FLUID DYNAMICS OF THE NASAL CAVITY: HOW TO, WHAT FOR.

Maurizio Quadrio

Politecnico di Milano
Dept. of Aerospace Sciences and Technologies
CREDITS

- Giovanni Felisati (Polo Osp. s.Paolo Milano & UniMI)
- Carlotta Pipolo (Polo Osp. s.Paolo Milano & UniMI)
- Francesco Messina (Polo Osp. s.Paolo Milano)
- Samuele Zampini (DAST PoliMI)
- Stefano Corti (DAST PoliMI, STR)
- Chiara Pesci (DAST PoliMI)
1. The nose

2. Our vision

3. The procedure

4. Why Open?

5. The future
FUNCTIONS OF THE HUMAN NOSE

- First (upper) part of respiratory airways
- Air filtering
- Air humidification
- Air heating
- Olfactive perception (+ taste)
INTERNAL STRUCTURE

Nose and Nasal Cavities

- Frontal sinus
- Nasal concha
- Sphenoid sinus
- Middle nasal concha
- Internal naris
- Inferior nasal concha
- Nasopharynx
- External naris
The nose

Our vision

The procedure

Why Open?

The future

**Sinuses and Turbinates**
A 3D view
CORONAL SECTION: TURBINATES AND MEATA

A: Olfactory region
B: Main passageway below middle meatus
C: Lower middle meatus region
D: Deep middle meatus region
E: Main passageway below inferior meatus
F: Inferior meatus

A-A': olfactory region

B-B': superior meatus
The nose
Our vision
The procedure
Why Open?
The future

SIGNIFICANT LONGITUDINAL VARIATIONS
How to study the nasal cavity

- *In-vivo* approach: difficult, not useful
- *In-vitro* approach: rarely used
- First meaningful CFD study in 2004 (Zhao, Chem. Senses)
The nose
Our vision
The procedure
Why Open?
The future

CFD: STATE OF THE ART
CHARACTERISTICS AND LIMITATIONS

- Long times (weeks/months) for producing a mesh
- Questionable (but never questioned!) modellistic approaches
- RANS (or laminar)
- Results cannot not be verified
Modelling limitations

The nose
Our vision
The procedure
Why Open?
The future
1. The nose
2. Our vision
3. The procedure
4. Why Open?
5. The future
The nose

Our vision

The procedure

Why Open?

The future

THE PROBLEM

In 2009 Regione Lombardia has spent:

- Septoplastic: 5600 procedures, 8.6M€
- Turbinates surgery: 3000 procedures, 4.3M€
- FESS: 5700 procedures, 11.6M€
Nowadays functional endoscopic sinus surgery (FESS) is the gold standard for chronic NBD treatment. The operation generally involves inferior/middle turbinoplasty and uncinate and ethmoid excision, sometimes followed by opening of the maxillary, sphenoid and frontal sinuses. A correction of a nasal septal deviation can also be necessary.

... However, we are currently unable to assess the relevance of every single anatomic anomaly and its surgical modification on the overall nasal flow quality and nasal obstruction.

Quadrio et al, 2013? 2014?
The procedure

- *Patient-specific* procedure
- CFD results from a CT scan
- Support to surgery planning (virtual surgery)
- **Reliable** results
- Robust and feasible procedure (*time* and *cost*)
- Goal: reduce / optimize surgery
THE TOOLCHAIN

1. Analysis of CT scan (3DSlicer)
2. STL from CT scan (3DSlicer)
3. Volume mesh (OpenFOAM – snappyHexMesh)
4. CFD (OpenFOAM)
1/4 ANALYSIS OF THE CT SCAN
IMPORTANT SEPTAL DEVIATION
1/4 Analysis of the CT scan (2)

Nearly-complete obstruction
The nose
Our vision
The procedure
Why Open?
The future

2/4 STL FROM CT scan
Wrong HU threshold
STL FROM CT SCAN (2)
CORRECT HU THRESHOLD

The nose
Our vision
The procedure
Why Open?
The future
The nose
Our vision
The procedure
Why Open?
The future

3/4 Volume mesh
Castellated mesh
3/4 **Volume mesh (2)**

**Castellated mesh**
VOLUME MESH (3)

The nose
Our vision
The procedure
Why Open?
The future
3/4  **VOLUME MESH (4)**

**CASTELLATED MESH**
The nose
Our vision
The procedure
Why Open?
The future

3/4 **Volume mesh (5)**
Adding layers
The nose
Our vision
The procedure
Why Open?
The future

4/4 CFD
STEADY INSPIRATION, LAMINAR
1  THE NOSE
2  OUR vision
3  THE PROCEDURE
4  WHY Open?
5  THE future
THE ROLE OF OpenSOURCE AND OpenFOAM

- Freedom
- Reliability
- Flexibility
The nose
Our vision
The procedure
Why Open?
The future

1  THE NOSE
2  OUR vision
3  THE PROCEDURE
4  WHY OPEN?
5  THE FUTURE
Next steps

- Virtual surgery
- 3D-PIV lab experiment for validation (grant from Ministry of Health)
- LES
- Trial before large scale deployment
VIRTUAL SURGERY
REMOVING SEPTAL DEVIATION / TURBINATE REDUCTION