An Individual Multi-scale Image-based Lung Model and a Statistics-based Strategy of applying it to Population-based Assessment of Lung Functions

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Abstract

Airway defense is a multi-scale process, involving mechanotransduction to transmit oscillatory mechanical force from macro scale (motion of lung) to micro scale (flow- or tissue-induced stresses), and further translation to biochemical responses via cell signaling to maintain the periciliary liquid (PCL) volume for mucociliary clearance. We hypothesize that lung diseases alter mechanical force, which then alters stress-mediated adenosine triphosphate nucleotide (ATP) release, disturbs PCL water homeostasis, and weakens the integrated airway defense system, forming a vicious cycle of events. To test this hypothesis, we are in the process of building a multi-scale lung model that integrates imaging processing and geometric modeling, computational technologies for breathing lungs with thermodynamics, and mathematical models for epithelial cells and nucleotide metabolism to understand the interplays between organ, tissue, and cells. In this talk, we will first present the current status of the model, including the 3-D and 1-D coupled multi-scale modeling framework, uncertainties in subject-specific boundary conditions, image-registration-data-driven deforming lung, thermodynamics (heat transfer and water vapor flux), and preliminary prediction of PCL height via integration of mechanics and cell models.

While the development of the above lung model for the individual is important, its application to a large population of data sets for assessment and prediction of lung function and pathophysiology is equally important, requiring a strategy due to a large number of geometric variables of lung morphology. We will briefly talk about the strategy based on a reduced-rank stochastic regression technique for cluster analysis (which is described in more detail in a companion abstract titled “Lung-airway Data Interrogation via Cluster Analysis”) and how to integrate the deterministic individual analysis with the statistics-based analysis.

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