Review: A Critical Overview of Limitations of CFD Modeling in Nasal Airflow

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Received 29 May 2011; Accepted 5 Aug 2011; doi: 10.5405/jmbe.948

Abstract
Computational fluid dynamics (CFD) modeling of nasal airflow has been carried out by several researchers. Virtual surgical treatment and aerosol deposition studies have also been conducted. However, the appropriateness of such modeling practices with regards to modeling and medical constraints needs careful consideration. The current numerical models for the study of nasal airflow, developed from the scanned images obtained from computed tomography or magnetic resonance imaging, are influenced by postural changes. These models neglect the mucous layer, other vital anatomical features, and nasal cycle effects. CFD studies make numerous assumptions that seriously limit their usefulness. Unless these constraints can be addressed, the interpretation of results from a CFD output cannot be considered as an appropriate definition of the flow behaviour. This review provides a critical overview of the limitations of the CFD modeling of nasal airflow. Some of the limitations and constraints associated with CFD modeling are reviewed and possible studies that could be carried out in the future to ascertain the effect of neglecting these parameters are discussed. This study also proposes a standardisation of the computational modeling procedure, which is necessary for studying airflow inside the nasal cavity.

Keywords: Computational fluid dynamics, Posture, Gender, Mucous, Pull flow, Virtual surgery

1. Introduction
The primary function of the nose is to maintain an appropriate air flow inside the nasal cavity to allow it to accomplish its physiological function. To investigate this function, many researchers have employed the computational fluid dynamics (CFD) method to study airflow profiles during nasal inspiration [1-15]. CFD enables the visualization of airflow inside the nasal cavity and can be used to determine flow parameters such as velocity, pressure, wall shear stresses, and vortex formation at any location inside the nasal cavity. This information is very useful as probes and other measurement devices cannot be inserted inside the nose during actual breathing operation. CFD studies on nasal anamolies such as atrophic rhinitis, septum deviation, and turbinectomy have also been useful to understand the necessity of surgical interventions [16-24]. Drug delivery studies and aerosol deposition studies have enhanced our understanding of nasal physiology [25-32].

However, several assumptions are made in modeling flow through the nasal cavity. Some medical constraints have not been given due consideration in studies that have used CFD. The 3D modeling of a nasal cavity is achieved using computed tomography (CT) or magnetic resonance imaging (MRI) images. The changes induced inside the nasal cavity due to posture significantly alter the physics of flow. The effects of the nasal cycle have also not been considered in CFD modeling studies. In addition, modeling limitations such as the simplification of the nasal model by neglecting the sinus and underlying mucous regions affect flow. Both engineers and medical practitioners need to be fully aware of the shortcomings of CFD modeling in order to make a realistic estimate of its appropriateness. Thus, this study provides a critical overview of the limitations of the CFD modeling of nasal airflow. Some of the limitations and constraints associated with CFD modeling are reviewed and possible studies that could be carried out in the future to ascertain the effect of neglecting these parameters are discussed.

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