Regional Deposition of Particles in a Model of Human Lungs: A Comparison of Numerical Simulation and Experimental Results

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Several studies have pointed out that knowledge of localised deposition of inhaled particles in the lungs is important, as the high particle concentration participates on the development of diseases such as bronchial carcinoma (Churg and Vedal, 1996 or Hofmann, 2011). The localised deposition can be predicted by numerical simulations nowadays, however, reliable experimental data for validation is difficult to obtain.

We developed a realistic replica of human airways consisting of the oral cavity and the tracheobronchial tree down to the seventh generation of branching. The identical geometry exists as a physical replica for experimental work and as a digital geometry serving for numerical simulations (Lizal et al., 2012).

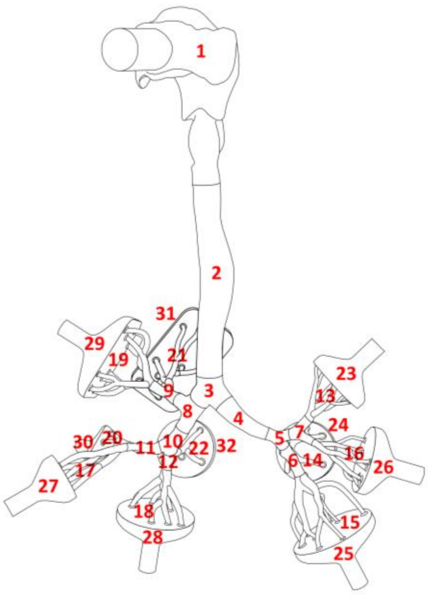

Figure 1. The replica of human airways with designation of segments.

Experimental setup

The measurement of particle deposition was performed using positron emission tomography (PET). Monodisperse particles in sizes of 2.5 and 4.3 µm were tagged by ^{18}F. Two constant inhalation flowrates (15 L/min and 30 L/min) were measured. The replica was scanned using Siemens Biograph 64 Truepoint PET-CT scanner immediately after the exposure. The amount of radioactivity was analysed using Carimas 2.4 (Turku PET Centre, Finland) software and transformed into the deposition fraction, efficiency and density. For details please see Lizal et al. (2015).

Numerical simulation

Numerical simulations were performed using commercial solver Star-CCM+. Airflow was calculated using steady RANS method with SST Menter´s k-ω model of turbulence with treated boundary layer, which satisfies the conditions for low Reynolds number. Particle deposition was simulated using Lagrangian multiphase model with 10,000 parcels.

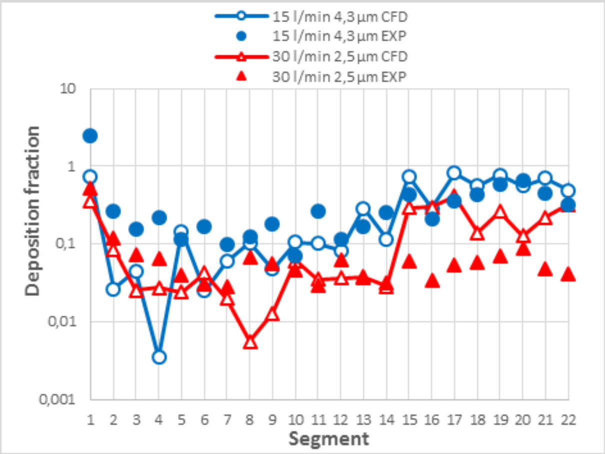

Figure 2. A comparison of experimental data and the simulated deposition.

Comparison

Relatively good agreement was found between experiments and simulation for the lower flowrate and segments with multiple bifurcations. Simulated deposition was systematically higher for segments 1 – 12. On the contrary, the first 12 segments agree well for the higher flowrate, however, the deposition in the multiple bifurcation segments was underestimated by the simulation.

Acknowledgement

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