

LES Study on the Poly-disperse Particle Deposition in the Human Upper Airway

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Abstract

Aerosol particle application of therapeutic agents into the deep lung represents an essential treatment of asthma and other lung diseases. The advantage of pulmonary drug delivery through inhalation is the topical treatment of specific lung conditions with limited whole-body effects. Aerosol particle deposition in this region has important impact in drug delivery efficiency, and it is highly desirable to study particle deposition in the human upper airway. Although significant investigations have been performed in this field, little research has focused on the study of poly-disperse particle deposition in the human respiratory system, considering a realistic drug dose. In the present study, a poly-disperse particle distribution as shown in Fig. 1 from a dry powder inhaler [1] is adopted using a realistic drug dose of 200 μg , which is introduced into the human upper respiratory system through the mouth. The mouth-throat configuration is constructed based on cast. Ansys ICEM-CFD 11.0 is used to generate the numerical grid. Two-way coupling is implemented to model the two phase flow. Large eddy simulation (LES) with the Smagorinsky sub-grid model is used to simulate the transitional laminar-turbulent gas flow, and the method is combined with a model for Lagrangian particle motion. The open source software of OpenFOAM 1.5 is adopted 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 numerical results show that the particle deposition in the human mouth-throat is dominated by particle distribution and dispersion. The contribution of particle deposition is related to both the initial particle size and the geometric region. It is found that particles in the initial size range of 1–5 μm contribute least to the particle deposition as can be seen from Fig. 2, although the major part of injected mass consists of these particles, c.f. Fig. 1. The total mass fraction of particles in the size ranges 0.35–1 μm , 1–5 μm , and 5–23.5 μm is 26.3%, 63.5%, and 10.2% respectively, whereas the corresponding particle deposition efficiencies are 1.79%, 0.59%, and 3.99%. It is found that the particle deposition in the trachea is mainly caused by particles less than 1 μm , in the pharynx and larynx by particles larger than 5 μm , whereas in the mouth cavity, contributions of both particle size ranges deposit. Thus, poly-disperse particle size distribution greatly influences particle deposition in the human upper airway, and particles in the size range of 1–5 μm are most likely to reach the deep lung. The present method is suitable to study particle deposition in more realistic mouth-throat models based on computed tomography (CT) scans.

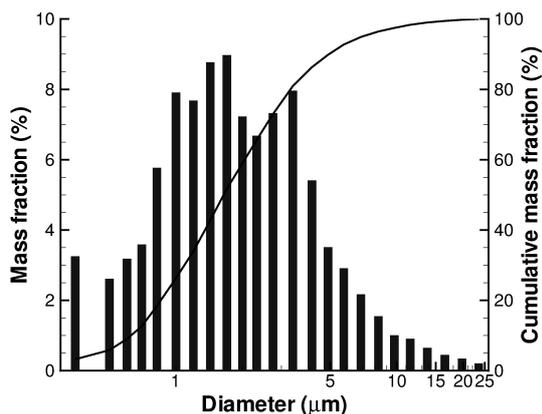


Figure 1. Initial poly-disperse particle size distribution measured from a metered-dose inhaler [1].

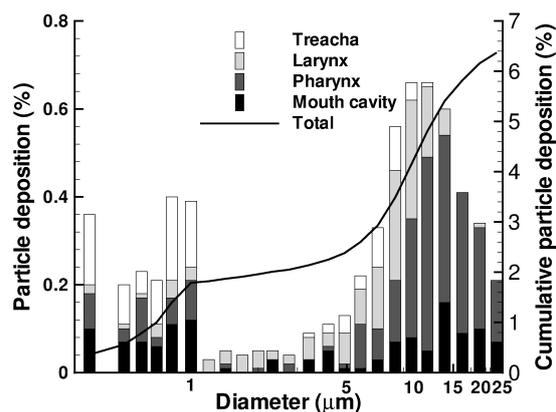


Figure 2. Particle deposition in different regions of the mouth-throat.

[1] Littringer, E. M., Mescher, A., Schroettner, H., Walzel, L. A. P. and Urbanetz, N. A., *European Journal of Pharmaceutical Sciences* (2011), accepted.

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