CFD Study of the Air Flow Field and Particle Deposition in the Human Nasal Cavity

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Abstract

The nasal cavity is a main part of the human upper airway, and it has the important functions of respiration, heating and humidifying the inhaled air. The properties of the air flow in the nasal cavity may contribute to the occurrence of respiratory disease. In addition, particles are filtered by the nasal cavity. This function prevents toxic particles to enter into the human body, but it also blocks the aerosol drug to reach the targeted position such as the middle region of the nasal cavity. Thus, it is very important to study the characteristics of both the air flow field and particle deposition in the nasal cavity.

In the present work, the computational surface grid of the nasal cavity is constructed based on computed tomography (CT) scans using NeuRA2 [1]. Ansys ICEM-CFD 11.0 is used to generate the numerical volume grid. Large eddy simulation (LES) with the Smagorinsky sub-grid model is used to simulate the gas flow, and the method is combined with Lagrangian particle motion. The open source software of OpenFOAM 1.5 is used to solve the governing equations, where a new solver has been constructed to account for the particle motion using a Lagrangian tracking method within the LES formulation for the flow field. The inspiration flow rate is 7.5 L/min, and 10,000 uniformly distributed particles are randomly released at the inlet plane with the same velocity as the air flow shown in Fig. 1. The particle density is 912 $\mathrm{kg/m^3}$, and the particle radius is 5 μm.

The numerical results reveal that the maximum velocity exists in the region of nasal valve, and the air impinges on the wall of the nasal valve. The air flow field in the left and right nasal passages is not uniform, which results from the asymmetric configuration of the nasal cavity. Only little air can reach the tips of meatuses and the olfactory region. The air flow passes the nasal cavity mainly through the main air passage. Vortices are observed in the nasopharynx region. The particle deposition in the nasal cavity is been compared with the numerical results of Matida et al. [2]. The present particle deposition rate in the nasal cavity is 24.54%, which is close to their result of 26.5% [2]. It is observed that the particle deposition in the nasal cavity mainly occurs in the anterior region, and particles mainly deposit on the impact sides such as the nasal valve, the anterior region of the middle meatus and the nasopharynx as shown in Fig. 2. The particle release positions at the inlet plane influence the particle deposition positions on the wall, and their ability to pass through the nasal cavity.

In the future, the grid will be refined, and different inspiration flow rates and particle diameters will be investigated. The interaction between the air flow field and particle transport will be studied in more detail.

Figure 1. Initial positions of the released particles at the inlet plane.

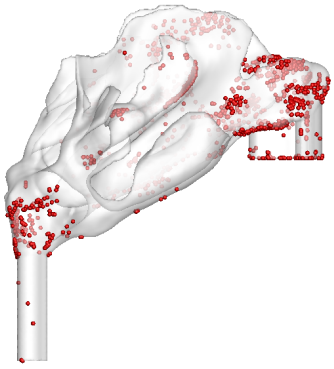

Figure 2. Particle deposition characteristics on the wall of the nasal cavity.

[1] Jungblut, D., Queisser, G., and Wittum, G., *Computing and Visualization in Science* 14: 181-186 (2012).
[2] Matida, E. A., Liu, Y., Gu, J., and Johnson, M. R., *Journal of Aerosol science* 38: 683-700 (2007).

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