COMPUTATIONAL FLUID DYNAMICS SIMULATION OF NASAL AIRFLOW WITH LES (LARGE EDDY SIMULATION) MODEL

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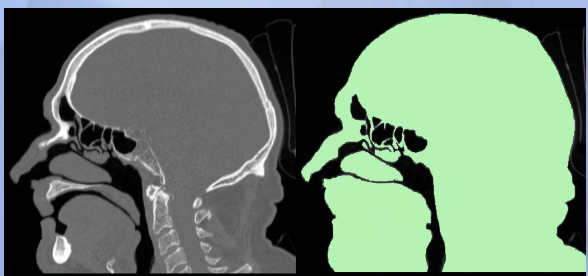
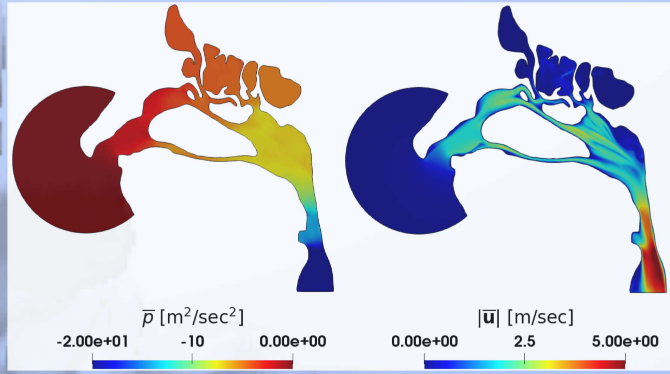
Introduction

Nasal surgery procedures performed in cases of nasal respiratory stenosis represent a considerable number of all the interventions in the ENT field. Nevertheless, the indications and modalities of these interventions (septoplasty, turbinoplasty/turbinectomy, nasal valve plastic) are based more on the experience of the surgeon than on scientifically measurable objective data. With new investigation techniques based on three-dimensional reconstructions of patients' CTs and computer simulations of nasal fluid dynamics it is possible to produce faithful models of the nasal air flow on the individual patient. Nevertheless there are currently no validated models of the healthy nasal flow.



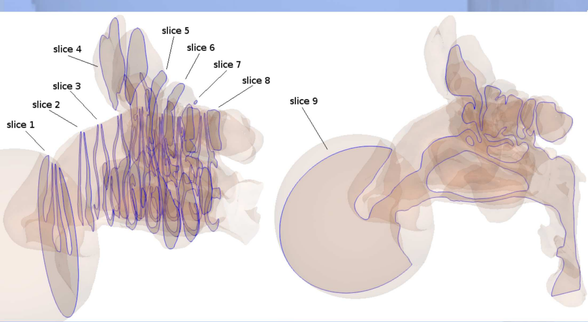
Sagittal CT slice (left) and its reconstruction (right)



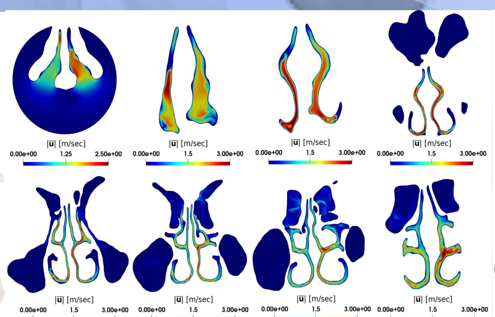
Module of average pressure ($\bar{p}$ [m^2/s^2])and average speed (m/s), after 0.6 sec of stationary inspiration, sagittal section

Materials and Methods

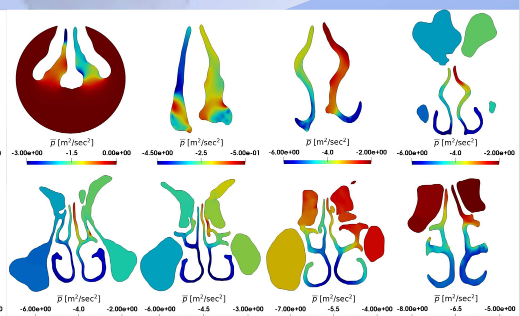
Our team has been working with the department of Aerospace Engineering of the Politecnico of Milan with the aim of developing rapid and accurate CFD-procedures (computation fluid dynamics) with a LES (Large Eddy Simulation) approach using a fully accessible open-source system. For this preliminary study we analyzed data from CT scans of healthy patients and obtained numerous parameters such us flow lines, speed, turbulence, resistance and pressure of a normal physiological nasal flux in the complex anatomy of the nasal cavities. We then compared these results with the current gold standard for nasal airflow evaluation, aka rhinomanometry, for a validation of global airflow.



Coronal slice, from 1 to 8, used for numerical results visualization



Module of average speed, after 0,6 sec of stationary inspiration, in 8 coronal slices from nostril to choana. LES simulation.



Average pressure trend, after 0,6 sec of stationary inspiration, in 8 coronal slices from nostril to choana. LES simulation.

Results

Among the most interesting outcomes obtained from the simulations is the evidence of a fully laminar flow at the level of the 3 meatuses during inspiration, in opposition to an area of vorticity during expiration at the level of the posterior wall of the nasopharynx. The average speed reaches a value of 4.5 m/s at the level of the epiglottis while inside the nasal cavities it results to be about 2.5 m/s. As for the pressure it tends to decrease at the nasal vestibule and the nasal valve (ΔP = 4 m^2/s^2) both in inspiration and in expiration.

Example of rhinomanometric examination

Conclusion

In the future these data may be used as a reference model to achieve the best possible outcome in nasal surgery.