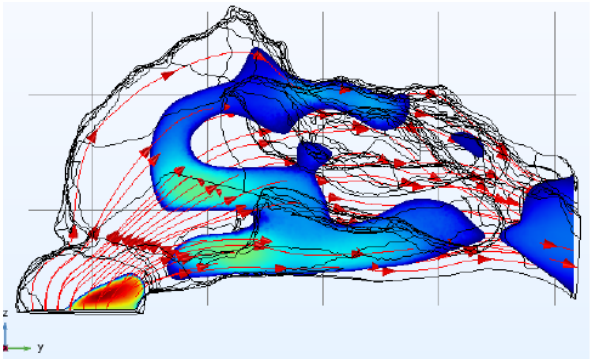
Assessment of nasal obstruction surgery, using CFD, and in vitro and in vivo measurements

Background

Nasal obstruction and symptoms of impaired nasal breathing is a common medical complaint in primary care and ear nose and throat (ENT) specialist care. Inflammatory nasal disease is present in at least 30% of the adult population and nasal obstruction due to structural nasal disease such as septal deviation in 2%. Each year around 2000 operations (septoplasties) are carried out in Sweden in order to increase nasal air flow, and 25% of the patients are not improved by the surgery. A major challenge to the clinician is to establish if the patient has an objective impairment of nasal breathing. Another to distinguish between structural nasal obstruction and inflammatory disease that is reversible by medical treatment. Methods available today to assess nasal airflow and resistance are labour intensive and inaccurate to define normal breathing, so called tidal breathing conditions. Previous attempts have been made to make computerised models of the nasal cavities based on nasal computer tomography scans. Nasal air flow has been simulated but mainly with the purpose to analyse the distribution of particles and aerosols in the nose as a tool in the design of new nasal medications. Less interest has been shown to detect and modify pathological flow restriction in these simulations, and the ability to predict accurately how nasal air flow and resistance can be modified as an aid in the clinical treatment of these patients still remains poor.

Previous work



In the spring of 2020, two students conducted the initiation of a collaborative project between Sahlgrenska University Hospital and Chalmers University of Technology aiming to construct a stable model for predicting nasal air flow and resistance. This first part included simulations of nasal air flow in a computerised algorithm using CFD (computational fluid dynamics). The effort was continued in 2021, by one student focusing on CFD, one student focusing on preparations of lab experiments, and a third student focusing on clinical aspects and lab experiments. Both the CFD and lab experiments were conducted under tidal breathing conditions. A 3D cast of the nasal cavities was manufactured based on CT images along with the corresponding CFD

model. Using an electrical pump connected to the cast, live in vitro simulations have been performed.

The present project

The purpose of the present project is to apply the methods developed previously under real-life conditions. Patients scheduled for septoplasty to relive nasal obstruction will be invited to a study where a cone beam CT (CBCT) scan will be performed before surgery and 2-6 months after surgery. Based on the CBCT, 3D casts will be printed and analysed with the established techniques. CFD models will be produced before and after surgery and rhinomanometry will be measured both on the patient and the cast before and after surgery. Nasal symptoms of obstruction, secretion and sense of smell will be assessed before and 2-6 months postop as well as patient satisfaction. The aim of the study is to use CFD simulations and lab experiments to assess real life settings when performing septoplasty.

Significance

While nasal surgery for nasal obstruction remains a common surgical intervention in adults, the knowledge of how this affects nasal air flow and resistance in detail is poorly understood and ¼ of patients are not improved. To be able to predict in a CFD model how air flow and resistance will react to surgical intervention is thus crucial in the understanding of success. There is a need for a quicker, easier and more accurate way to objectively diagnose nasal obstruction among patients with chronic, non-inflammatory obstruction. The diagnostic alternatives available today are difficult to use, time consuming and give a non-physiological representation of nasal air flow, leaving the physician with insufficient data to determine the right course of action. In the future, we also plan to suggest new methods of quantifying nasal obstruction as well as a more streamlined way of operations in silico to find an optimal surgical action plan.

Students and prerequisites for the thesis

Two students are needed, one with CFD knowledge, and one with clinical knowledge, both with interest in medical flows and improvements of surgical procedures.

Examiners/supervisors

- For numerical part - Prof. Håkan Nilsson, hakan.nilsson@chalmers.se
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- For biomathematical part – Prof. Torbjörn Lundh, torbjrn@chalmers.se

Publications of interest

Clement PA, Gordts F; Standardisation Committee on Objective Assessment of the Nasal Airway, IRS, and ERS. Consensus report on acoustic rhinometry and rhinomanometry. Rhinology. 2005 Sep;43(3):169-79. PMID: 16218509.

Jakob Widebrant and Johan Ronnås, Nasal Obstruction - Diagnosis and Prediction using Computational Fluid Dynamics, Chalmers Master Thesis, (supervisor T. Lundh), 2020