Numerical Simulation of Targeted Pulmonary Drug Delivery in Patient-based Human Lung Model Under Physiological Conditions

Abstract

Computational hemodynamics (CHD) characterization of cardiovascular disease physiological situations is essential. Effective inhalation medicine delivery depends on accurate deposition of dispersed drugs in specific lung regions. This research aims to create a computational framework using numerical simulation to model and optimize pulmonary medication delivery in unique lung geometries under physiological settings. Anatomically precise airway models from medical imaging are used to simulate nanoparticle movement and deposition using high-fidelity CHD and Lagrangian particle tracking. Unsteady, three-dimensional airflow, patient breathing dynamics, and nano particle behavior will be simulated to accurately predict lung medication distribution. CT images will be used to generate three-dimensional lung models reflecting anatomical variability, age, disease, and form. Tidal and vigorous inhaling will be mimicked when boundary conditions change. Airflow dynamics will be solved using Navier-Stokes equations and turbulence models, while particle motion will account for drag, gravity, Brownian diffusion, and inertial impaction. Clinical imaging, fluid dynamics, and drug delivery models are integrated in this computational system. This instrument can be used for chronic illness management, emergency respiratory care, and gene or nanoparticle-based therapy delivery due to its versatility. Nanoparticle-based targeted drug delivery models for cardiovascular disease prediction, diagnosis, and treatment are lacking. Thus, the proposed method should be reevaluated to ensure physical consistency and improve lung artery vascular hemodynamic model numerical efficiency.