Multipatient DNS study of nasal flow

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The flow in the human nose is a challenging fluid dynamical problem with implications for the health, social, and economic points of view. For example, more than one-third of the world's population is affected by Nasal Airway Obstructions (NAO), having a significant impact on the quality of life and making them one of the medical conditions for which patients mainly consult ear-nose-throat (ENT) doctors. Breathing disturbances are often subjective, and the link with a specific physiological and topological condition of the nose is difficult. For this reason, a large portion of the patients subjected to septoplasty remain unsatisfied [1]. The simulation of the nasal flow could thereforebe beneficial to asses the functional properties of the nose and assist doctors in their surgical choices.

Due to the complexity and the relevance of the problem, high-fidelity simulations are required to support the surgeons. For this purpose our research group developed a fast DNS solver based on an implicit in time, second-order accurate ghost-cell immersed boundary method (IBM) for the incompressible Navier–Stokes equations [2], tailored to the specific problem of the nasal flow. Figure 1 represents the velocity and pressure of a sagittal nasal section computed with our solver.

Numerical simulations where the spatio-temporal resolution is sufficient to deal with the smallest scales of turbulence, i.e. DNS, are uncommon in this field given their complexity and computational cost. With our ongoing work, we intend to create a reliable dataset (DNS only) granting statistical meaning (high number of patients), completeness (full results in the same format after the same procedure), and coverage of various pathologies. In this regard, it is worth mentioning that the functionally normal nose still has to be identified, and we believe that our simulations will be the starting point to extract fluid flow features defining the normal function. A comprehensive and comparative analysis of the complete dataset will be the core of the present work and the basis for underlining the anatomical, physiological, and pathological features from an otolaryngological standpoint. This will be an important achievement for human pathophysiology, where the role of dynamic airflow is invariably evaluated based on hypothetical arguments.

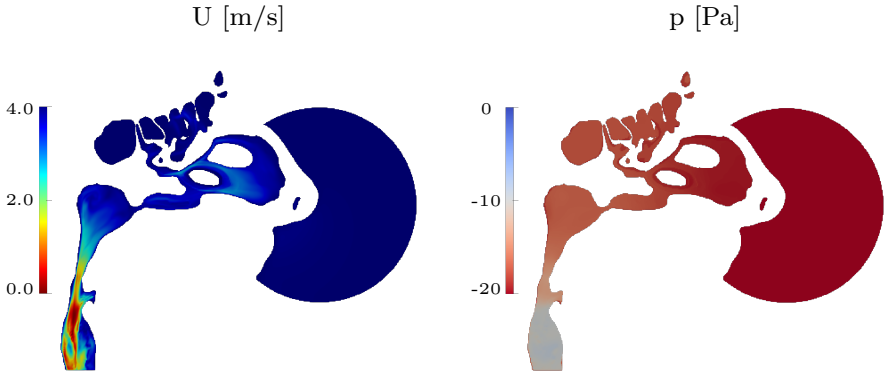

Figure 1: Velocity (U) and pressure (p) computed at a sagittal section of the nose.

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[1] Fuccillo et al., *The Journal of Laryngology & Otology* **134** (2020)

[2] Luchini, *European Journal of Mechanics B/Fluids* **55** (2016)