Temperature and humidity profile of the anterior nasal airways of patients with nasal septal perforation*

Jörg Lindemann, Stephan Kühnemann, Vera Stehmer, Richard Leiacker, Gerhard Rettinger, Tilman Keck

Department of Otorhinolaryngology , University of Ulm, Ulm, Germany

SUMMARY

Introduction*: The most frequent symptoms of patients with nasal septal perforations are crusting and bleeding. The aim of this study was to determine the influence of septal perforations on temperature and humidity of the anterior nasal airways.*

Patients and Methods*: Intranasal temperature and humidity were measured in the nasal valve area, the anterior turbinate area and in the nasopharynx during normal respiration. A miniaturized thermocouple and a humidity sensor were used for continuous detection. Ten patients with septal perforations were enclosed into the study. The results were compared to matched healthy control subjects.*

Results*: There were no significant differences of the temperature and humidity values between the left and right side of the nasal cavity in each study group. At the end of inspiration, nasal air temperature did not differ significantly between the two study groups. The humidity values at the end of inspiration were statistically significantly lower in the patient group.*

Conclusions*: Nasal septal perforations seem to be related to lower humidity in the anterior nasal airways during inspiration. Reduced humidity may contribute to crusting as a main symptom.*

Key words: septal perforation, air conditioning, humidity, temperature

INTRODUCTION

The perception of nasal obstruction and dryness are common complaints in rhinologic patients. These symptoms are frequently observed of patients with septal perforations. In most of the cases, septal perforations are located in the anterior part of the septum. Former septal surgery is the most common cause for perforations in this area (Fairbanks, 1980; Schultz-Coulon, 1997). Other well-known causes are cauterisation, packing, septal abscesses or haematoma, Wegener`s granulomatosis, nasal cocaine abuse and others. Rare reasons are AIDS associated (Rejali et al., 1999), cryoglobulinaemia (Smith et al., 1996), Non-Hodgkin`s lymphoma (Abbondanzo and Wenig, 1995), and rheumatic diseases (Wilkens et al., 1976). Besides the perception of nasal obstruction and dryness, crusting and recurrent epistaxis are typical symptoms of patients with septal perforation (Schultz-Coulon, 1997). They are attributed to changes of the nasal airflow, depending on the size and location of the perforation (Cole, 1992). Since the anterior nasal segment plays also an important part in air conditioning of the inspiratory air (Keck et al., 2000a; Keck et al., 2000b), nasal dryness and crusting may also be related to the loss of nasal mucosa of the anterior nasal septum. However, data about air conditioning of patients with septal perforations are still missing. Therefore, there were three main goals of the present study:

- Is there any difference in heating and humidification of inspired air between the two nasal cavities of patients with septal perforations?
- Do temperatures and humidities at different locations in the nose differ between patients with septal perforations and healthy control subjects at the end of inspiration?
- Is there any relation between measured values of temperature and humidity and subjective assessment of clinical symptoms?

MATERIAL AND METHODS

All experimental procedures were explained in full detail to the study participants, who provided written informed consent.

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The study was performed in accordance with the Declaration of Helsinki / Hong Kong (1964/1989) after receiving approval of the local ethic committee.

Patients and control subjects

Ten patients with septal perforation were entered into the study (6 females and 4 males) with an average age of 32 years (range: 20-54 years). Diagnosis was established on the basis of a thorough history and endoscopic findings. The duration of clinical symptoms due to the septal perforations ranged from one year to six years. In nine patients the septal perforation was located in area II (according to Cottle), in one patient in area III. The median diameter of the septal perforation was 1.5 cm. In seven patients the septal perforation was related to septal surgery, in two patients it was posttraumatic and in one patient the aetiology remained unknown. The patients were compared to ten age-matched healthy control subjects (1 female and 9 males; average age of 33 years; range: 22-50 years). The control subjects had no history of nasal surgery or nasal trauma and were non-allergic subjects. All study participants underwent an otorhinolaryngological examination including anterior rhinoscopy and endoscopy of the nasal cavity without application of decongestants or local anesthesia.

Temperature recording equipment

A thermocouple with an outer diameter of 0.34 mm (thermocouple type K, thermoelectric wire consisting of Chromel® and Alumel®, Thermocoax, Suresnes, France, technical temperature range –200 to +800 °C) was used for temperature recording. Its actual response time in non-moving air is 0.4 second; its actual response time in high velocity air is 0.1 second.

Humidity recording equipment

A capacitive thin-film humidity sensor (Humichip 17204 HM, Vaisala, Vantaa, Finland) was used for measuring relative humidity (RH). The capacitance of the sensor's polymer film changes sensitively with the absorption of water and is a measure of relative humidity (Ohhashi et al., 1998). The humidity sensor was incorporated in an acrylic glass box and connected to a suction system. Via a silicon suction probe with a length of 7 cm, an outer diameter of 2.5 mm and an inner diameter of 1.5 mm, air was transported to the humidity sensor. The volume of air sampled through the suction tube came to 17 ml/s. With this equipment relative humidity between 0 and 100 % could be measured. In high velocity air it took less than 2 s to reach 90 % of the steady state.

Calibration system

Calibration of the humidity sensor was carried out against saturated calibration salt solutions (LiCl 11.3 ± 0.3 %, NaCl 75.5 ± 0.1 %; HMK15 humidity calibrator, Vaisala, Vantaa, Finland) and results were compared to humidity values obtained by a standardized reference humidity indicator (HM14 and HMP41, Vaisala, Vantaa, Finland).

Registration of the respiratory cycle

The phase of inspiration and expiration during the respiratory cycle was continuously measured using a stress-sensitive belt around the chest (MAP, Martinsried, Germany). The signal of the sensor, integrated in the belt, was amplified and continuously recorded.

Simultaneous temperature and humidity recording

Initially the patients and the control subjects had to adapt for 20 to 30 min to the laboratory environment with a room temperature of 22 ± 1 °C (± SD) and relative humidity of 35 ± 2 % (± SD) while breathing quietly through the nose in an upright position. Attaching the suction probe to the thermocouple resulted in simultaneous humidity and temperature measurements. The technical equipment for intranasal measurements within the airstream has been described in detail previously (Keck et al., 2000). For measurements the suction probe was consecutively positioned in the nasal valve area close to the head of the inferior turbinate, in the anterior turbinate area close to the head of the middle turbinate and in the centre of the airstream of the nasopharynx. The mentioned nasal areas were exactly defined by Kern (1978). The probe was inserted into the nasal cavity by means of a nasal speculum and a headlight. Nasal endoscopy was then performed in the same nostril in which the probe was inserted to check its correct position. During recording the head was fixed in a head holder. Both nasal cavities of each patient and control subject were examined without decongestion and topical anaesthesia. Humidity and temperature in the airstream at each site of the nasal cavity was continuously recorded during respiration at quiet breathing for one minute. An interval of three minutes between each measurement at different locations within the nasal cavity allowed for mucosal adaptation (Keck et al., 2000).

Data processing and analysis

The humidity and temperature data were amplified and transferred to a computer via an analogue-to-digital card. Continuous registration using the computer program TurboLab (Bressner Technology, Munich, Germany) was achieved. For calculation respiratory cycles of 1 minute at each detection site in the nasal cavity were analysed. The mean end-inspiratory and end-expiratory relative humidity (RHaI=relative humidity after inspiration; RHaE=relative humidity after expiration) of one respiratory cycle of one minute was calculated. When the end-inspiratory values differed more than 3 percent RH, measurements were repeated after an interval of 3 minutes. The relative humidity of the ambient air (RHAA) was the reference value and was subtracted from the humidity at the end of inspiration (RHaI) to describe the increase in humidity after inspiration (RHaI-RHAA). This is termed as humidity difference. Analysis of temperature was done in the same way (TaI=temperature after inspiration; TaE=temperature after expiration; TAA=temperature of the ambient air; TaI-TAA=temperature difference). The mean of 3 repeated measurements was used for further calculation and analysis.

Nasal symptom score
The clinical symptoms of nasal obstruction, nasal dryness and recurrent epistaxis were assessed on a five point box scale with symptoms labeled 0= not present, 1= mild, 2= moderate, 3= severe, 4= very severe.

Statistical analysis
The non-parametric Wilcoxon signed rank test was used for comparison of both temperature and humidity increase between both nasal cavities in the patients and the control subjects. To compare the temperature increase at each detection site between both study groups the U-test (Mann-Whitney-Wilcoxon) was carried out. The null hypothesis (no difference of temperature increase between the patients and the controls) was to be rejected at the α= 0.05 significance level (Werner, 1992). The same test was used for comparison of the humidity data and the nasal symptom scores.

RESULTS

Intranasal temperature and humidity recording
A complete set of temperature and humidity data of the nasal valve area and the anterior turbinate area could be obtained in all patients and control subjects. Due to the vulnerable nasal mucosa of patients with septal perforations, measurements in the nasopharynx could not be done in all patients to avoid bleeding. Since some of the investigated patients with septal perforation also had a septal deviation, insertion of both an endoscope and the suction probe might have irritated the mucosa in the area of the septal perforation and bleeding might have occurred. The first series of measurements in some of the patients, however, showed temperatures between 32 and 34 °C and a relative humidity between 85 and 95 percent in the nasopharynx at the end of inspiration. These data were the same as the nasopharyngeal data in the control subjects, indicating that there seems to be no major difference in nasal airway temperature and humidity in the nasopharynx between the two study groups. However, nasopharyngeal data were not used for further calculation in this study.

Temperature and humidity increase in both nasal cavities
The increase in temperature and relative humidity in the nasal valve area and the anterior turbinate area was calculated as explained above. The values of the patients and the control subjects are shown in Table 1 and 2. Neither in the control group nor in the patient group a significant difference of increase in temperature and relative humidity at both detection sites between both nasal cavities was found.

Increase in temperature in the control subjects and the patients
The increases in temperature are calculations of the right nasal cavity. At both detection sites (nasal valve area, anterior turbinate area) the mean increase in temperature at the end of inspiration is slightly higher in the patients, compared to the controls. However, there is no significant difference of increase in temperature between the two study groups. The tendency of a higher end-inspiratory temperature in the patient group is more pronounced in the nasal valve area than in the anterior turbinate area (Figure 1).

Increase in humidity in the control subjects and the patients
The humidity results of the right nasal cavity were used for calculation. At both detection sites the mean increase in relative humidity at the end of inspiration is statistically significantly higher in the control group (Figure 2).

Table 1. Increase in relative humidity and temperature in the left and right side in the patient group (RHaI-RHAA; TaI-TAA; n=10; mean ± SD).

	Relative Humidity (%)		Temperature (°C)	
Intranasal location	Left	Right	Left	Right
Nasal valve area	40.7 ± 3.7	37.9 ± 10.3 (n.s.)	4.3 ± 1.9	4.8 ± 1.9 (n.s.)
Anterior turbinate area	47.1 ± 8.6	44.5 ± 9.7 (n.s.)	5.7 ± 3.4	4.8 ± 2.4 (n.s.)

Table 2. Increase in relative humidity and temperature in the left and right side in the control group (RHaI-RHAA; TaI-TAA; n=10; mean ± SD).

	Relative Humidity (%)		Temperature (°C)	
Intranasal location	Left	Right	Left	Right
Nasal valve area	49.8 ± 7.8	46.7 ± 7.2 (n.s.)	4.2 ± 1.7	4.1 ± 1.2 (n.s.)
Anterior turbinate area	53.9 ± 5.7	55.8 ± 4.0 (n.s.)	5.4 ± 1.7	4.5 ± 2.0 (n.s.)

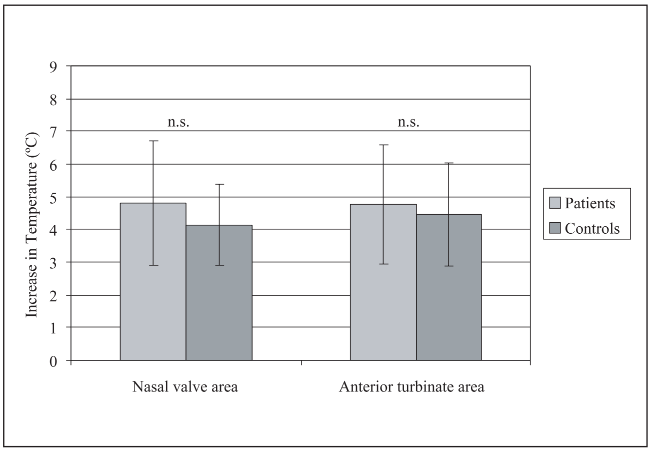

Figure 1. Increase in temperature within the nasal cavity compared to the ambient air (TaI-TAA; mean ± SD).

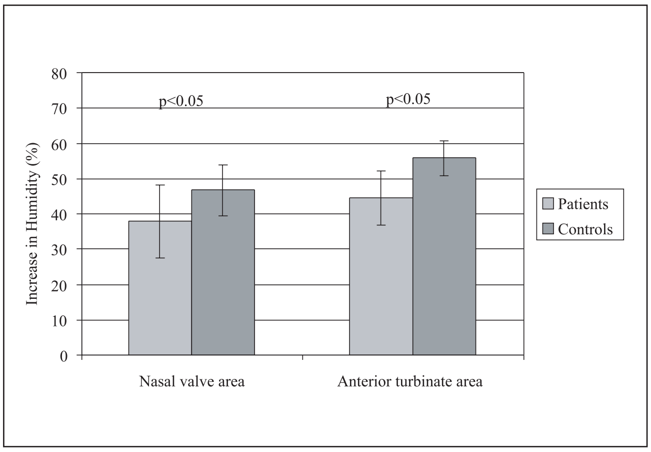

Figure 2. Increase in relative humidity within the nasal cavity compared to the ambient air (RHaI-RHAA; mean ± SD).

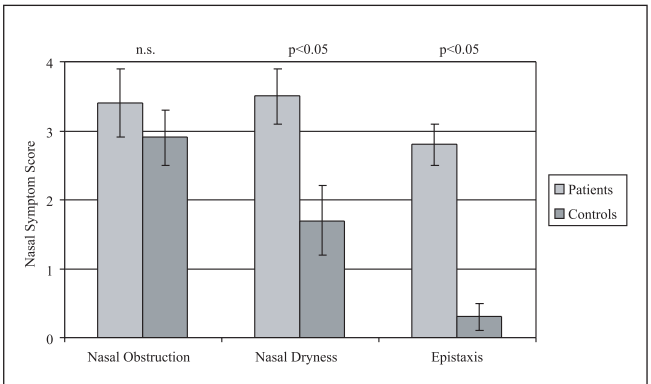

Figure 3. Nasal symptom score (0-4) in the patients and the control subjects (mean ± SD).

Nasal symptom score

The results of the nasal symptom scores are shown in Figure 3. Unsurprisingly, the patients with septal perforation suffered significantly more from nasal dryness and recurrent epistaxis than the control subjects. There was, however, no significant difference in the subjective assessment of nasal obstruction in both study groups.

DISCUSSION

The aim of this study was to investigate whether there is a difference in heating and humidification of inspired air between both nasal cavities of patients with septal perforation. In addition we investigated whether the increase in temperature and humidity at different intranasal sites at the end of inspiration differed between patients and control subjects. A further objective of the study was to evaluate a possible relation between data of temperature and humidity recording and subjective assessment of nasal symptoms. Temperature data were obtained from a miniaturized thermocouple, which could be previously shown to be suitable for in vivo measurements in the human nose (Keck et al., 2000a). Relative humidity was recorded using a capacitive humidity sensor connected to a suction probe. The clinical symptoms of nasal obstruction, nasal dryness and recurrent epistaxis were assessed on a five-point box scale.

In our study no significant difference of increase in temperature and relative humidity at the nasal valve area and the anterior turbinate area between the left and right nasal cavity in the patient group and the control group was found. Due to easy bleeding after trauma of the septal mucosa and frequent septal deflections behind the perforation, nasopharyngeal measurements were not feasible in all patients. However, similar temperature and humidity results to those of the control subjects in the nasopharynx could be observed in some patients. In the temperature measurements, a tendency to a higher increase at the nasal valve area and the anterior turbinate area in the patient group compared to the control group was observed. The increase in humidity at the nasal valve and the anterior turbinate area was significantly higher in the control subjects, compared to the patients. The patients suffered more from nasal dryness and recurrent epistaxis than the healthy subjects. However, a relation between air conditioning data and subjective assessment of nasal symptoms could not be clearly investigated in this study.

No comparative data are available about nasal air conditioning of patients with septal perforations (Drettner et al., 1977). Previous measurements in healthy subjects demonstrated that the inspired air is primarily heated already in the anterior nasal segment (Keck et al., 2000a; Keck et al., 2000b). Therefore it could be assumed that changes in the airflow due to septal perforations in the anterior septum and the loss of mucosa in this area could lead to a reduced heating of the inhaled air.

However, no significant difference in heating in the anterior nasal segment was found between the patients and the controls. When the inspiratory air passes the nasal valve area, the laminar airflow becomes turbulent and allows contact to the nasal mucosa. The loss of mucosa of the anterior septum seems not to be relevant for heating since the airflow pattern is disrupted in the nasal valve area and the air is spread over the entire nasal walls at the level of the perforation and behind it (Cole, 1992). Perforations in the anterior nasal septum may reduce the velocity of the inhaled air and allow longer contact of the air with the surrounding mucosa. The increased contact time seems to be long enough to warm the inspiratory air effectively. During expiration, septal perforations also disrupt the airflow of the expired air. It is possible that an increased recovery of heat from the expiratory air occurs in the anterior nasal segment due to turbulences and an increased contact time with the mucosa. Lower end-expiratory airway temperatures at the nasal valve and anterior turbinate area of patients with septal perforations compared to healthy control subjects (unpublished data), underline a sufficient recovery of latent heat which contributes efficiently to the heating of inspiratory air. The observation of warmer inspiratory air during narrowing of the nasal vestibule, compared to a dilated vestibule (Cole, 1954), demonstrates the complexity of the relationship of airflow pattern and heating in the nose. It also underlines our observation of slightly increased mean end-inspiratory temperatures in the patients, even if an objective assessment of reduced nasal patency was not feasible and narrowed nasal airways were not objectively measured in our patients.

The significantly lower increase in relative humidity in the patient group was observed in the nasal valve area and the anterior turbinate area. An explanation is the loss of nasal mucosa of the septum. The anterior nasal mucosa contains a relatively big amount of small seromucous glands (Tos and Mogensen, 1976). The nasal glands are known to contribute to humidification in the nose (Ingelstedt and Ivstam, 1949) and, therefore, the loss of nasal tissue may lead to reduced water supply to inspiratory air. During expiration the recovery of water from the expired air can be reduced due to the loss of nasal mucosa in the anterior septum.

Since the airflow during inspiration and expiration is disturbed in the area of the septal perforations, both a reduced water supply to the inspiratory air and a lower water recovery from the expiratory air imbalance the water vapour gradient between the air and the mucosa. Furthermore, dryness occurs in the area of septal perforations.

Measurement results of one side of the nose could not easily be correlated to subjective assessments of both nasal cavities, even if no difference of temperature and humidity results in both nasal cavities were found. However, the significantly higher degree of dryness in the nose of patients with septal perforation underlines the pathophysiological model of imbalanced nasal airway humidity in septal perforations.

CONCLUSION

Nasal air conditioning is important for protection of the lower respiratory tract. Septal perforations seem to be related to lower humidity in the anterior nasal airways during inspiration. Reduced humidity may contribute to crusting and nasal dryness as main symptoms. Further investigations about the regeneration of the nasal function and its influence on nasal patency and symptoms after surgical closure of septal perforations will follow.

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Jörg Lindemann, MD
Department of Otorhinolaryngology
University of Ulm
Prittwitzstr. 43
D- 89075 Ulm
Germany

Tel: + 49 731 5027501
Fax: + 49 731 5026703
E-mail: wiesmiller-lindemann@t-online.de