A NON-INVASIVE TECHNIQUE FOR IN-VIVO EVALUATION OF NASAL FUNCTION

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INTRODUCTION

Humans usually inspire through their nasal cavity since it protects the internal milieu of the lung against invading particles and it conditions the inspired ambient air to nearly alveolar conditions (e.g., body temperature and fully saturated with water vapor). Presently, nasal dysfunction is mainly diagnosed according to subjective complaints of the patient, while only nasal patency may be measured objectively using rhinomanometry techniques [1]. However, most of these techniques are invasive and do not allow simultaneous measurements from both nostrils. In this study we developed a non-invasive technique for simultaneous measurement of nasal airflow rate and temperature from both sides of the nose. For objective evaluation of the measuring devise we also built a modular nose model for *in-vitro* experiments with a respiratory simulator.

METHOD

Measuring device. The measuring system was designed to allow for non-invasive simultaneous measurement of nasal airflow rate and temperature from both nostrils. The nasal airflow rate was evaluated from the resistance to airflow of a tube that can distinguish between inspiratory and expiratory flows of up to 1 L/sec. Based on preliminary experiments, it was built from an aluminum tube (10 mm internal diameter, 200 mm long) with a commercial nosepiece (Eccovision) attached to its proximal end to ensure air-tide sealing during measurements (Fig. 1). The pressure gradient was measured with a highly sensitive differential pressure transducer along a distance of 50 mm, starting 50 mm distal to the nosepiece. The nasal airflow transducer was calibrated with a simulator that can produce human respiratory signals that mimic different breathing efforts [2]. The temperature was measured with a fast responding K type thermocouple that was installed within the nosepiece. All the measurements were fully computerized using an A/D board and a personal computer.

Nose replica. A rigid aluminum model of the nose was built to allow for accurate and repeatable *in vitro* experiments. The nasal replica was composed of the internal cavity and an external nose (Fig. 2). It reproduced the most important inner structures of the cavity and was based on mean anatomical values [3]. A thin aluminum plate representing the septum separated the cavity into two symmetric compartments. Each compartment contained the inferior and middle turbinates that can be removed for simulations of pathologies. The external nose was made from white clay in three sizes of the nostrils cross-section including a constriction to simulate the nasal valve.

In vitro experiments. The respiratory simulator [2] was used to induce sinusoidal airflows through the nose replica with maximal airflows of 1 L/sec and 2 L/sec (Fig. 3). Measurements were conducted for the following cases: 1) all the turbinates intact, 2) the upper right turbinate removed, 3) the lower right turbinate removed, and 4) both right turbinates removed.

In vivo experiments. Nine healthy volunteers participated in the *in vivo* evaluation of the new device. Measurements were acquired while the subjects were sitting with erected backs (Figure 4). In each test the subject breathed a sequence of regular breathing, breathing with increased effort and deep breathing during 90 seconds. The subject relaxed for about 1-2 minutes between successive tests. Immediately after the second test the geometry of the subject's nose was measured with an acoustic rhinometer for comparison with the airflow study.

RESULTS AND DISCUSSION

The *in vitro* study with the nose model revealed that in the normal and healthy nose the airflow is equally divided between the nostrils, as expected in a symmetrical structure. However, when the two turbinates were removed from the right side of the cavity, a difference of about 10% was obtained between the airflow rates from both nostrils. In this respect it should be considered that the calibration sensitivity of the transducer was about 6%.

Analysis of patients' data in patients included mean and maximum temperature and airflow rate for each side of the nose, and ratios between these parameters for left and right nostrils. As expected, measurements from left and right nostrils of healthy subjects demonstrates almost the same values for both temperature and airflow rate. The measured data demonstrated a total volume of about 0.5 L in quiet breathing with a respiratory cycle of 4 to 6 seconds where expiration is usually longer than inspiration. These results were in the range of published physiological data. In seven subjects the acoustic rhinometer results correlated well with the airflow rate measurements with higher airflow rates in the patent nostril.

CONCLUSION

A new method for non-invasive assessment of nasal function has been developed. It has the ability to measure information from both nostrils simultaneously. However, the sensitivity of the airflow transducer needs improvements in order to differentiate small changes in the nose geometry. The nose model was found very useful in determination of the characteristics of the new device. The *in vivo* study revealed the potential of simultaneous measurements from both nostrils that can be utilized to more accurately study the nasal cycle as well as for clinical applications in the diagnosis of nasal pathologies.

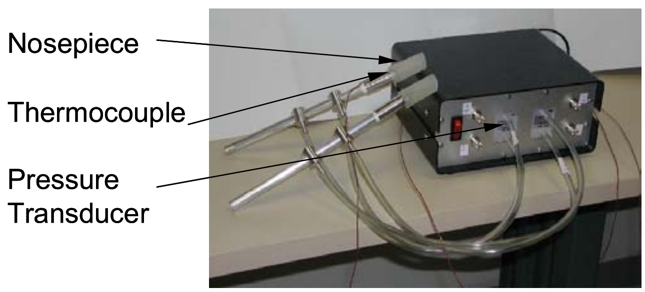
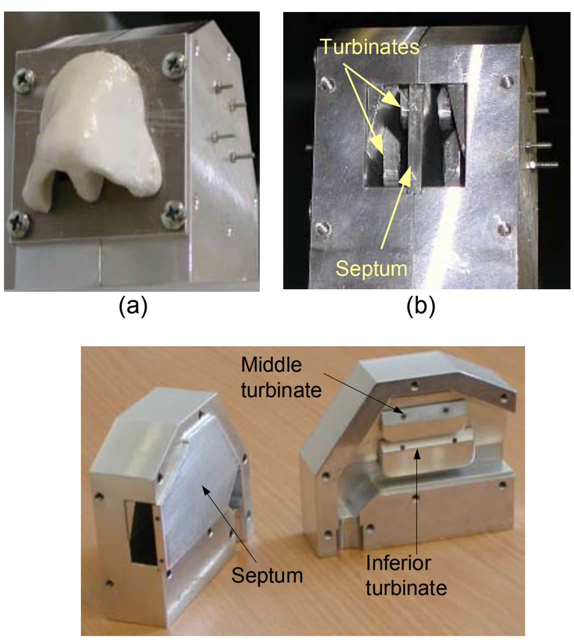


Figure 1. Device for measuring nasal airflow and temperature.



(a) (b)

(c)

Figure 2. The nose replica: (a) external view,
(b) coronal cross-section, (c) internal structures.

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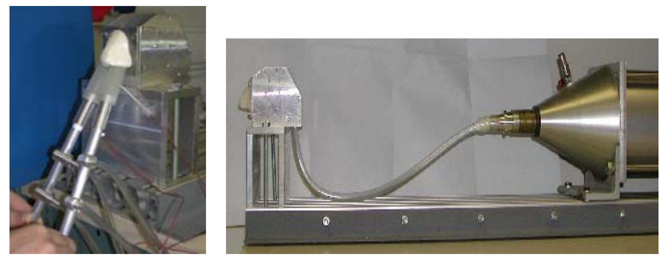

(a) (b)

Figure 3(a-b). *In vitro* experiments with the nose replica.

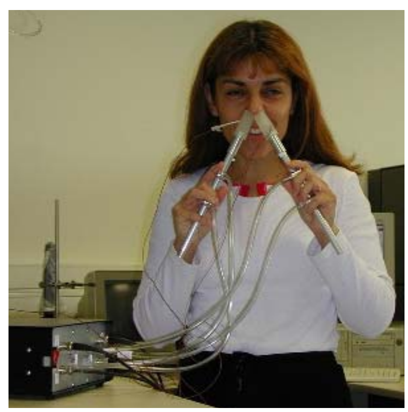

Figure 4. *In vivo* measurement of nasal functions.