Simulation of Nasal Air Flow from High Resolution MRI Images of Patients with Empty Nose Syndrome

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Introduction. To improve nose ventilation in cases of obstruction, commonly the nose cavities are widened by partial resection of the inferior turbinates, sometimes even the middle turbinates. However, some patients still suffer from subjective impaired nose patency even after radical surgery. The still unsolved problem is how to help patients suffering from this so called ‘empty nose syndrome’.

Purpose. To apply air flow simulation to mathematical models derived from MR datasets of patients with empty nose syndrome.

Methods. Ten patients were examined at 1.5T with a 3D proton-density weighted TSE sequence. Parameters were TR/TE 600/9.5 ms, FA 150° and resolution 0.33x0.33x0.74 mm. Acquisitions were performed a) during breathing room air and b) during inhalation of menthol. A third dataset was acquired c) after the application of the widely used decongestant drug xylometazoline.
The nasal cavity was segmented from all datasets by grey value thresholding and manual correction using AMIRA software, which also transformed the surface of the cavity into a mesh. Air flow was simulated with ANSYS ICEM CFD software. Different flow rates were used as input for simulation and pressure difference required for the certain amount of flow as well as the flow distribution were calculated. The results were compared to those obtained from healthy subjects [1] as well as results derived from CT data [2].

Results. Flow velocity distribution showed great differences between patients (Fig.1, left) and healthy subjects (Fig. 1, right). Airflow in patients tends to exhibit a higher inhomogeneity through the cavity with high flow values distant from the mucosa. In none of our patients flow of more than 0.5 m/s was shown in large portions of the widened airspace. Maximum flow in patients doesn’t differ largely between left and right cavity, in contradiction to healthy controls. This effect can also be demonstrated in flow-pressure-diagrams (Fig. 2), which show also reduced pressure for patients. Different curves are observed for different medication. After decongestant application, pressure differences between both nasal cavities are further reduced.

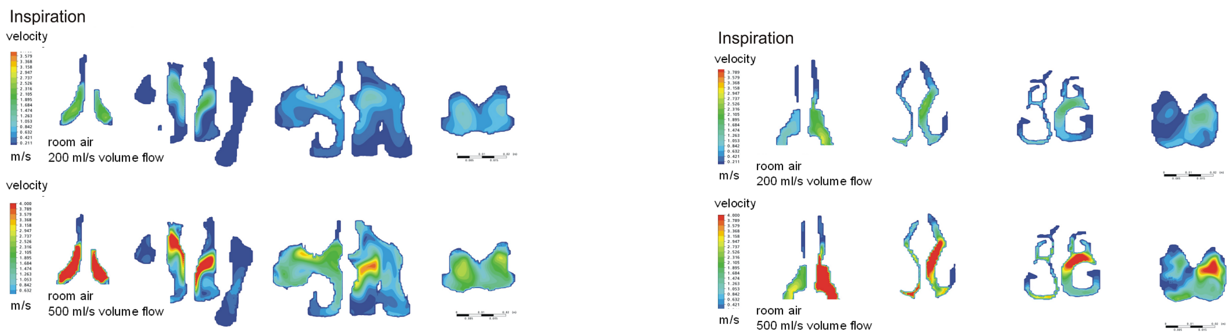

Fig. 1. Coronal slices of nose cavity showing flow velocity distribution during inspiration coded in colours; cf. color bar to the left. Left: patient data showing exemplarily a typical flow distribution, right: healthy control.

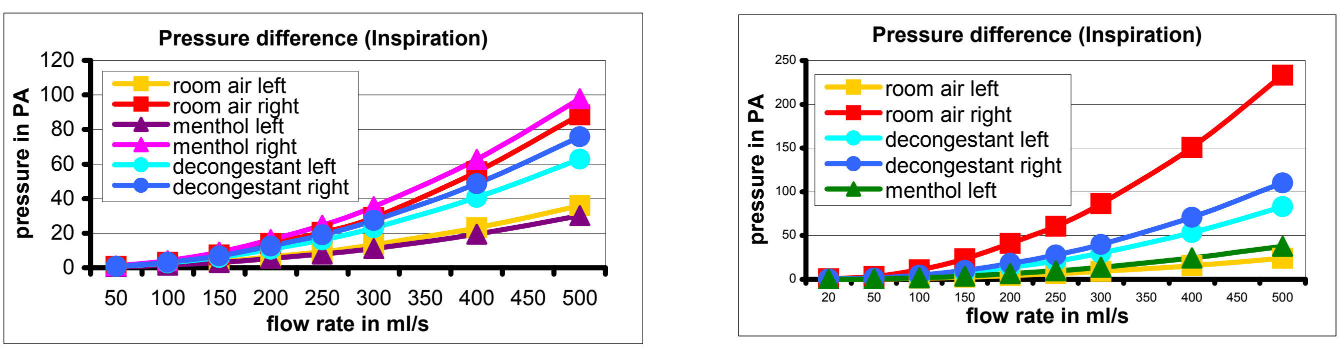

Fig 2. Comparison of pressure-flow-diagrams resulting from simulation for datasets acquired for different medication.
Left: the same patient as in Fig. 1, right: healthy control.

Discussion. Flow simulation has been performed successfully in models derived from CT data [2]. Previously, we showed that this works also for MR datasets despite the reduced resolution and signal to noise ratio compared to CT [1]. Flow patterns can be simulated for patients as well. We observe that the physiologic flow distribution, where one nose cavity is responsible for the majority of the air flow, is absent in patients. Lower flow resistance of the nose, indicated by lower pressure values, has been identified as the reason for subjective feeling of impaired nose breathing experienced by patients. With information derived from the flow patterns, surgeons can selectively reduce the size of nose cavities to improve subjective nasal patency.

References. **1.** Wunderlich, AP. et al: Simulation of Nasal Air Flow from MRI Data – a feasibility study. Proc. ISMRM (2009), 4668
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