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

**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: $p_{tot} = p + \frac{1}{2} \rho |U|^2$ 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
   - $U_{\text{Mean}} = \frac{1}{N} \sum_{i=1}^{N} U_i$

**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?
   - $\nu = 1.45 \cdot 10^{-5} \text{ m}^2/\text{s}$
   - $\nu_{\text{SGS}} < \nu$ → LES works as DNS
3. Differences
   - RANS/LES models:
   - Total pressure vs velocity:
   - Second vs first order:
4. 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.

**Conclusions & Future Research**
- Future work:
  - Ongoing Particle Image Velocimetry to validate CFD.
  - Unsteady breathing cycle.

**References**