Simulation of Nasal Air Flow from MRI Data – a feasibility study

A. P. Wunderlich[1], B. Doll[2], M. Scheithauer[3], W. Freund[1], K. Urban[4], and U. Simon[2]

[1]Diagnostic and Interventional Radiology, Univ.-Clinic Ulm, Ulm, Baden-Württemberg, Germany, [2]Scientific Computing Centre, University Ulm, Ulm, Baden-Württemberg, Germany, [3]Otolaryngology, Univ.-Clinic Ulm, Ulm, Baden-Württemberg, Germany, [4]Institue for Numerical Mathematics, University Ulm, Ulm, Baden-Württemberg, Germany

Purpose. The study aim was to evaluate the feasibility of flow simulation using mathematical models derived from MR data.

Methods. After approval of our local ethics committee, we acquired data from a healthy volunteer with a 3D proton-density weighted TSE sequence. Parameters were TE/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 after c) the application of the widely used decongestant drug xylometazoline.

The nasal airways were segmented from both datasets by grey value thresholding and manual correction using the AMIRA software, which also transformed the segmented surface into a mesh. Air flow was simulated with the 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 separately for each nose concha. The resulting values were compared to published values [1] derived from CT data.

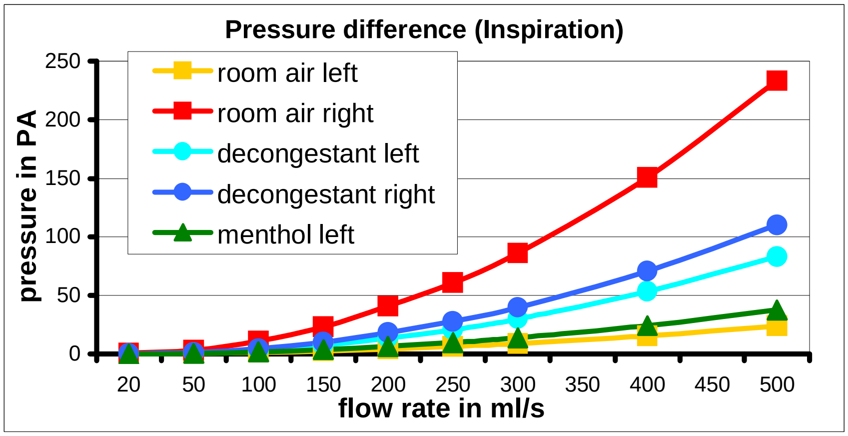

Fig. 1. Simulated pressure-flow-diagrams for various medications.

Results. Flow-pressure diagrams derived from simulation (Fig.1) show good agreement with literature values. During inhalation of menthol, the right concha was too narrow to extract a reliable surface, therefore, no values can be shown. Flow distribution differs between left and right nasal conchae and changes between inspiration and expiration (Fig. 2a). The physiological differences in cross-section width between left and right concha (cf. Fig. 2b), which lead to different pressure-flow-curves, tend to equalise after decongestant application. Flow velocity is affected in a similar manner (Fig. 2b).

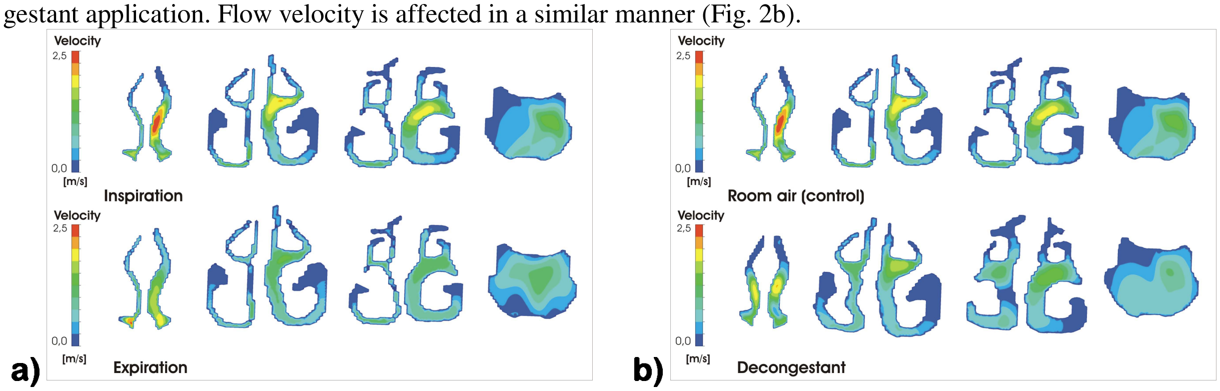

Fig 2. Coronal slices of the nasal airways showing color coded flow velocity distribution; blue: low, yellow: high velocity.
a): room air breathing in (top) and out (bottom); b): inspiration – top: after decongestant, bottom: room air.

Discussion. Flow simulation has been performed successfully in models derived from CT data [1,2]. In our study we were able to show that this also works on models extracted from MR data. The resolution is less than that of CT which causes larger errors in surface determination. Also, the signal to noise ratio is worse in MR than in CT, therefore contours found by thresholding have to be corrected manually. A comparison shows that pressure-flow-diagrams derived with our simulation are in good agreement with literature values [1]. Since there is no ionizing radiation in MR exams, measurements were repeated with different medication. We were able to assign changes in pressure-flow-relation to changes in flow distribution caused by widening of nasal conchae after decongestant application. Menthol however, which leads to a subjective feeling of better air flow, did not show measurable effects. The narrowing of the right concha which precluded us from a reliable segmentation could have occurred due to the physiologic nasal cycle.

References. **1.** Weinhold, I. ; Mlynski, G.: Numerical simulation of air flow in the human nose. Eur Arch Otorhinolaryngol 261 (2004), 452-455

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