Towards a comprehensive computational model for the respiratory system

Wall, W.A.; Wiechert, L.; Comerford, A.; Rausch, S

Abstract:
This paper is concerned with computational modeling of the respiratory system against the background of acute lung diseases and mechanical ventilation. Notionally, we divide the lung into two major subsystems, namely the conducting airways and the respiratory zone represented by lung parenchyma. Due to their respective complexity, both parts are themselves out of range for a direct numerical simulation resolving all relevant length scales. Therefore, we develop detailed individual models for parts of the subsystems as a basis for novel multi-scale approaches taking into account the unresolved parts appropriately. In the tracheo-bronchial region, CT-based geometries up to a maximum of approximately seven generations are employed in fluid-structure interaction simulations, considering not only airway wall deformability but also the influence of surrounding lung tissue. Physiological outflow boundary conditions are derived by considering the impedance of the unresolved parts of the lung in a fully coupled 3D-1D approach. In the respiratory zone, an ensemble of alveoli representing a single ventilatory unit is modeled considering not only soft tissue behavior but
also the influence of the covering surfactant film. Novel nested multi-scale procedures are then employed to simulate the dynamic behavior of lung parenchyma as a whole and local alveolar ensembles simultaneously without resolving the alveolar micro-structure completely.

Stichworte: respiratory mechanics; fluid-structure interaction; multi-scale modeling; tissue mechanics; interfacial phenomena

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