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

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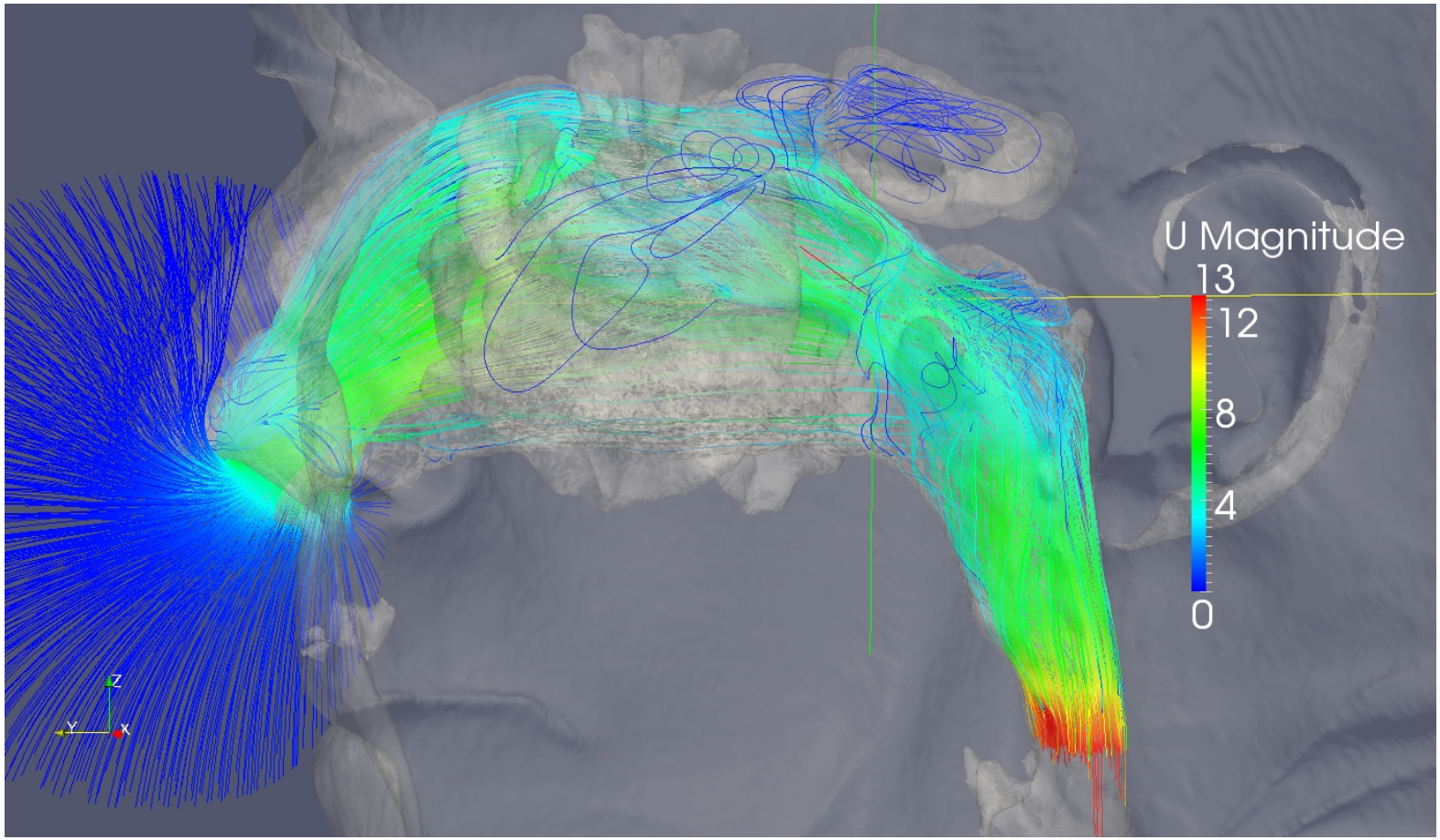


# Credits



- 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)

# Outline

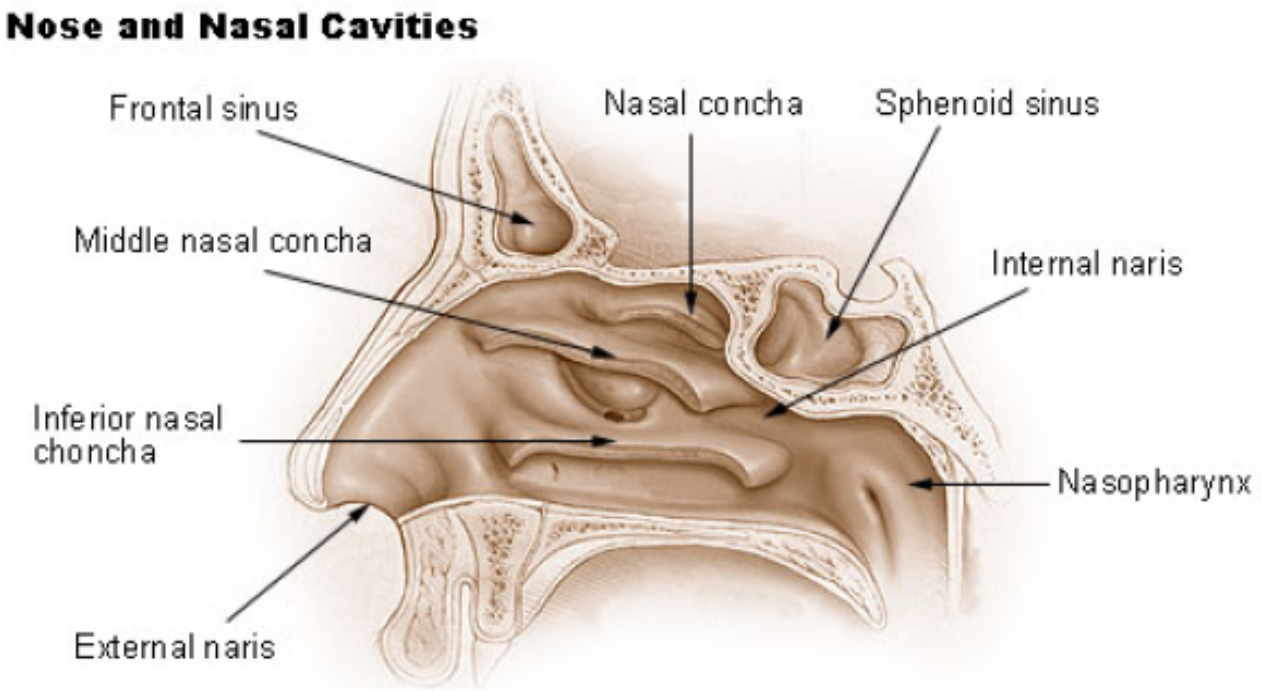
# Functions of the human nose



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

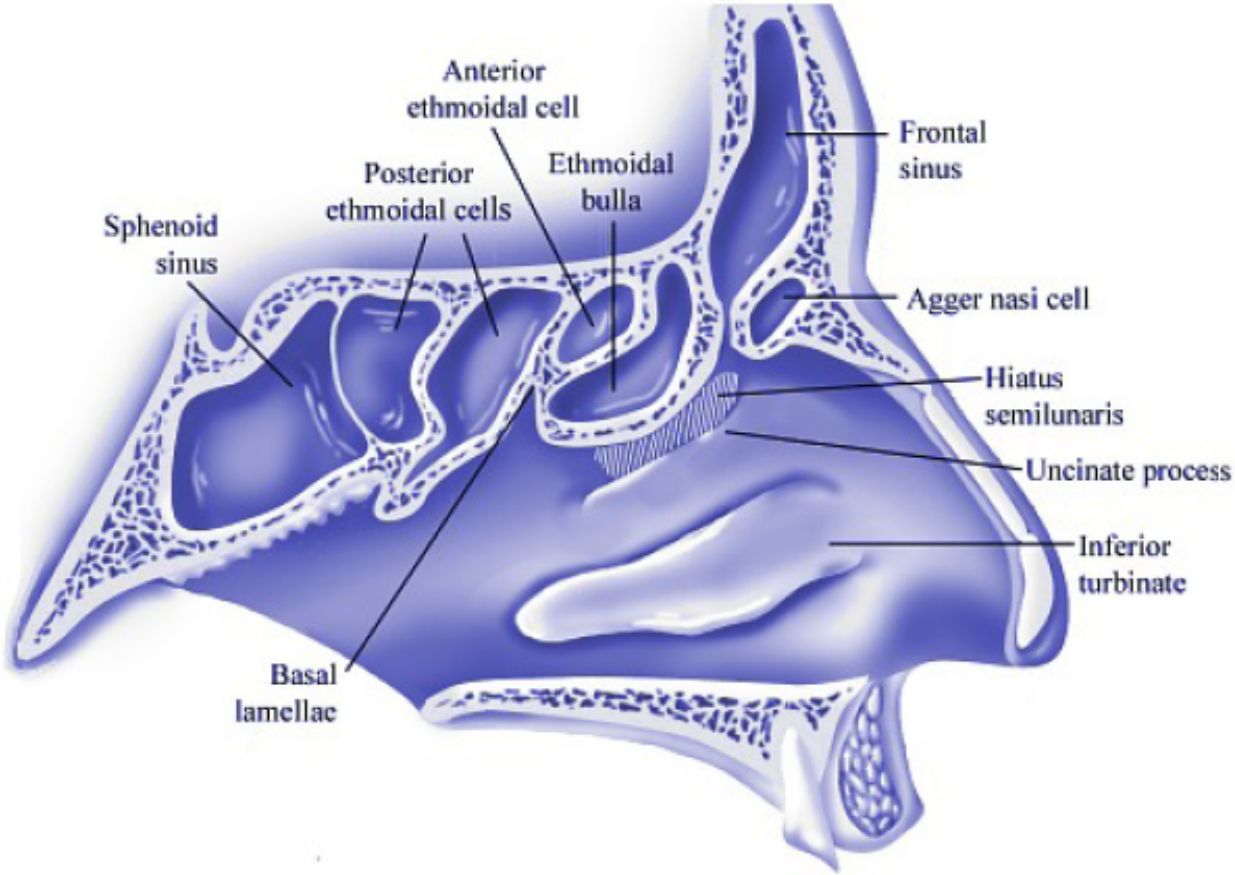
# INTERNAL STRUCTURE





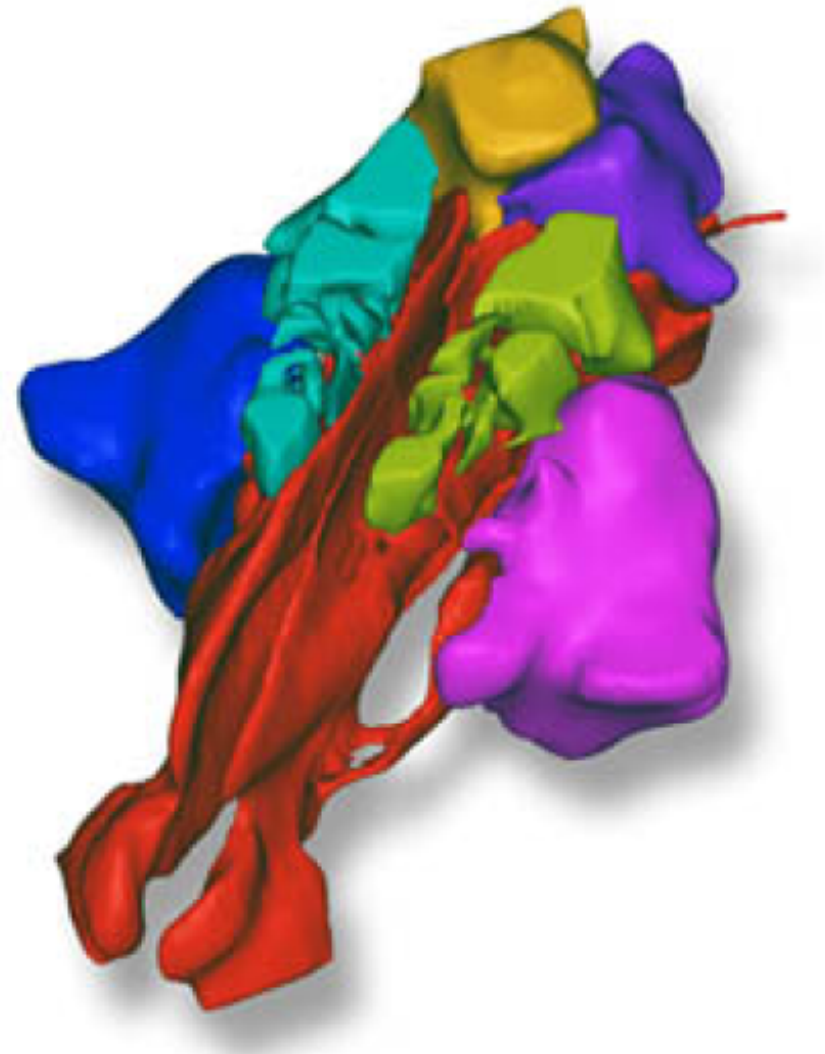
# Sinuses and turbinates





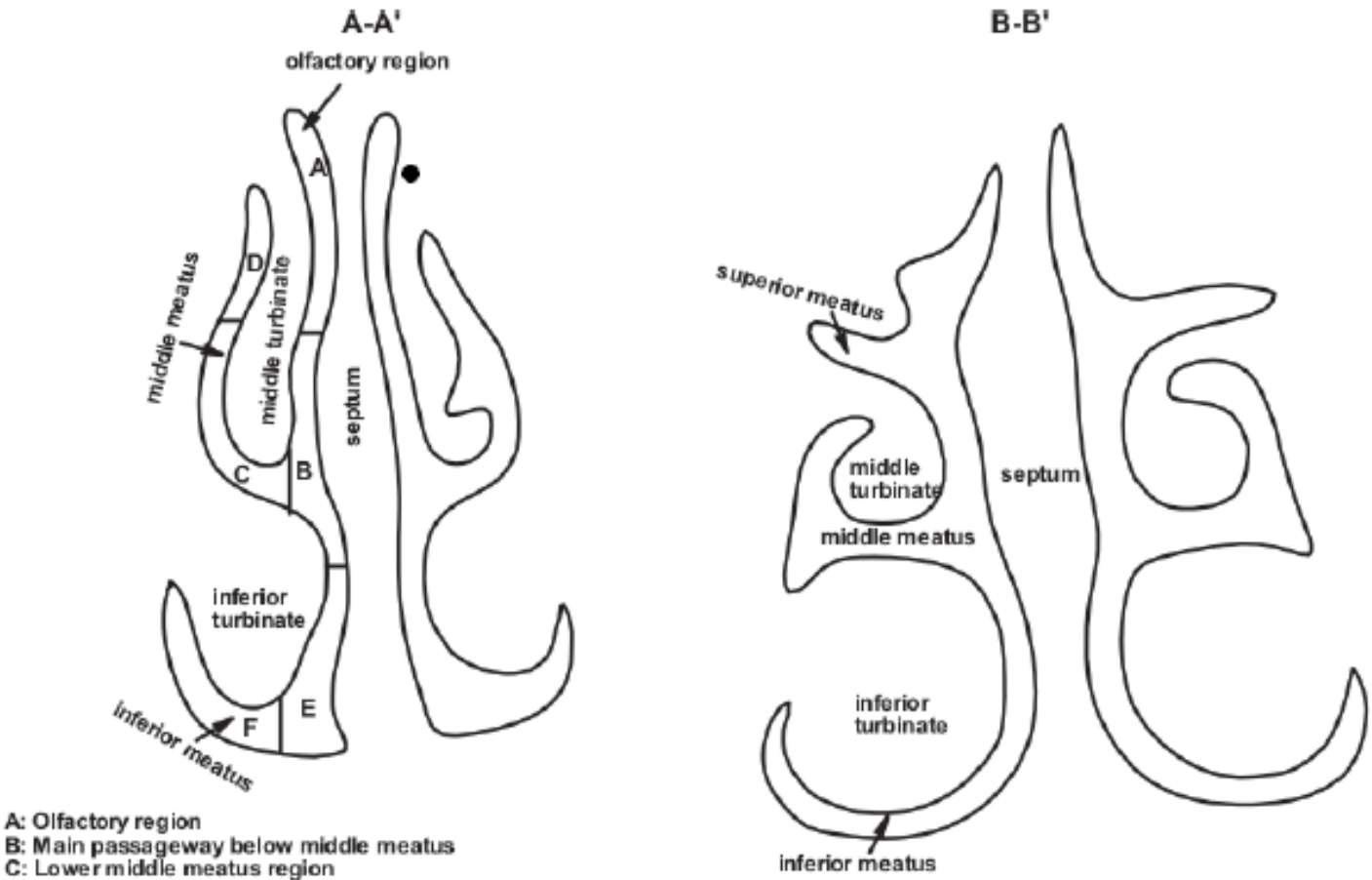
# A 3D view





# Coronal section: turbinates and meata

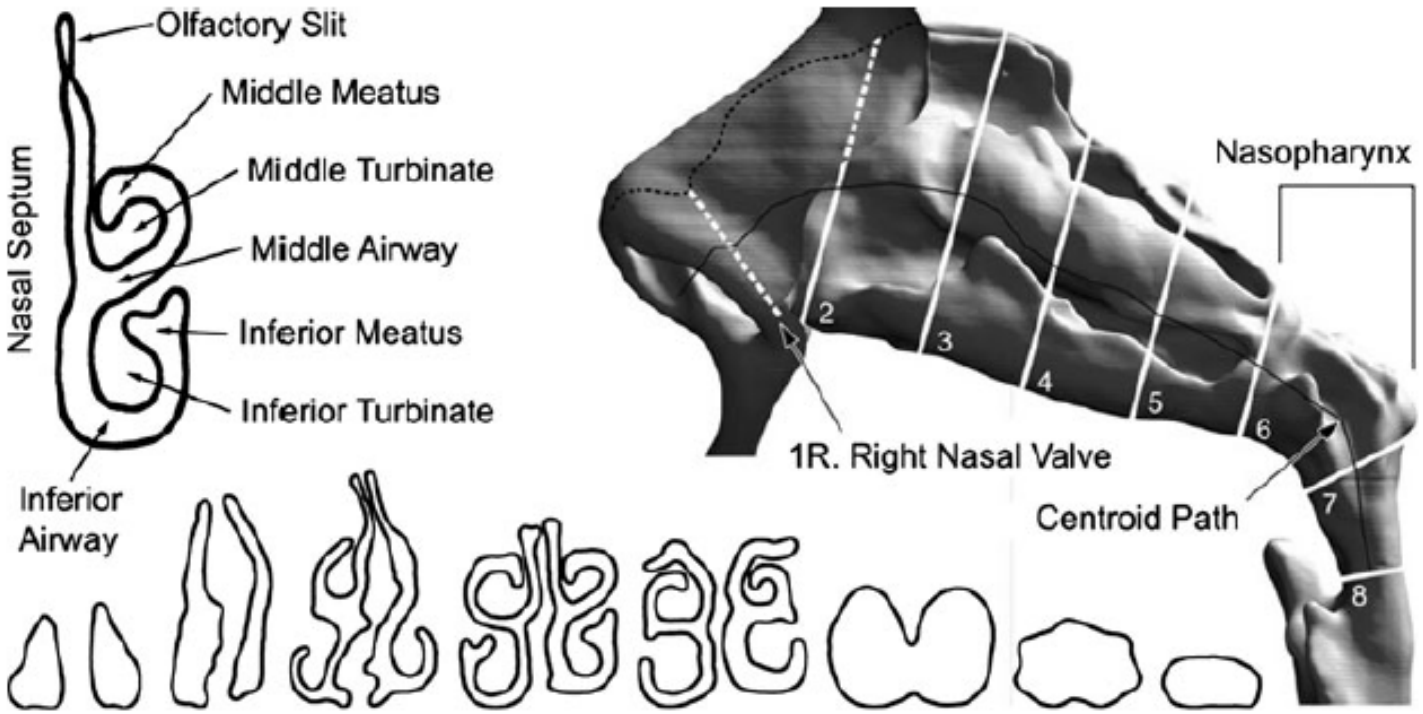





A: Olfactory region
B: Main passageway below middle meatus
C: Lower middle meatus region
D: Deep middle meatus region
E: Main passageway below inferior meatus
F: Inferior meatus

# 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)

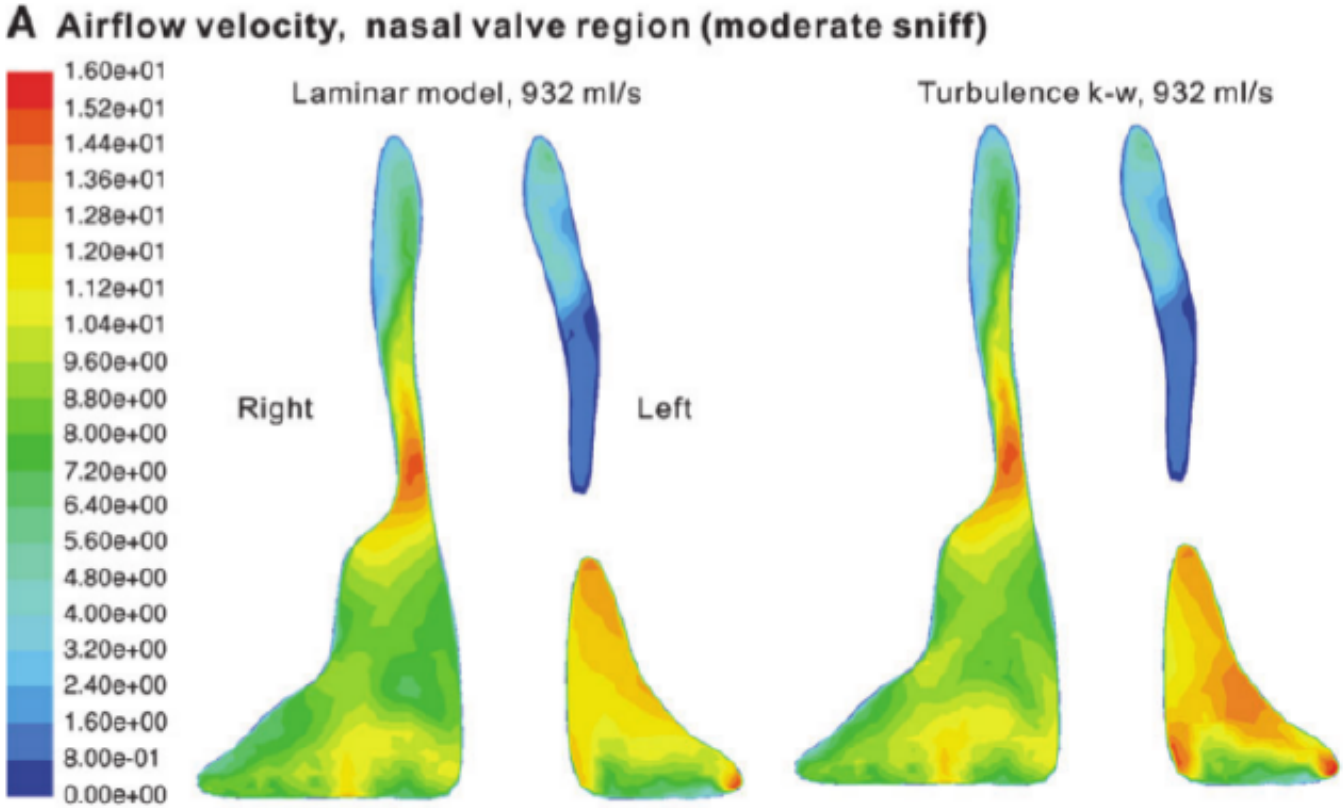
# CFD: STATE OF THE ART
## CHARACTERISTICS AND LIMITATIONS



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

# Modelling limitations





# Outline

# The problem



In 2009 Regione Lombardia has spent:

- Septoplastic: 5600 procedures, 8.6M€
- Turbinates surgery: 3000 procedures, 4.3M€
- FESS: 5700 procedures, 11.6M€

# FESS



*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?

# Outline

# 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

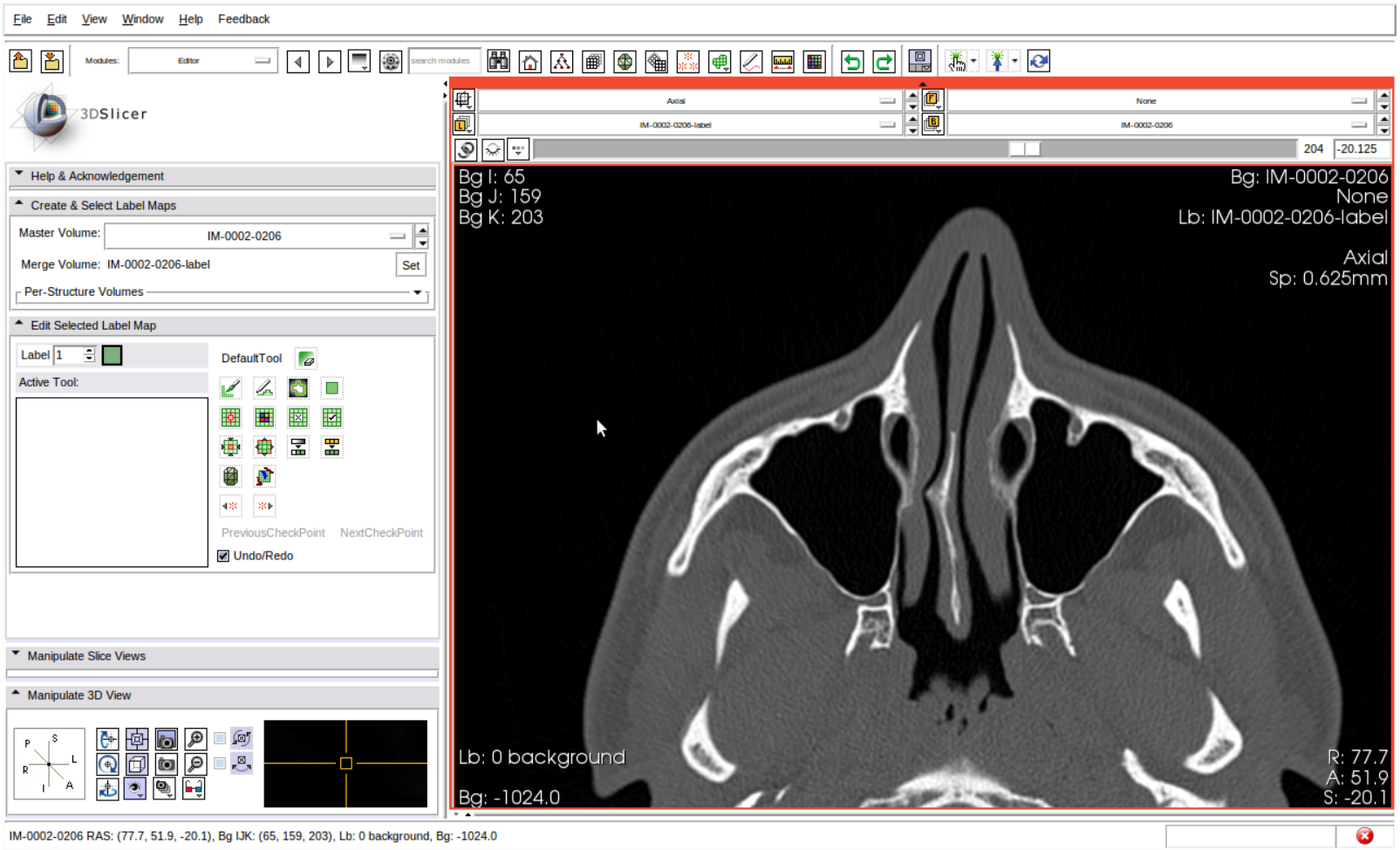


1. Analysis of CT scan (3DSlicer)
2. STL from CT scan (3DSlicer)
3. Volume mesh (OpenFOAM – snappyHexMesh)
4. CFD (OpenFOAM)

# 1/4 Analysis of the CT scan

## Important septal deviation

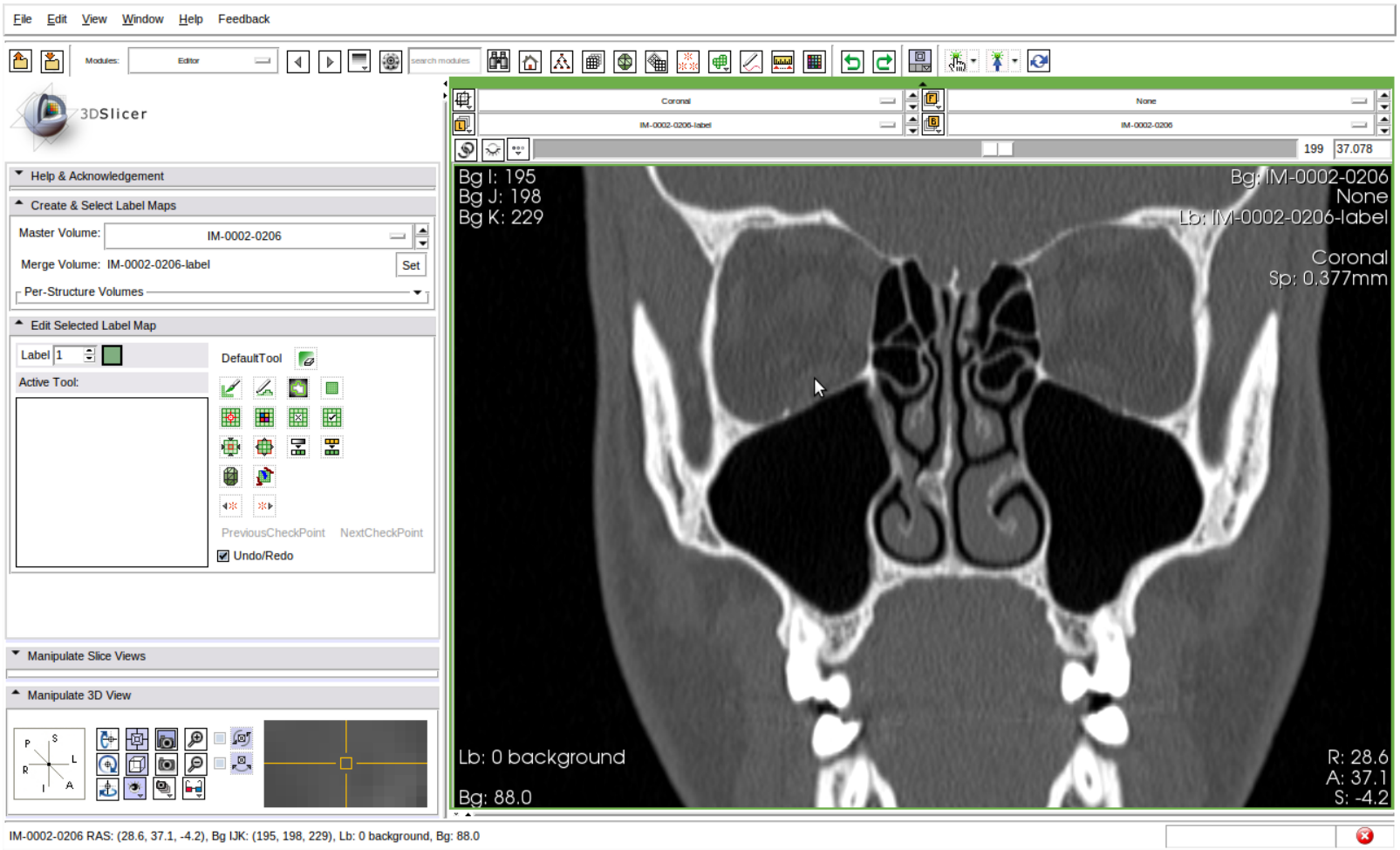




# Analysis of the CT scan (2)

## Nearly-complete obstruction

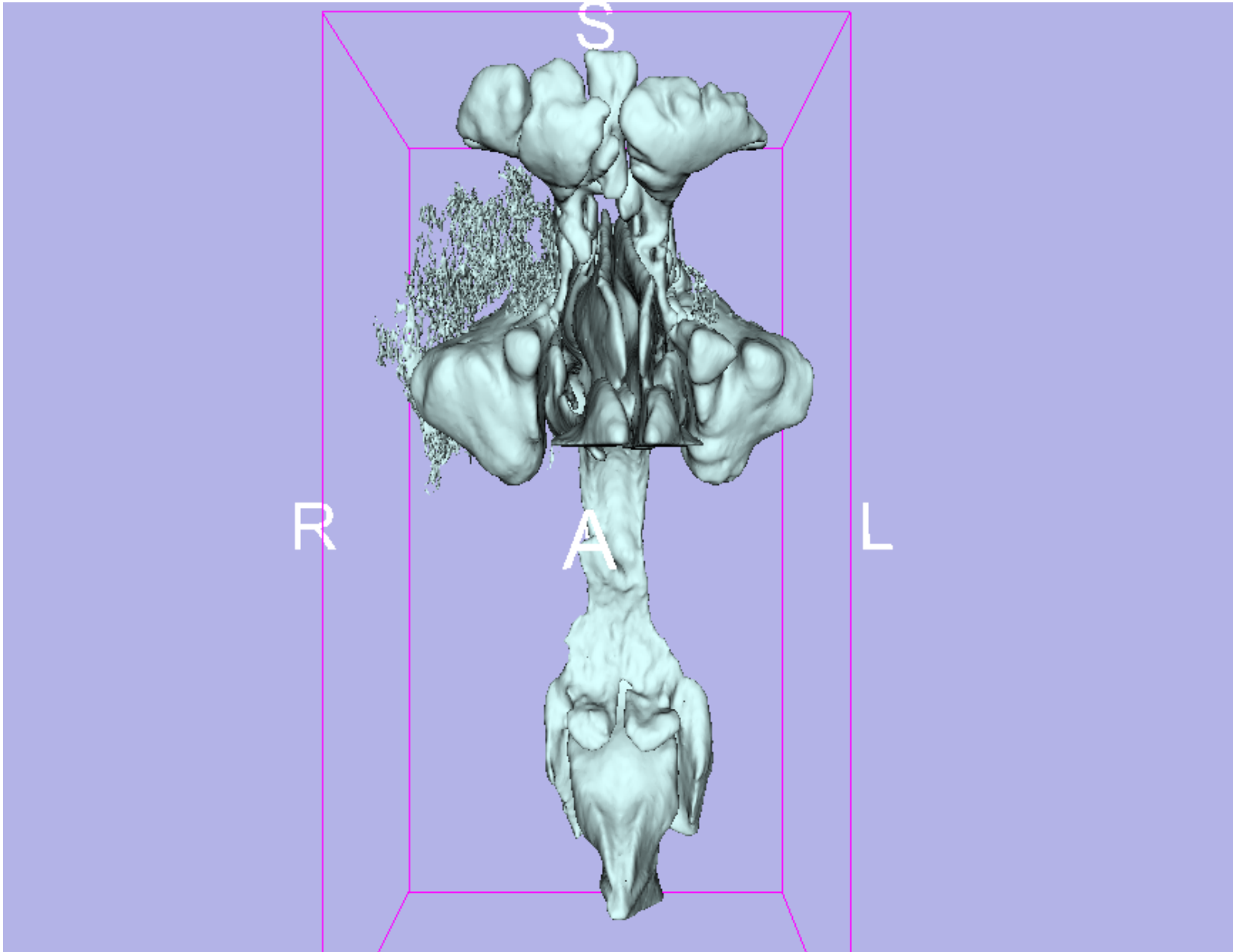




# 2/4 STL FROM CT SCAN

## WRONG HU THRESHOLD

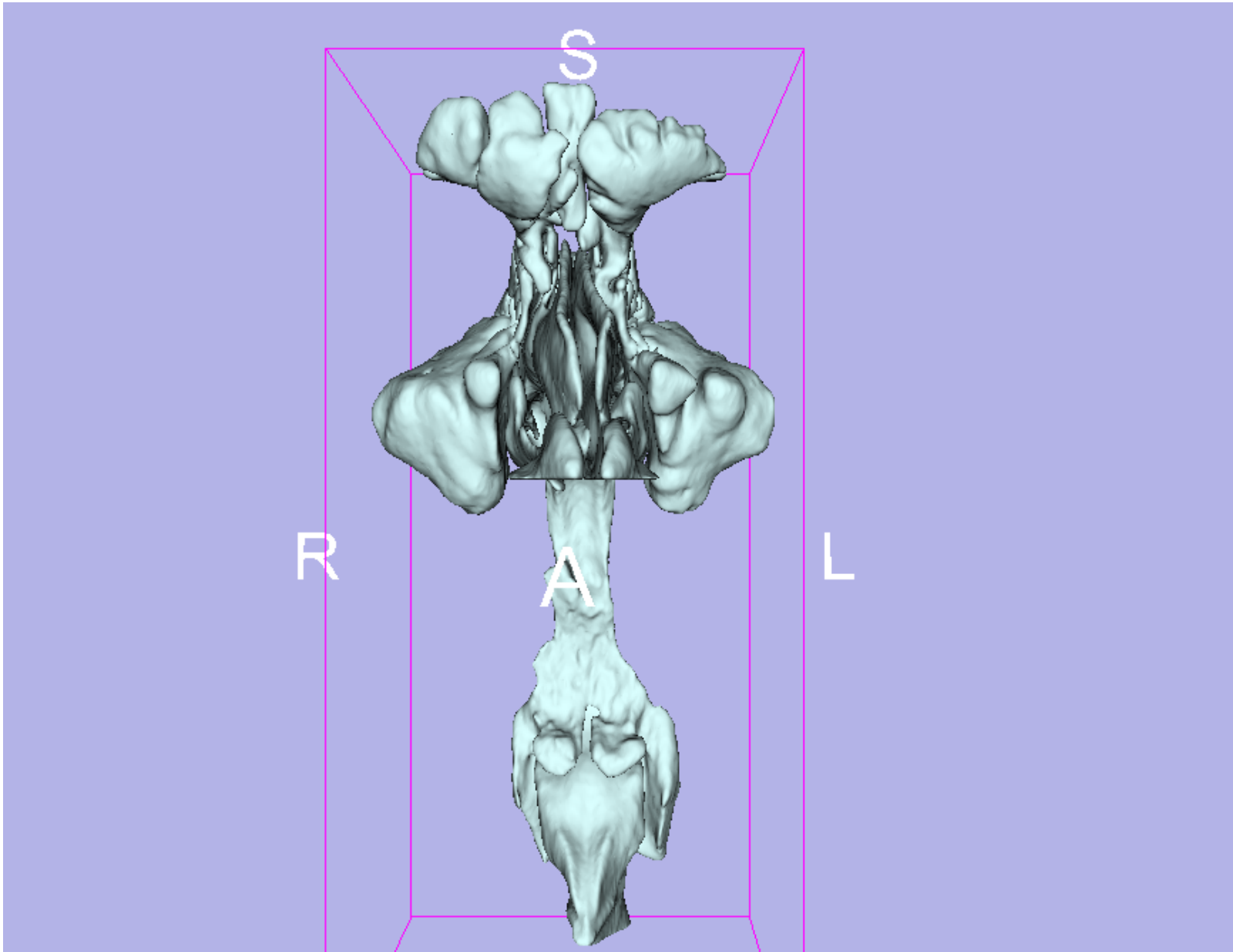




# 2/4 STL FROM CT SCAN (2)

## CORRECT HU THRESHOLD

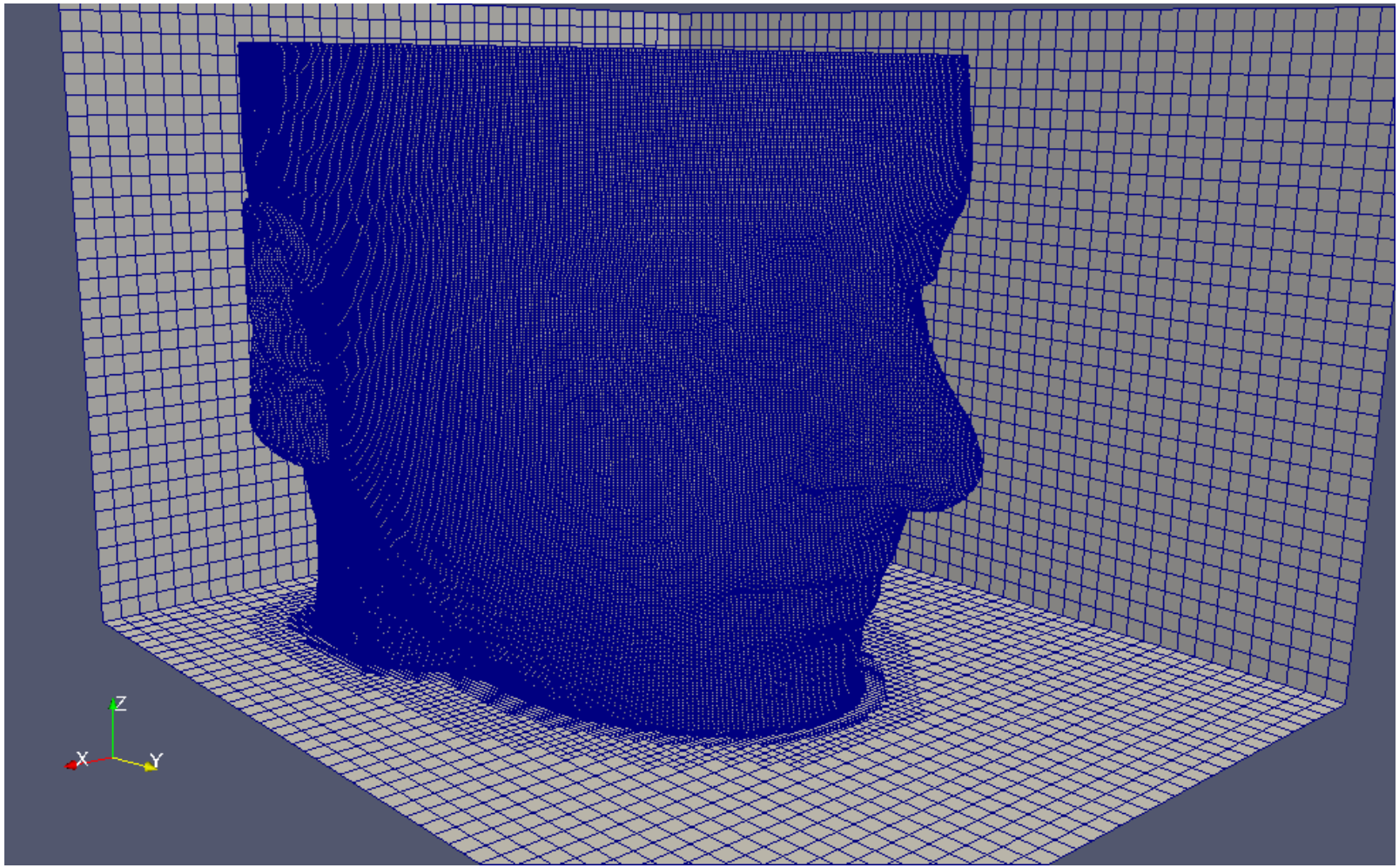




# 3/4 VOLUME MESH

## CASTELLATED MESH

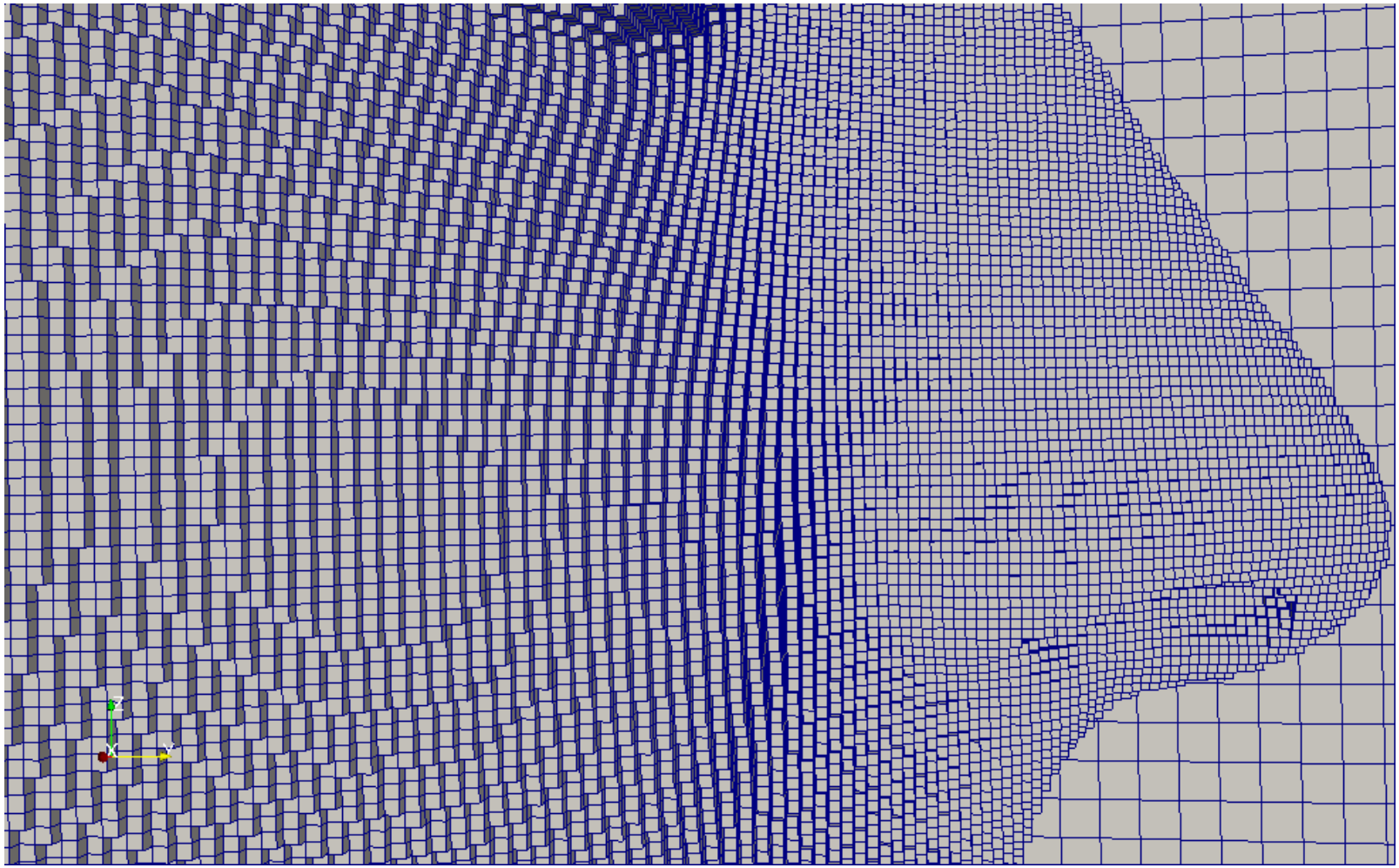




# 3/4 VOLUME MESH (2)

## CASTELLATED MESH

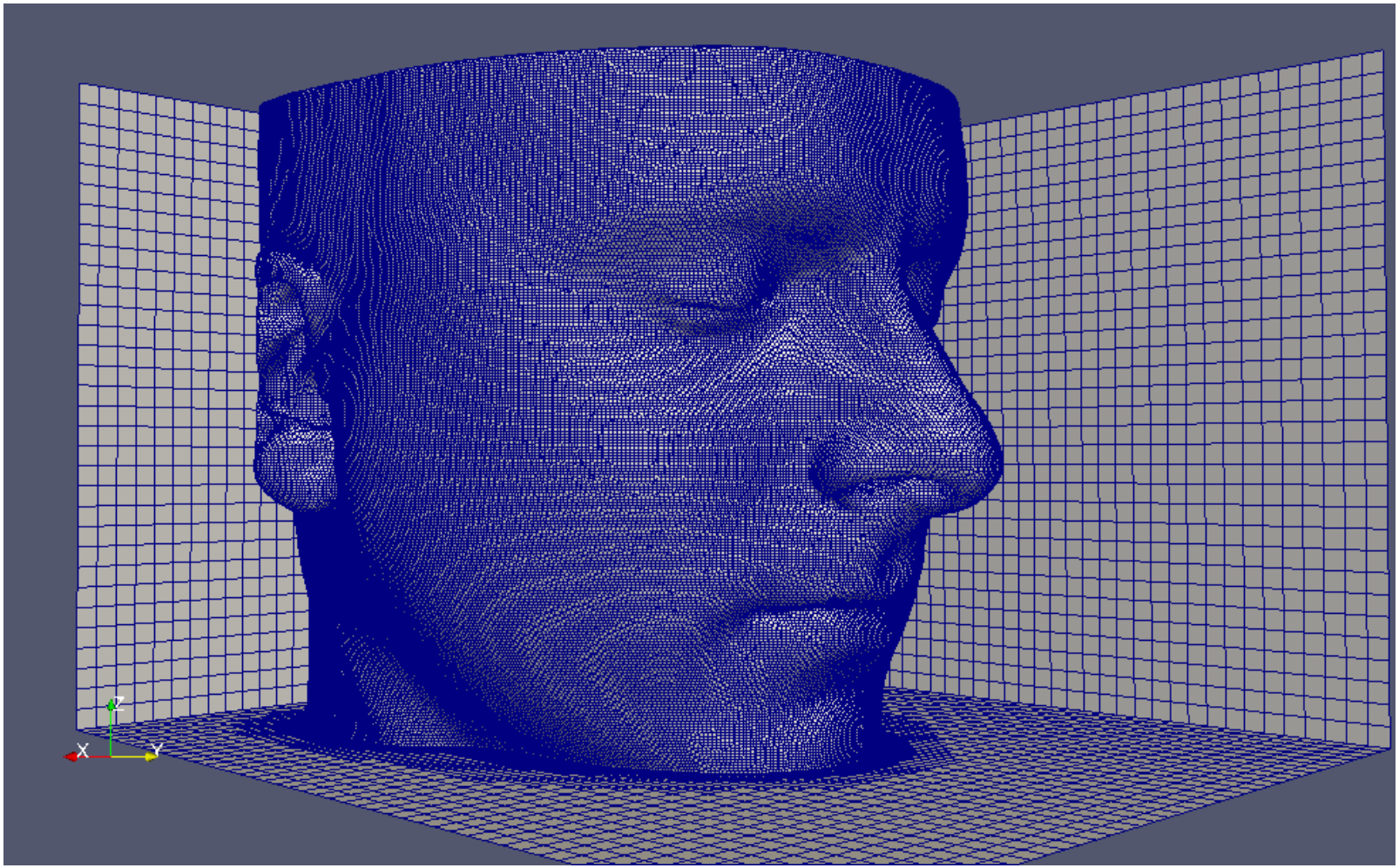




# 3/4 VOLUME MESH (3)

## SNAP

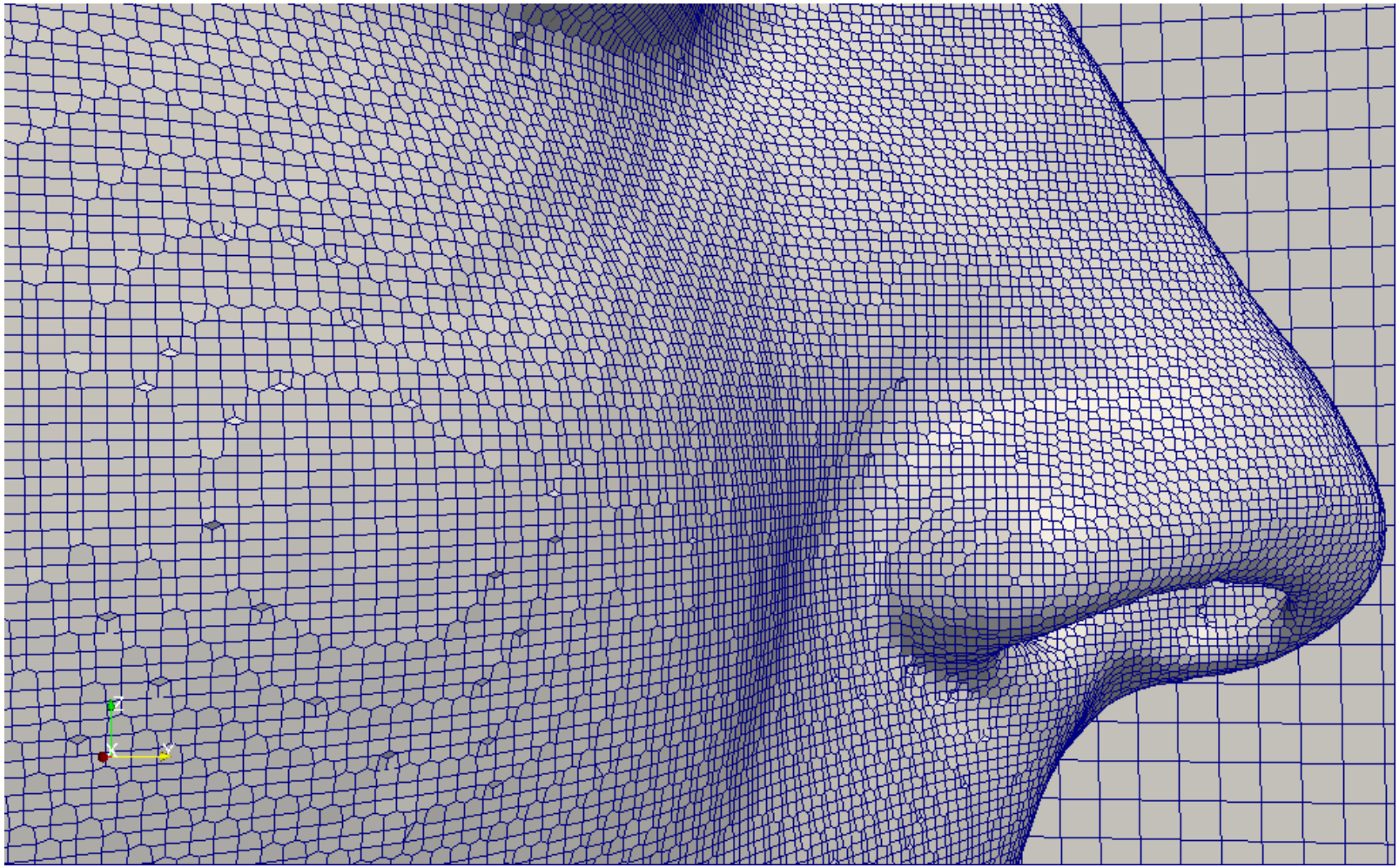




# 3/4 VOLUME MESH (4)

## CASTELLATED MESH

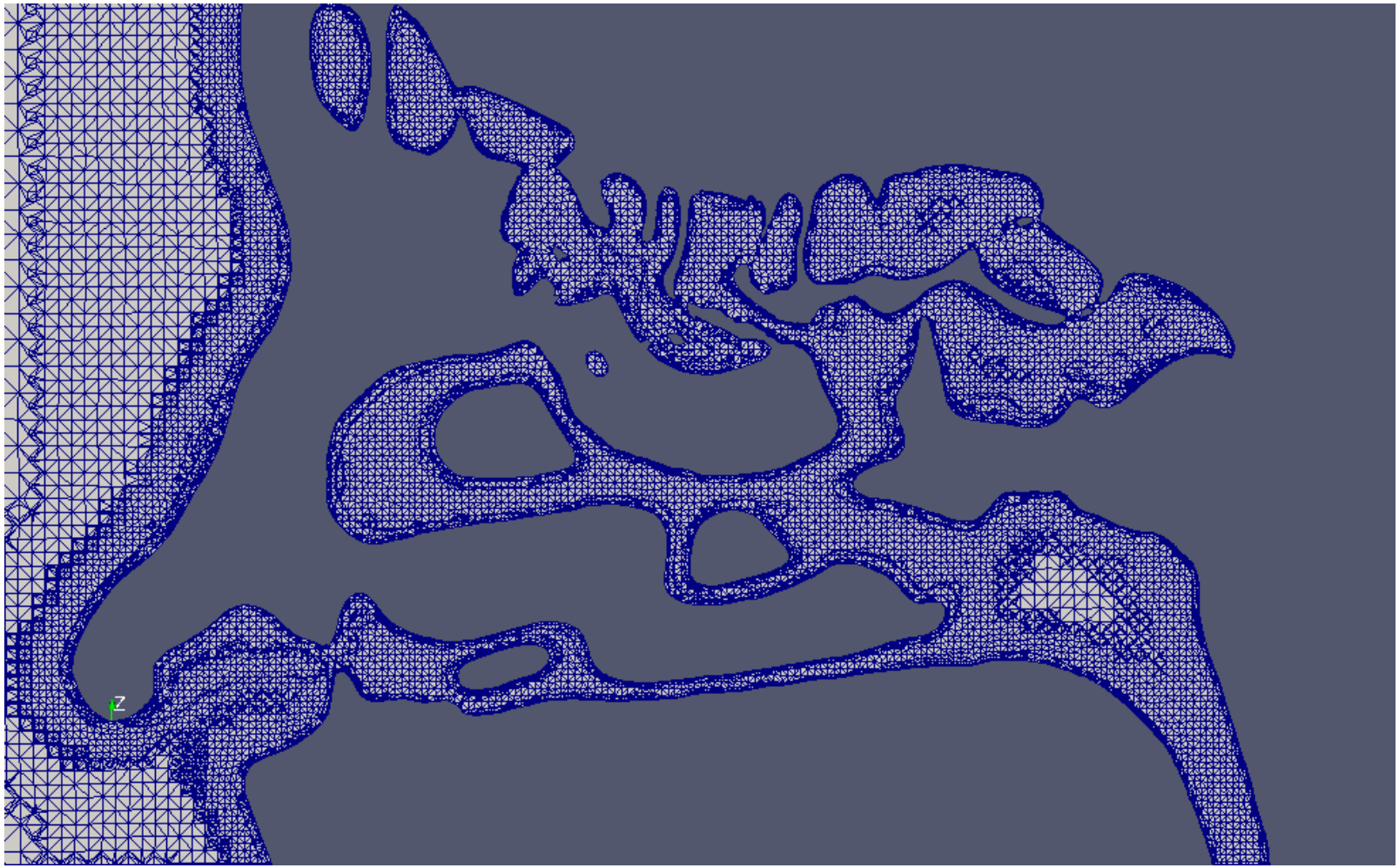




# 3/4 VOLUME MESH (5)

## ADDING LAYERS

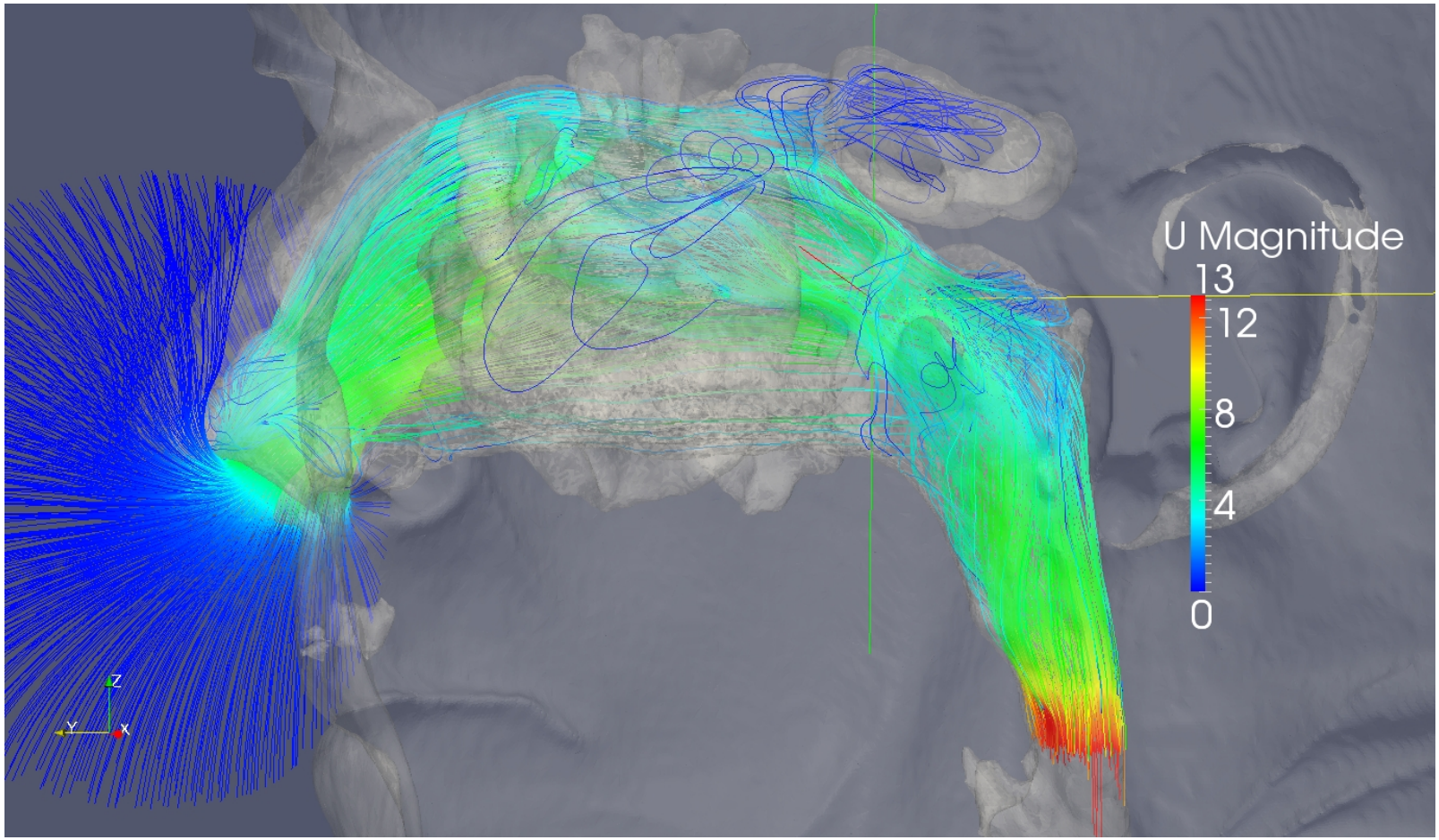




# 4/4 CFD

## STEADY INSPIRATION, LAMINAR





# Outline

# THE ROLE OF OPENSOURCE AND OPENFOAM



- Freedom
- Reliability
- Flexibility

# Outline

# 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