RANS/LES/DNS SIMULATIONS OF THE AIRFLOW IN NASAL CAVITIES

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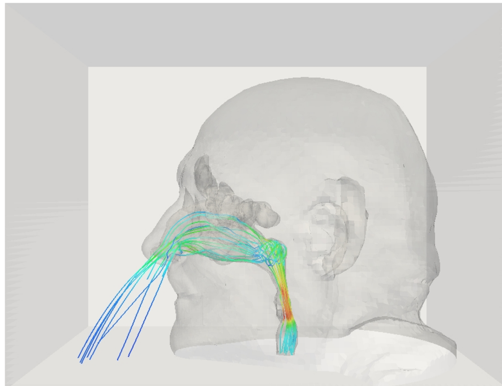
Introduction

- Predicting flow patterns in nasal cavities by CFD can provide essential information on the relationship between patient-specific geometrical characteristics and health problems.
- Understanding must improve further for CFD to become a reliable tool in clinical use.

Objectives

Evaluate the effect of:

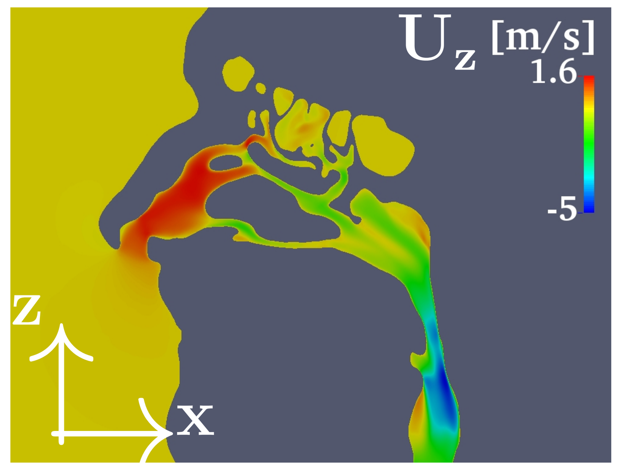
1. RANS/LES models
2. Boundary conditions
3. Numerical schemes



Results

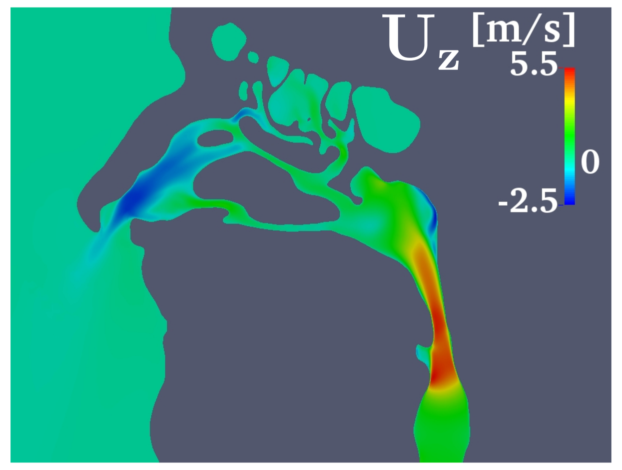
1. **General trend**

LES, steady inspiration:



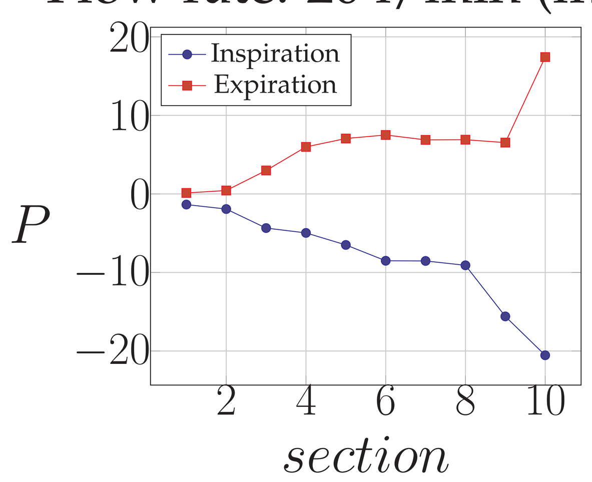
Separation below larynx

LES, steady expiration:



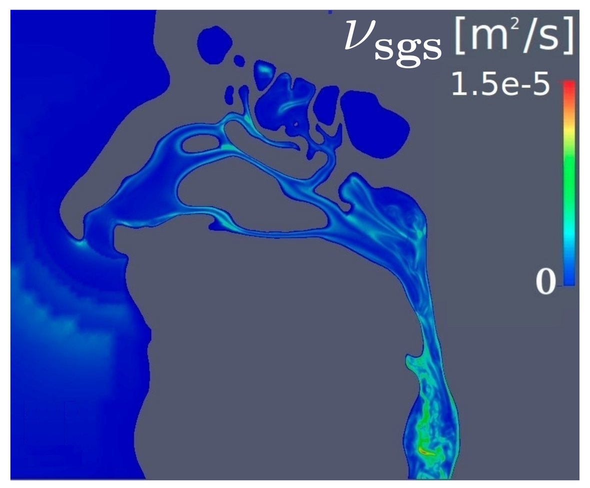
Strong laryngeal jet

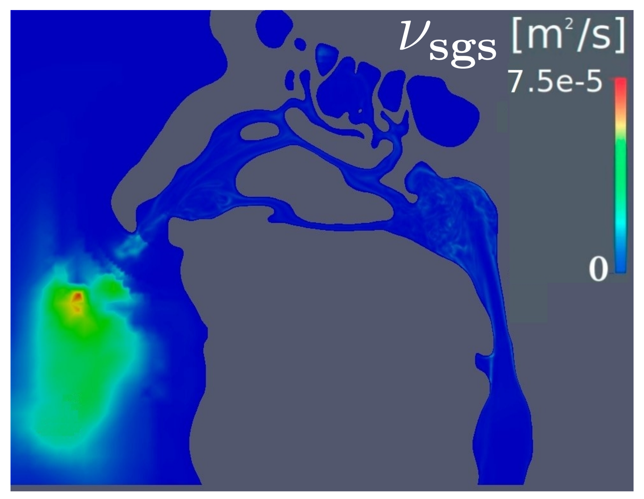
Flow rate: 20 l/min (mild)



Main pressure drop at larynx

2. **LES or DNS ?**



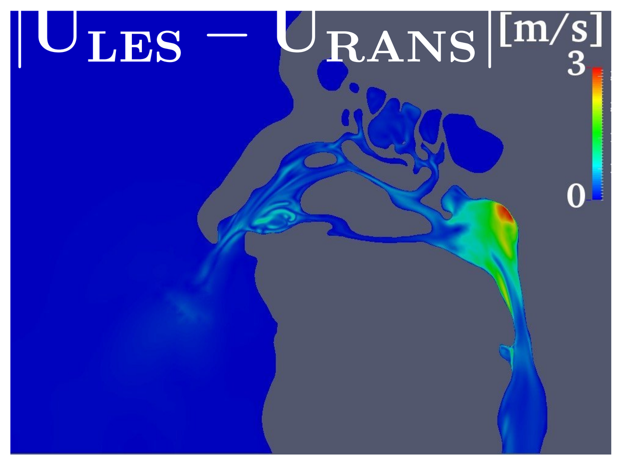


- $\nu = 1.45 \cdot 10^{-5}$ m^2/s
- $\nu_{sgs} < \nu$

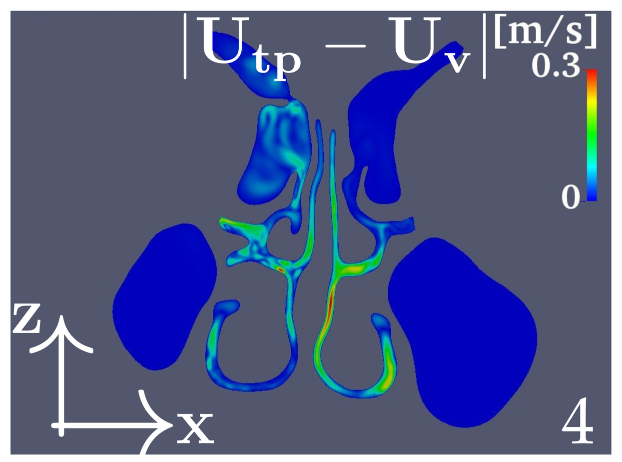
⇒LES works as DNS

3. **Differences**

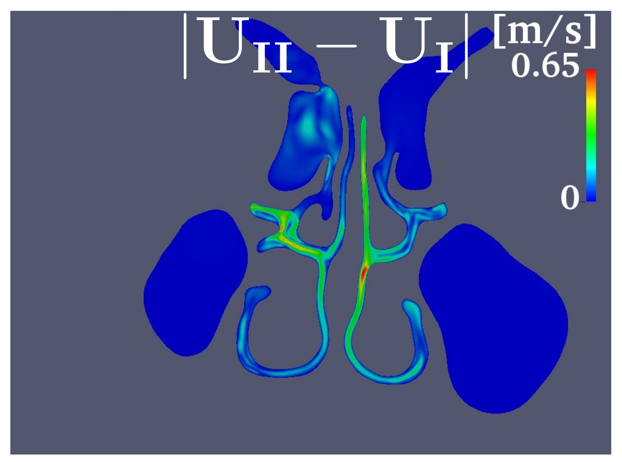
RANS/LES models:



Total pressure vs velocity:

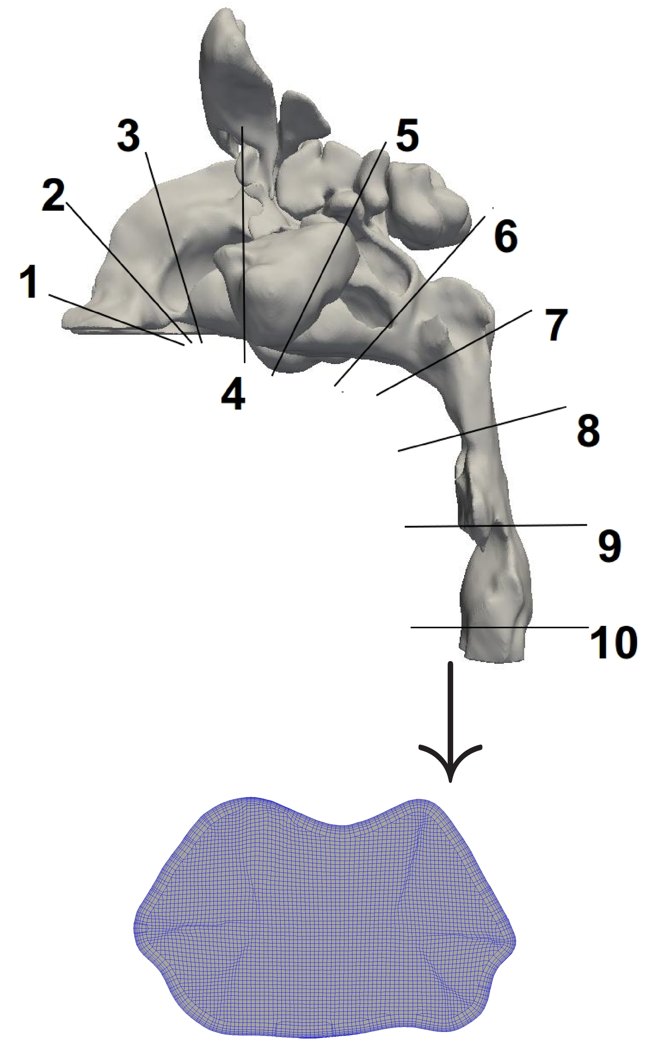


Second vs first order:



Materials & Methods

1. Geometry:
   - Carefully selected anatomy
   - Paranasal sinuses included
2. Mesh:
   - Number of cells 7M
   - 6 near-wall layers
   - y^+ first cell between 4 and 5



3. Boundary conditions at inlet/outlet:
   - External boundary moved away from the nostrils
   - Section 10 is critical: inlet during inspiration and outlet during expiration
   - Two tests: $p_{tot} = p + \frac{1}{2}\rho|\mathbf{U}|^2$ and constant velocity realized with a fringe region with body forces.
4. Solver: OpenFOAM finite volume method
   - RANS:
     - $k - \omega$SST turbulence model
     - SimpleFoam steady incompressible solver
   - LES:
     - Smagorinsky turbulence model
     - PimpleFoam unsteady incompressible solver
     - $\mathbf{U}_{\mathbf{Mean}} = \sum_{i=1}^{n} \frac{1}{N} \mathbf{U}_{\mathbf{i}}$

Conclusion & Future Research

- Once a suitable boundary condition is found its effect on the solution is small.
- High influence of numerical schemes. Difficult to find a steady second order solution with RANS equations.
- Large difference between RANS and LES simulations, mainly at the nasopharynx.

Future work:

- Ongoing *Particle Image Velocimetry* to validate CFD.
- Unsteady breathing cycle.

References

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