PATIENT SPECIFIC NUMERICAL SIMULATION OF FLOW IN THE HUMAN UPPER AIRWAYS, FOR ASSESSING THE EFFECT OF NASAL SURGERY

Maria Rolstad Jordal(1) , Sverre Gullikstad Johnsen(2), Sigrid Kaarstad Dahl(2), Balram Panjwani(2), and Bernhard Müller(1)

1. NTNU, Dept. Energy and Process Engineering, Norway; 2. SINTEF Materials and Chemistry, Norway

Introduction

Obstructive Sleep Apnea Syndrome (OSAS) is a disorder characterized by repeated collapses of the upper airways, preventing air from flowing freely, during sleep. The severity of sleep apnea is indicated by the apnea-hypopnea index (AHI), where <5 is considered normal and >30 severe. At St. Olavs Hospital, Trondheim University Hospital, Norway, intranasal surgery is being performed on patients with clinically significant nasal obstructions for alleviation of OSAS, but only one third of the surgeries are successful [1]. The goal of this study is to establish pre- and post-operative mathematical models of the air-flow in the upper airways of selected patients in order to investigate if changes in the flow pattern due to surgery can be correlated to the change in AHI. This presentation reports from the computational fluid dynamics (CFD) studies of one of these patients.

Method

Two 3D models of the upper airways were created from datasets obtained from computed tomography (CT) of an OSAS patient before, and after, intranasal surgery. The selected patient had a good response to surgery, with an improved AHI from 23 to 5.7. Segmentation of the CT images was performed in the freeware ITK-SNAP 3.2.0 [2], and the quality of the resulting 3D models was assured by clinicians. The flow field in the upper airways was studied pre- and post-operatively using the software ANSYS Fluent [3]. The study was limited to steady state, laminar, inhaling flow, with constant pressures at the inlets (nostrils) and outlet (larynx). The grid was refined until the numerical solution of the flow-field showed insignificant grid dependency. A comparison of the flow in the upper airways before and after surgery was done based on results from the CFD simulations. Selected computed results were compared with measured data to validate the CFD models.

Results and Discussion

CFD modelling results clearly show that the reduced hydrodynamic resistance in the nasal cavity after surgery affects the airflow. For identical volumetric flows, the static pressure in the upper airways is increased after surgery. This reduces the risk of collapse. However, the reduced hydrodynamic resistance may result in higher flow velocities, increasing the risk of airway collapse due to the Venturi effect where the airflow is accelerated through narrow passages (Figure 1).

Understanding how intranasal surgery changes the flow-pattern in the upper airways, and may affect the AHI in OSAS patients, is essential for improving the success-rate of current treatment options. We expect that, in the future, CFD will be used as a design tool for optimizing surgical intervention and minimizing risk for the patient. Being part of a larger set of patient-specific CFD studies, this study is a corner-stone in the ongoing work to improve our understanding of human upper airways airflow, and it is thus an important step towards computer-aided diagnostics and treatment of OSAS.

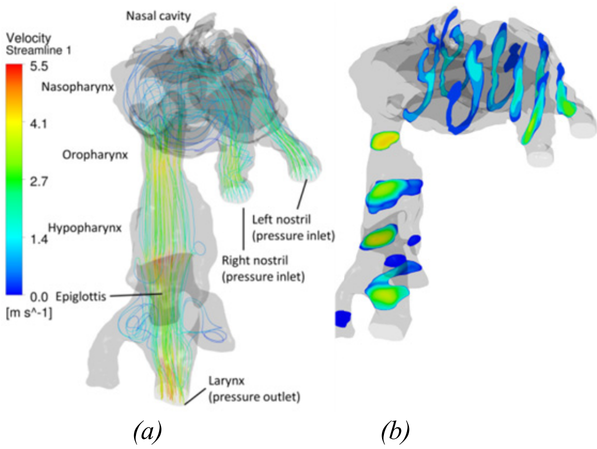

Figure 1: Velocity stream-lines (a) and contours (b) depicting the flow pattern in a patient-specific CFD model of the human upper airways.

References

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