FLUENT - Nasal Airway Model

This tutorial is designed to show the process of extracting a nasal airway cavity geometry from a set of CT scans using Materialize MIMICs software. The tutorial also explains meshing the geometry in ICEM CFD and solving the model in FLUENT.

This process was created for my Masters of Engineering research which the goal is to model and quantify nasal reconstruction surgical procedures. Comparing the various surgical techniques using CFD results will help surgeons determine the proper procedure for the type of nasal airway obstruction in the patient.

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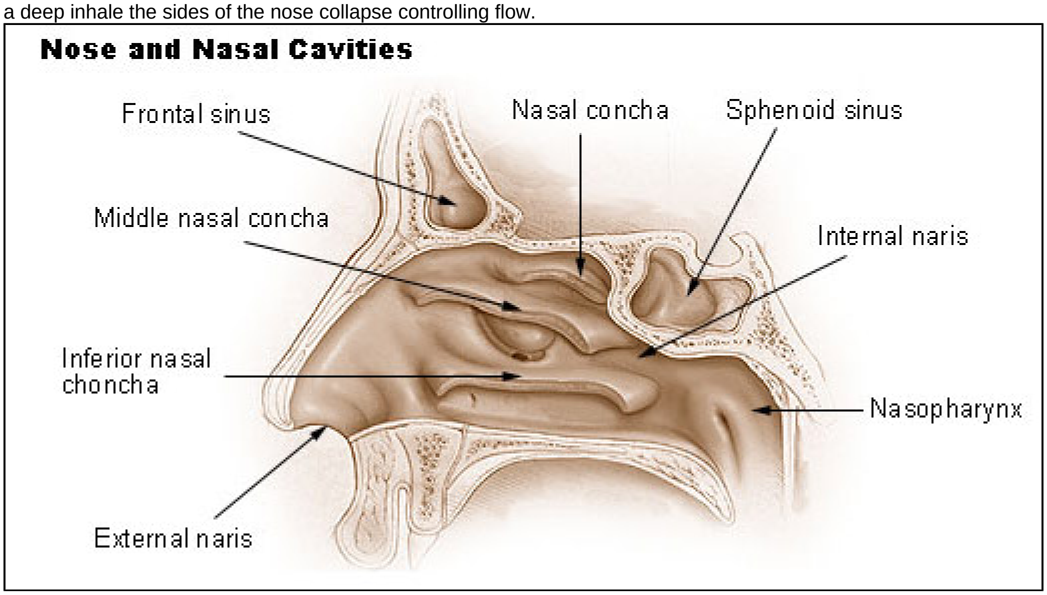
Nasal Airway Model

Created using ANSYS 14.0

Problem Specification

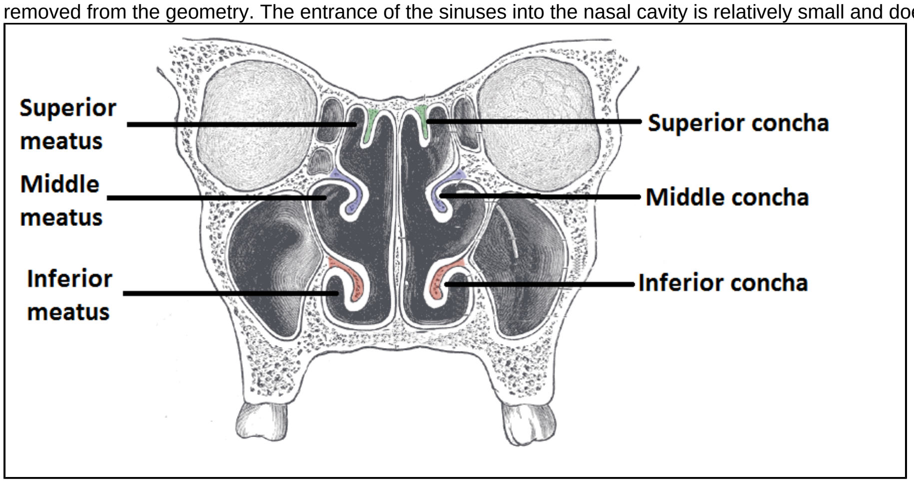
Goals
1- Process the set of CT Scan images
2- Extract the Geometry of the cavity using MIMICs software
3- Mesh the created STL file in ANSYS ICEM CFD
4- Solve the model in FLUENT
5- Compare the pressure and shear stress on the nasal wall

Anatomy
Understanding the nasal anatomy is essential in determining the proper geometry for the model. The nasal airway cavity is a very complex structure extending from the nostrils at the anterior of the head, to the nasopharynx at the posterior of the throat. For a reference the cavity extends all the way to the uvula in the back of your throat, so your nasal cavity extends deep inside the skull. The right and left nostril are separated by the septum, a membrane that is mostly cartilage in the anterior of the nose but becomes a thin bone in the posterior of the cavity. Air flow enters the nose through the nostrils, entering vertically and the flow is redirected horizontally with the curvature of the nose. The nose itself contains flaps of cartilage that act as valves, during a deep inhale the sides of the nose collapse controlling flow.



http://training.seer.cancer.gov/images/anatomy/respiratory/nose_nasal_cavities.jpg

The most complex section of the geometry is nasal concha or turbinates that occupy most of the cavity. These bones are long finger-like shelves in the nasal passage, extending from the top of the exterior nose to the nasopharynx. There are three sets of concha, inferior, middle and superior. Viewing the skull from the coronal plane, like you are facing the patient, shows that these concha are actually curved. These concha serve to distribute the incoming air and also warm and moisten the air before entering the lungs. Additionally there are four sets of sinuses around nasal cavity, which for this study will be removed from the geometry. The entrance of the sinuses into the nasal cavity is relatively small and does not impact the flow in cavity to any great extent.



http://www.teachmeanatomy.com/wp-content/uploads/2012/12/Conchae-and-Meatuses.png

Nasal Airway Obstructions (NAO)- The focus of this study is relieving the stress to the patient cause by nasal airway obstructions. There are many types of obstructions but the most common is a deviated septum caused by some trauma to the nose. This causes a change in the geometry between the right and left nasal passage, and the patient then experiences constant discomfort when inhaling due to the differences in pressure or shear stress on the nasal wall. Correction of these NAO is done with a 'shot-gun' surgical approach, doing as many surgeries in one procedure in hope of alleviating the problem. Being able to quantify the various surgical procedures would then help determine a single proper surgery for the patient.

Biological Specifications

1- A negative pressure should be placed at the nasopharynx, to simulate a normal inhale
2- From rhinometry data, the targeted flow out the nasopharynx should be 15 L/min during normal inhale
3- The provided patient has a deviated septum, so there should clear distinction between the pressure on the nasal wall in the right and left nasal passages
4- From previous studies, the flow may be modeled as laminar

Reference studies

Rhee, J. S., Cannon, D. E., Frank, D. O., & Kimbell, J. S. Role of Virtual Surgery in Preoperative Planning: Assessing the Individual Components of Functional Nasal Airway Surgery.

Rhee, J. S., Pawar, S. S., Garcia, G. J., & Kimbell, J. S. (2011). Toward personalized nasal surgery using computational fluid dynamics. Archives of Facial Plastic Surgery, 13(5), 305-310.

Lee, H. P., Poh, H. J., Chong, F. H., & Wang, D. Y. (2009). Changes of airflow pattern in inferior turbinate hypertrophy: A computational fluid dynamics model.American journal of rhinology & allergy, 23(2), 153-158.

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