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Investigating the relationship between shape and flow in the human nose using a statistical shape model

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Introduction
The nose is an extremely important organ of the human body; its functions include ventilation, filtration, heating, humidification and olfaction, which all depend on the airflow through the nasal cavity [1]. Patients with long term nasal function impairment have a reduced quality of life. The condition affects the patient in physical, functional and emotional domains [2]. How shape and shape changes of the nasal cavity exactly influence factors like airflow, heating and particle deposition is not yet fully understood. Work in this area consists of mostly case studies, e.g. [3, 4, 5, 6, 7]. In this work we aim to extend this knowledge by using a different method for shape comparison.

Method and validation
The subjects used in this study are patients presented at the ENT-department with different pathologies where the physician requested a CT-scan of the nasal cavity and sinuses. This tomographic data was converted manually into a surface model of the nasal cavity using a procedure called segmentation. For each CT-scan this was done by the same operator to avoid inter-operator generated variations between segmentations.
Next a statistical shape model [8] of the human nose based on 46 nasal cavities and their mirrored counterpart was created. Such a shape model provides a compact representation of the variation that is present within the population of shapes. Besides the nasal cavity, also a part of the postnasal region was included. Shape modes of the shape model were split into symmetrical and asymmetrical modes. These modes were then added to the average nose shape and the effect on e.g. the flow was investigated. This allowed examining the effect of a shape change on flow more accurately and with more control than in the case of comparing two segmented noses coming from different patients. Also the effect of symmetry or the lack of it was studied.

For the CFD simulations the Lattice Boltzmann method was used. Parameters such as flow allocation percentage [4] were calculated and compared for the different shapes.

Validation of the CFD results was done using 3D printed box models of the negative of the nasal cavity (Materialise, Belgium). At the back end of the printed model a negative pressure was generated to induce air flow. Flow versus pressure curves were measured using a rhinomanometer giving nasal resistance. Measurements were also done using tiny flow sensors placed at specific points in the printed models. Both nasal resistance and local flow measurements were compared with their computational analogue.

Results
Results will be presented and discussed during the conference.

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