Numerical Simulation on Airflow Structure in the Human Upper Respiratory Tract Model

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Abstract : The respiratory diseases such as asthma, emphysema and bronchitis are connected with the air pollution and the number of these diseases tends to increase, which may attribute to the toxic aerosol deposition in human upper respiratory tract or in the bifurcation of human lung. The therapy of these diseases mostly uses pharmaceuticals in the form of aerosol delivered into the human upper respiratory tract or the lung. Understanding of airflow structures in human upper respiratory tract plays a very important role in the analysis of the “filtering” effect in the pharynx/larynx and for obtaining correct air-particle inlet conditions to the lung. However, numerical simulation based CFD (Computational Fluid Dynamics) technology has its own advantage on studying airflow structure in human upper respiratory tract. In this paper, a representative human upper respiratory tract is built and the CFD technology was used to investigate the air movement characteristic in the human upper respiratory tract. The airflow movement characteristic, the effect of the airflow movement on the shear stress distribution and the probability of the wall injury caused by the shear stress are discussed. Experimentally validated computational fluid-aerosol dynamics results showed the following: the phenomenon of airflow separation appears near the outer wall of the pharynx and the trachea. The high velocity zone is created near the inner wall of the trachea. The airflow splits at the divider and a new boundary layer is generated at the inner wall of the downstream from the bifurcation with the high velocity near the inner wall of the trachea. The maximum velocity appears at the exterior of the boundary layer. The secondary swirls and axial velocity distribution result in the high shear stress acting on the inner wall of the trachea and bifurcation, finally lead to the inner wall injury. The enhancement of breathing intensity enhances the intensity of the shear stress acting on the inner wall of the trachea and the bifurcation. If human keep the high breathing intensity for long time, not only the ability for the transportation and regulation of the gas through the trachea and the bifurcation fall, but also result in the increase of the probability of the wall strain and tissue injury.

Keywords : airflow structure, computational fluid dynamics, human upper respiratory tract, wall shear stress, numerical simulation
Conference Title : ICAFMMS 2017 : International Conference on Applied Fluid Mechanics and Mechanical Systems
Conference Location : Paris, France
Conference Dates : May 18-19, 2017