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CFD Simulation of the Pressure Distribution in the Upper Airway of an Obstructive Sleep Apnea Patient

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Abstract : CFD simulations are performed in the upper airway of a patient suffering from obstructive sleep apnea (OSA) that is a sleep related breathing disorder characterized by repetitive partial or complete closures of the upper airways. The simulations are aimed at getting a better understanding of the pathophysiological flow patterns in an OSA patient. The simulation is compared to medical data of a sleep endoscopic examination under sedation. A digital model consisting of surface triangles of the upper airway is extracted from the MR images by a region growing segmentation process and is followed by a careful manual refinement. The computational domain includes the nasal cavity with the nostrils as the inlet areas and the pharyngeal volume with an outlet underneath the larynx. At the nostrils a flat inflow velocity profile is prescribed by choosing the velocity such that a volume flow rate of 150 ml/s is reached. Behind the larynx at the outlet a pressure of -10 Pa is prescribed. The stationary incompressible Navier-Stokes equations are numerically solved using finite elements. A grid convergence study has been performed. The results show an amplification of the maximal velocity of about 2.5 times the inlet velocity at a constriction of the pharyngeal volume in the area of the tongue. It is the same region that also shows the highest pressure drop from about 5 Pa. This is in agreement with the sleep endoscopic examinations of the same patient under sedation showing complete contractions in the area of the tongue. CFD simulations can become a useful tool in the diagnosis and therapy of obstructive sleep apnea by giving insight into the patient's individual fluid dynamical situation in the upper airways giving a better understanding of the disease where experimental measurements are not feasible. Within this study, it could been shown on one hand that constriction areas within the upper airway lead to a significant pressure drop and on the other hand a good agreement of the area of pressure drop and the area of contraction could be shown.

Keywords : biomedical engineering, obstructive sleep apnea, pharynx, upper airways
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