on test persons of an average age of 28 years were carried out by means of thermistors for measuring the mucous membrane temperature and by means of photo transistors for measuring the state of cavernous tissues.
The tactile stimulus during the insertion of the probe regularly leads to a temperature increase and a swelling of the nasal mucous membrane.
Pronounced changes in the temperature do not take a linear course but are interrupted by intercurrent temperature inversions.
The changes in the state of cavernous tissues take a course synchronous to this. After the first tactile stimulus there adjusts a preliminary temperature equilibrium in the mucous membrane temperature and in the cavernous state. Then there follow temperature oscillations taking a completely different course, of changing amplitudes and frequencies. These temperature oscillations may take courses in the same or in opposite directions in the two nose halves.
The causes proposed for discussion, on the one hand for the intercurrent temperature inversions in case of considerable temperature changes, and on the other hand for the differing temperature oscillations after the attainment of the preliminary temperature equilibrium, are central regulating mechanisms, while at the same time analogous animal experiments are taken into consideration.

Already in 1895 Kayser observed that the state of cavernous tissues of the two nose halves changes alternatingly without external influence. In 1949 Pellegrini and Riva could observe temperature oscillations during warm-cold-alternating baths of a lower extremity with different time intervals, the most considerable temperature changes taking place in intervals of 10 minutes. The authors concluded from this that the body changes by itself the temperature of mucous membranes within these ten-minute intervals. Their illustrations indicated small wave-like temperature decreases after the caloric stimulation, within the frame of a greater temperature change. They did not, however, attach any importance to this phenomenon. Wyt (1958) measured the temperature of the membrane while closing the nostril and observed a considerable temperature increase in the beginning which, during the examination lasting for 20 minutes, changed over to temperature oscillations with a temperature difference of 0.05 °C. In his illustrations one can also find short wave-like temperature decreases after the insertion of the probe. During the following measuring time, which lasted for 20 minutes all together, temperature oscillations could be observed. The measurements, however, were carried out while excluding nose breathing, always on one side and without checking the state of cavernous tissues.

By means of the light absorption method of Simon and Schmidt-Kloiber (1971) it was possible for the first time to record, during unhindered nose breathing on both sides, the temperature of the mucous membrane and at the same time the state of cavernous tissues.

By means of this method, the reaction of the mucous membrane to thermal stimuli over a time period of up to 90 minutes was examined (Simon, 1980). During this examination first indications were found as to additional factors in the reaction behaviour of the mucous membrane.

METHOD

We measured the mucous membrane temperature in both of the lower meatus of the nose, by means of thermistors. The measurement of the cavernous state was determined at the lower concha of the nose by the light absorption method. This method allows a temperature measurement in the required range with a dissolution of 0.05 °C and a very sensitive recording of changes in the state of cavernous tissues. During the measurement the room temperature fluctuates between 21 °C and 23 °C and the air humidity between 43% and 50% relative moisture.

During this series of examinations, care was taken that reactions of the mucous membrane caused by infections were excluded.

Test persons were reclining in a comfortable position; thus examination periods between 60 and 145 minutes were possible without arising restlessness falsifying the measuring results.

From the preceding series of examinations (Simon, 1980) it was known that not exactly defined psychological alterations may lead to changes in the swelling state and the temperature. Therefore even seemingly neglectable observations and events were registered and related in time to the recorded changes of state.

Evaluation mode of the temperature behaviour after the contact stimulus

After the insertion of the probes into the lower meatus of the nose the tendency of the membrane temperature was always rising. The extent of the total temperature increase, the times of observed repeating and short-time changes in the temperature behaviour, as well as the choice of arisen interruptions in the total temperature increase fluctuated between individuals and measurements.

The time intervals and the extent of short-time temperature decreases were also characterized by considerable individual differences (Figure 1).

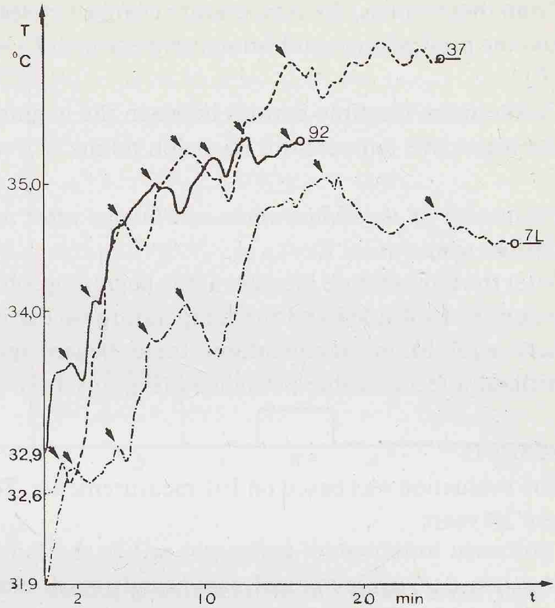

Figure 1.
Three typical instances of temperature increases, as could be recorded after inserting the probes into the lower meatus. The temperature inversion points (U_i) are marked by arrows.

In order to be able to interpret the multitude of observed curves and find connections between them, it was necessary to analyse the respective temperature curves according to different points of view. From each measurements curve the first four to six distinct temperature inversions were taken for evaluation and compared with the following values:

a. Initial temperature (T_a):
   The temperature recording began after the adaption of the probe temperature to the membrane temperature. This was achieved already within fractions of seconds.
b. Preliminary equilibrium temperature (T_v):
   After a quick temperature increase in the beginning (for 5 to 15 minutes), the curves later became distinctly flatter, the extent of the intercurrent temperature oscillations decreased with respect to frequency and amplitude, and within 16 to 30 minutes changed over to minimal temperature oscillations whose average value was determined as preliminary equilibrium temperature (T_v).

On the basis of a few typical measurement results the following parameters were evaluated (Figure 1):

- Initial temperature (T_a)
- Preliminary equilibrium temperature (T_v)
- Temperature inversion points (U_i), from which the temperature changes could be read.

From these values, the temperature change between the initial temperature (T_a) and the preliminary equilibrium temperature (T_v) was determined and related to (T_v).
Furthermore the time periods between the beginning of the measurement and the respective temperature inversion points (U_i) were measured.

Evaluation of the temperature oscillations after reaching the preliminary equilibrium temperature T_v
After the temperature increase at the beginning, obviously caused by contact irritation, had subsided and the temperature oscillations had reached the preliminary equilibrium temperature, there began again temperature oscillations without a recognizable periodicity (Figures 4–7).

RESULTS

The evaluation was based on 101 measurements. The average age of test persons was 28 years.

Temperature changes at the insertion of probes
The initial temperatures of the individual measurements were very different, they ranged from 31.9 °C to 35.6 °C. From this there results an individual temperature difference of 3.7 °C. Even between two nose halves temperature differences of up to 1.9 °C could be observed.
The recording of the mucous membrane temperature and of the filling state of the cavernous tissue, which changed considerably from the beginning, was only possible if we succeeded in immediately placing the probes correctly. The temperature increase, which in principle always showed a similar behaviour, was analysed more exactly on the basis of 17 measurements, which could be evaluated especially well according to the criteria mentioned below.
These criteria were:

a. Distinct temperature oscillations during the temperature increase.
b. Reduction of the temperature oscillations after a period of 17 minutes on average, and reaching a preliminary equilibrium temperature (T_v), which normally exceeded the initial temperature.

The four to six distinct temperature inversion points were taken as a basis of the evaluation.

Analysis of the temperature increase
The respective temperature inversion points were examined according to time and temperature difference. The results are presented in the Figures 2 and 3 by block diagrams. The block diagram in Figure 2 indicates that the preliminary equilibrium temperature is obviously aimed at by the organism.

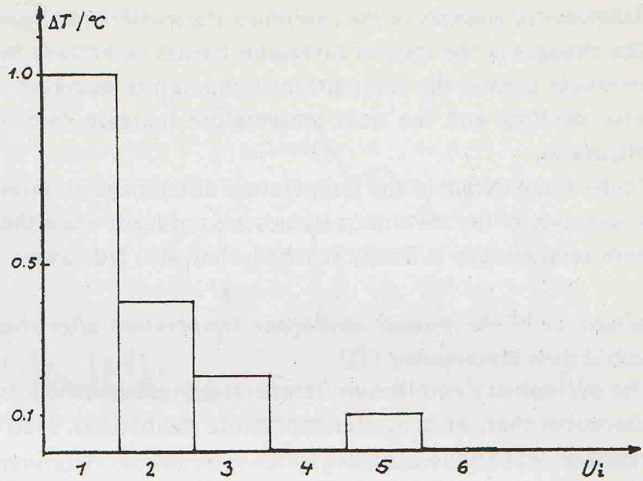

Figure 2.
Block diagram of the average temperature difference (ΔT) between the individual temperature inversion points (U_i) during the temperature increase.

In Figure 3 the average time periods of the respective temperature inversion points are shown. If one compares this with the block diagram of Figure 2, one can see that the temperature difference and the time period are not connected with each other by a simple correlation. On the contrary, complicated regulating mechanisms can be assumed.

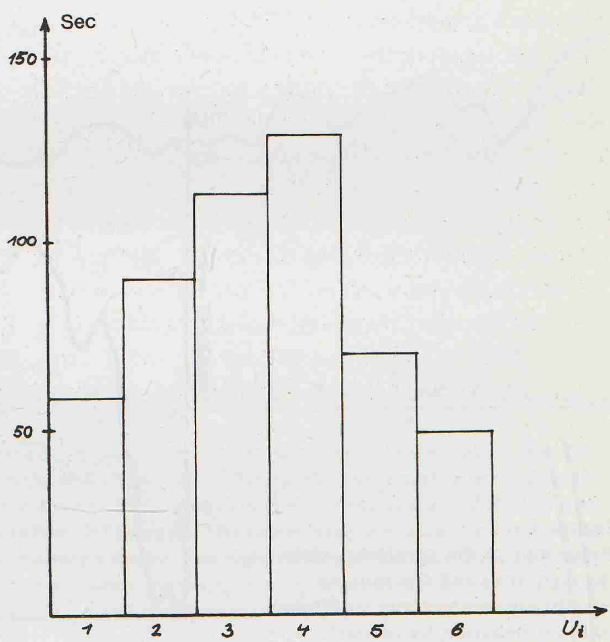

Figure 3.
Block diagram of the time differences between the individual temperature inversion points (U_i) during the temperature increase.

Behaviour of changes in the cavernous state within the frame of contact irritation
The changes in the state of cavernous tissues essentially follow the temperature inversion points; the intercurrent temperature decrease coincides with short-term swelling and the next temperature increase coincides with a shrinking (Figure 4).
To the same extent as the temperature differences become smaller, the changes in the state of the cavernous tissues are reduced; when the preliminary equilibrium temperature is finally reached, they also fade away.

Behaviour of the mucous membrane temperature after reaching the preliminary equilibrium temperature (T_v)
The preliminary equilibrium temperature remains the same for a few minutes; afterwards there arise again temperature oscillations, even though no deliberate irritation was applied (Figure 5).
The evaluation of the individual temperature curves shows deviations of T_v in both directions without any recognizable periodicity. According to continued recording, in a majority of cases the membrane temperature oscillated around the reached preliminary equilibrium temperature. For some test persons, a slow decrease of the temperature was noticed (Figure 5). Psychical alterations, however, can lead to a long-lasting temperature increase exceeding beyond the preliminary equilibrium temperature (Figure 6).

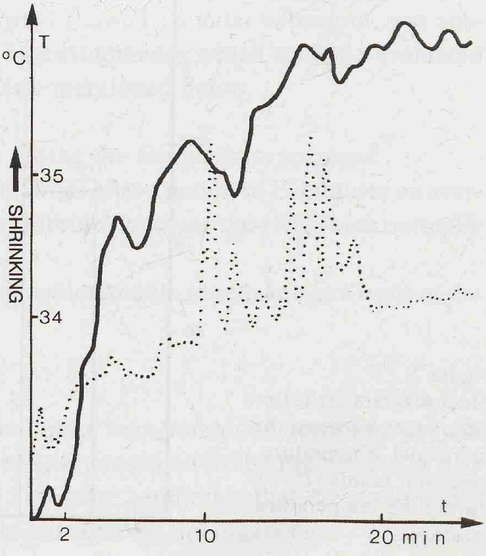

Figure 4.
Behaviour of the cavernous state (broken line) and the mucous membrane temperature (unbroken line) on irritation by contact.

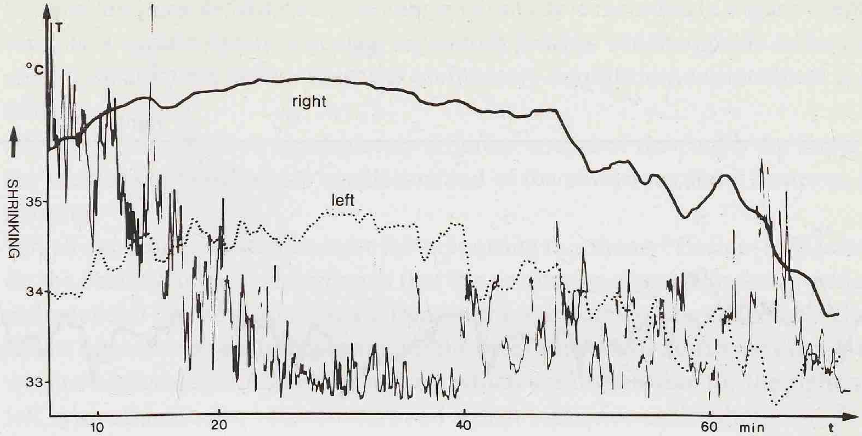

Figure 5. The initial temperature oscillations reach the preliminary equilibrium temperature (T_v) on both sides after approximately 30 minutes. The initially very strong shrinking process in the left nose remains constant during the achieved equilibrium temperature and afterwards it swells anew. After passing the preliminary equilibrium temperature (T_v), the temperature oscillations are again increased, on the left more actively than on the right, while the temperature gradually decrease on both sides.

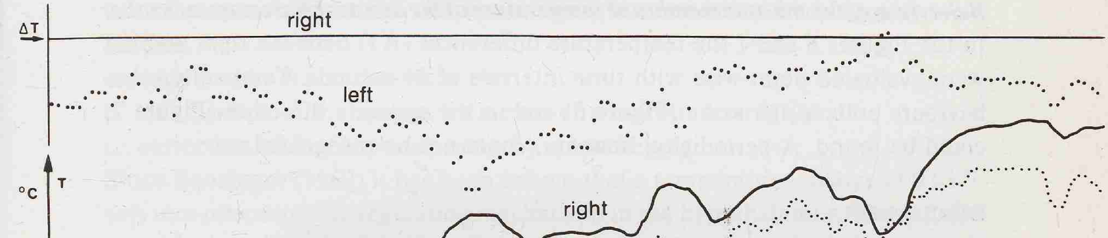

Figure 6. After the preliminary equilibrium temperature (not shown before the 20th minute) is reached, changes in the same direction of the membrane temperatures in the left and right halves of the nose are shown. The changes in the cavernous state of the left nose half go along with the temperature oscillations. The upper diagram shows the respective temperature differences (ΔT) between the left and right halves of the nose. In the 61st minute (↕) the temperature on both sides increases during a conversation. In the 109th minute, the test person is startled (↕) and the temperature sinks shortly on both sides, but rises again afterwards.

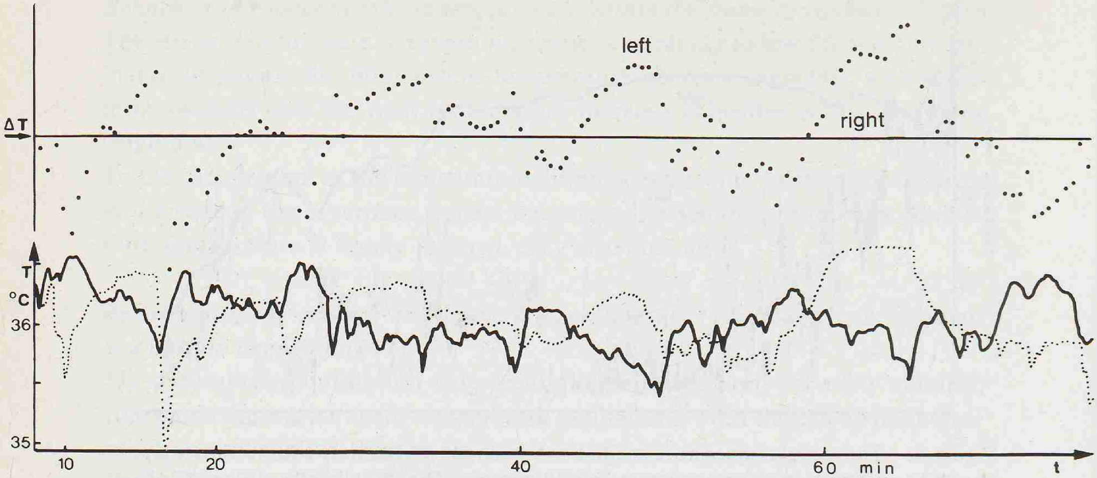

Figure 7. Changes in the opposite direction of mucous membrane temperatures in the left and right halves of the nose. The upper diagram shows the respective temperature difference (ΔT) of the left half of the nose as compared to the right half.

Behaviour of the mucous membrane temperature of the two nose halves to each other
In the Figures 6 and 7 the temperature differences (ΔT) between right and left were evaluated point-wise with time intervals of 24 seconds. Temperature behaviours both in the same (Figure 6) and in the opposite direction (Figure 7) could be found. A periodicity, however, could not be recognized.

DISCUSSION

Numerous observations and measurements of oscillations in the state of cavernous tissues - be it either within the frame of the cirkadian rhythm or of the so-called left-right-rhythm - of animals and human beings have been published (Simon, 1980; Eccles, 1978, 1983).

Above all the investigation by Bamford and Eccles (1982) showed that on anaesthetized cats there occurs an oscillation of the cavernous state between the right and left sides, without stimulation and during exclusion of physiological breathing, within time intervals of approximately 10 minutes. Although measurements carried out on the human nasal mucous membrane in such detail as the ones presented here have not been published so far, it is evident that the temperature of the nasal mucous membrane also oscillates. The characteristic abrupt temperature increase after the insertion of the probes is obviously induced by the tactile stimulus. The temperature inversions occurring within the first 20 minutes after the contact stimulus, with the preliminary equilibrium temperature apparently aimed at, give rise to supposing an endogenic oscillation rhythm which is thereby temporarily irritated. The course of the curve recorded in Figure 1 represents to a certain extent a central regulating process which appears to be concluded for the time being when the preliminary equilibrium temperature is attained.

After this there follows a completely different course of the curve, the factor of the membrane temperature oscillation and of the cavernous state, however, remaining.

Which experimental studies serve for supporting this theory? Eccles (1983) states on the basis of animal experiments that the oscillating changes in the cavernous state depend on the regular oscillations of the sympathicotonus. His theoretical model presumes a regulating centre for the breathing oscillation in the brain stem with two subsequent regulating centres which are responsible for the right and left sympathicotonus, respectively, and which influence each other.

Brown and Brengelmann (1970) developed a similar model on the basis of caloric stimuli where the complete body surface had been subjected to full baths with changing temperatures. In case of thermal stimuli with temperature changes of triangular or rectangular shapes, the metabolic process followed these temperature changes with a small delay, in the sense of a readjusting function. According to these authors, this regulating mechanism between a peripheric stimulus and a central response assumes a course according to a *not-linear-leed-lag-systeem,* as follows:

a. anticipation of the thermal stress;
b. stabilisation of the system by means of a built-in retardation;
c. correction of the response curve by smoothening.

Since Benzinger (1969) it has been known that a temperature change of 0.01 °C sets into operation the regulating mechanism in the hypothalamus. This similarity of the readjusting function of the metabolic process to the balancing out-process after a contact stimulus gives rise to the assumption that these short-term temperature inversions within the frame of the temperature increasing tendency reflect a central regulating mechanism. The nasal mucous membrane can only react by temperature increase or decrease to stimuli of any kind independent of whether a caloric stimulus from a distance (Simon, 1980), a direct contact stimulus or a vegetative stimulus is applied.

In case of a tactile stimulus the central response therefore is a temperature increase! From the following temperature inversions (Figures 1 and 4) the central readjusting mechanism becomes visible.

If the temperature differences after the tactile stimuli are represented in a block diagram (Figure 2), it can be clearly recognized that the organism aims at a new equilibrium temperature, depending on the influencing stimuli. For the block diagram (Figure 3), in which the time differences between the individual temperature inversion points are graphically represented, the theoretical models of

Brown and Brengelmann as well as of Eccles would provide an explanation for the non-conforming behaviour of the time differences as compared to the temperature differences.
If the central significance of the nose as that organ which provides information for the organism about the condition of the aerosol environment with respect to the ambient temperature is taken into consideration, the pronounced central response is easily understandable. Bamford and Eccles were able to measure the pronounced and prompt central response at the brain stem in case of a cooling of the nasal mucous membrane of animals.
The oscillations of the temperature and of the cavernous state, which are observed after the attainment of the preliminary state of equilibrium, are also endogenic, centrally regulated oscillations, which are additionally influenced by continuing probes stimuli, by also centrally controlled breath-induced oscillations as well as by a number of further psycho-vegetative factors difficult to attribute.

CONCLUSIONS

1. The tactile stimulus on the nasal mucous membrane leads to a temperature increase and to a shrinking of cavernous tissues.

2. A pronounced tendency of a temperature change is interrupted by temporary short-term temperature inversions.

3. The changes in the state of cavernous tissues take a course essentially synchronous with the temperature inversions, the temperature increase being coupled with the unswelling process and the temperature decrease with the swelling process.

4. Within 16 to 30 minutes the mucous membrane temperature and the state of cavernous tissues reach a preliminary equilibrium.

5. Without a new stimulus, a few minutes after reaching the preliminary equilibrium there occur again distinct oscillations of the membrane temperature and of the cavernous state, essentially within the range of the preliminary equilibrium.

6. The temperature oscillations in the two halves of the nose may exhibit behaviours both in the same or in the opposite direction.

7. It is presumed that the reaction behaviour of the nasal mucous membrane reflects central regulating processes.

ZUSAMMENFASSUNG

Mittels Thermistoren zur Schleimhauttemperaturmessung und Fototransistoren zur Schwellzustandsmessung wurden Langzeituntersuchungen an Probanden mit einem Durchschnittsalter von 28 Jahren durchgeführt.

Der Berührungsreiz bei Einführen der Sonden führt regelmäßig zu Temperaturerhöhung und Anschwellen der Nasenschleimhaut. Ausgeprägte Temperaturänderungen verlaufen nicht linear sondern sind durch interkurrente Temperaturumkehrungen unterbrochen. Die Schwellzustandsänderungen verlaufen dazu synchron. Nach dem ersten Berührungsreiz stellt sich bei Schleimhauttemperatur und Schwellzustand ein vorläufiges Temperaturgleichgewicht ein. Es folgen völlig anders verlaufende Temperaturschwankungen von wechselnder Amplitude und Frequenz. Diese Temperaturschwankungen können in beiden Nasenhälften zueinander sowohl gleich-, als auch entgegengerichtet verlaufen.

Als Ursachen einerseits für die interkurrenten Temperaturumkehrungen bei starken Temperaturänderungen und anderseits bei den anders gearteten Temperaturschwankungen nach Erreichen des vorläufigen Temperaturgleichgewichtes werden unter Heranziehung analoger Tierversuche sowohl zentrale als auch lokalautonome Regelmechanismen diskutiert.

ACKNOWLEDGEMENTS

This study was carried out at the university clinic of otolaryngology, Graz. We express our thanks to the head of the clinic, Univ.-Prof. Dr. W. Messerklinger, for his support of the examinations.

These investigations were made possible by the financial support of the fund for the advancement of scientific research (project number 1345).

REFERENCES

1. Bamford OS, Eccles R. The central reciprocal control of nasal vasomotor oscillations. Pflügers Arch 1982; 394:139–43.
2. Bamford OS, Eccles R. The role of sympathetic efferent activity in the regulation of brain temperature. Pflüger Arch 1983; 396:138–43.
3. Benzinger TH. Clinical temperature. New physiological basis. J Am Med Ass 1969; 209:1200.
4. Brown AC, Brengelmann GL. The interaction of peripheral and central inputs in the temperature regulation system. In: Hard J. Physiological and behavioral temperature regulation. Springfield, Illinois: Charles C. Thomas, 1970; 684–702.
5. Eccles R. The central rhythm of the nasal cycle. Acta Otolaryngol (Stockh) 1978; 86:464–8.
6. Eccles R. Sympathetic control of nasal erectile tissue. Eur J Resp Dis 1983; 64 (suppl 128):150–4.
7. Kayser R. Die exakte Messung der Luftdurchgängigkeit der Nase. Arch Lar Rhinol 1895; 3:101.
8. Pellegrini A, Riva G. Comportamento della temperatura della mucosa nasale in rapporto a stimuli termici cutanei. Arch Fisiol 1949; 48:320.

9. Simon H, Schmidt-Kloiber H. Messungen des Schwellungszustandes der menschlichen unteren Nasenmuschel durch Lichtabsorption. Mschr Ohrenheilk Lar-Rhinol 1971; 105:204.
10. Simon H. Die Nase als Erfolgsorgan thermischer Hautreize. Lar Rhinol 1980; 59:808–19.
11. Wyt L. Untersuchungen über die Oberflächentemperatur der Nasenschleimhaut. Mschr Ohrenheilk Lar-Rhinol 1958; 92:33.

H. Simon, M.D.
ENT-Department of the hospital Leoben
Vordernbergerstrasse 42
A-8700 Leoben
Austria