Simulation of the nasal airflow with Computational Fluid Dynamics in Nasal Breathing Difficulties: definition of parameters

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Nasal Breathing Difficulties (NBD)

* One of the most common medical conditions in the daily practice of ENT surgeons
* High socio-economic impact *
* Our daily aim is the optimization of nasal airflow and its perception

NBD-Evaluation today

- Clinical assessment (endoscopy etc.)
- Rhinomanometry
- Acoustic rhinometry
- CT scan
Day to day practice

WE HAVE NO METHODS THAT:

* assess nasal airflow at specific anatomical areas (middle meatus, inferior turbinate etc.)
* assess the perceived quality of the flow
* measure the impact of anatomical anomalies on nasal flow and mucosa
Airflow evaluation—available techniques

- **in vivo:** rhinomanometry (only overall data)
- **in vitro:** modified Mink boxes (anatomical reconstruction)
- **Computational fluid dynamics** (virtual reconstruction and simulation)
Computational Fluidodynamics

- Simulation of a flow pattern, shear stress, temperature and humidity exchange
OpenNOSE-Methods

* from CT scan
OpenNOSE-Methods

3D reconstruction (3D slicer)
generation of a mesh
(freeCad; openFoam; snappyHexMesh)
flow simulation
Open questions for viable CFD procedures in clinical practice

- How the end results are affected by the segmentation threshold used to convert the CT images into a three-dimensional computational volume mesh

- How the end results are affected by the quality (spatial resolution) of the CT scan
Definition of parameters -Threshold-

Effect of the radiodensity threshold on the reconstructed geometry. By going from -200 HU to -280 HU, the internal volume becomes progressively reduced, and several volume fractions related to the maxillary sinuses (circled) are excluded.
Definition of parameters

- Adding Spatial Resolution

- Reconstruction and CFD simulation with 0.625 mm slices in the axial direction.

- Reconstruction and simulation with 1.25 mm slices in the axial direction.

Flow rate (expressed in liters per second) through the right (green curve, circles) and left (red curve, squares) nostrils, as a function of the radiodensity threshold (expressed in HU) employed for the reconstruction of the three-dimensional volume of interest. The plateau between -240 and -220 HU can be appreciated. The open symbols are for the low-quality reconstruction at -230 HU.
What we currently do

-The LES Approach-
alteration of the mesh allows the simulation of changes of flow, humidity, temperature after surgery
Virtual Surgery!
Conclusions
Definition of correct parameters pivotal to:

- objectify flow anomalies due to anatomical alteration and their impact on nasal mucosa
- pre-surgical planning and simulation of surgical outcome
Next/Current

- In vitro validation through silicone models from CT scan and their analysis with particle image velocimetry (currently operational)

- Applying simulation to specific anatomical variations: e.g. septal perforation, olfactory deficits and more

- Readying the technology for day to day use
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