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A non-planar Hele-Shaw model for the nasal cavity flow

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The complex morphology and the anatomical variability of the human upper airways are among the root causes for the failures in surgical corrections of pathological nose anatomies, e.g. 50% failures for septoplasty[1]. To improve the success rate of such surgeries, complementing medical considerations with fluid mechanical information is necessary. CFD has gained recognition as an effective diagnostic tool: a detailed description of the nose flow can be obtained with high-fidelity simulations like DNS[2], although less resolved methods as LES and RANS might be sufficient [3] for large-scale clinical applications. These approaches, however, are generic, and do not account for the specific features of the nose anatomy. In fact, the nasal fossae are very narrow irregular conduits; air speeds are relatively low, and heat exchange is important. At least in the areas of surgical interest, the flow is typically laminar.

This work introduces the first computational approach where *ad hoc* simplifications are adopted for the nasal airflow. This makes a complete informative simulation possible with exceptionally low computational effort, measured in seconds of CPU time. The method is based on an extension of the Hele–Shaw model to non-planar channels of arbitrary geometry, with one cross-stream dimension smaller that the others. The airway is treated as a heterogeneous porous material, with variable permeability that at every point is a function of the distance from the walls. The program also includes the computation of a passive scalar, e.g. temperature in the airway. It accepts a native CT scan as input, so that segmentation and meshing are carried out transparently, and outputs its results in the same format, for ease of consultation by medical doctors.

The simplicity, versatility and extreme computational efficiency of the procedure pave the way towards real-time virtual surgery analysis. The code can also be a crucial building block of a large data-driven model, because thousands or tens of thousands of CT scans can be processed automatically with affordable computational, economical and logistic costs.

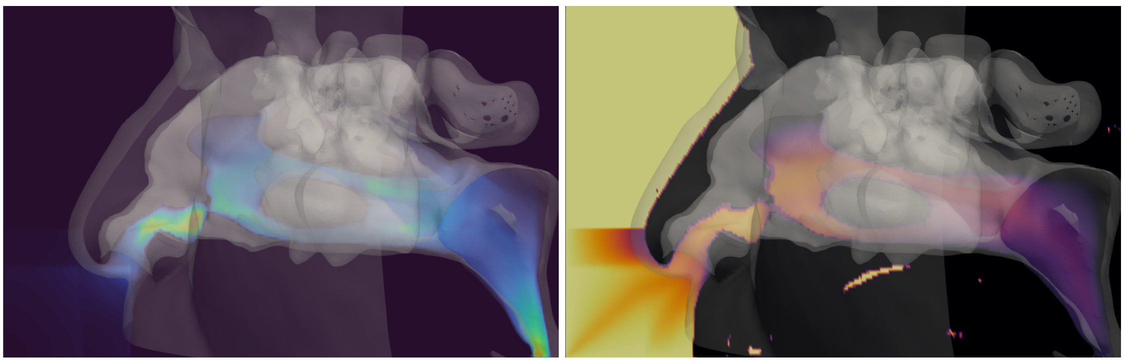

Figure 1: Velocity magnitude (left) and temperature (right) of the airflow on a sagittal slice.

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[1]Sundh, C. & Sunnergreen, O., *Eur Arch Otorhinolaryngol* **272** (10), 2871-2875 (2015)
[2]Schillaci, A. & Quadrio, M., *Journal of Biomechanics*, **138** , (2022)
[3]Calmet *et al.*, *Computer Methods in Biomechanics and Biomedical Engineering*, **24** (4), 440-458 (2020)