The primary goal of this research is to develop biomechanical models for fluid-particle interaction and structural dynamics in the upper and tracheal airways. The ultimate aim is to demonstrate the capability of biomechanical modeling as a predictive tool in the evaluation and treatment of diseases. The respiratory tract, in other words, the airway, is the primary airflow path for several physiological activities such as coughing, breathing, and sneezing. Diseases can affect airway functionality through various means including cancer of the head and neck, neurological disorders such as Parkinson’s disease, and sleep disorders, all of which are considered in this study.

The work described in this dissertation, therefore, is divided into three biomechanical models, of which fluid and particulate dynamics under cough is the first. Cough is an airway protective mechanism, which results from a coordinated series of respiratory, laryngeal, and pharyngeal muscle activities. Patients with diminished upper airway protection often exhibit cough impairment resulting in aspiration pneumonia. Computational Fluid Dynamics (CFD) technique was used in this study to simulate airflow and penetrant behaviour in the airway geometry reconstructed from Computed Tomography (CT) images acquired from human subjects. The second study describes Obstructive Sleep Apnea (OSA) and the effects of dilator muscular activation on the human retro-lingual airway in OSA. Computations were performed for the inspiration stage of the breathing cycle, utilizing a fluid-structure interaction (FSI) scheme to couple structural deformation with airflow. The spatio-temporal deformation of the structures surrounding the airway wall was predicted and found to be in good agreement with known changes on luminal opening and the distribution of airflow from upright to supine postures. The third study describes the effects of cancer of the tongue base on tongue motion during swallow. A three-dimensional biomechanical model was developed and used to calculate the spatio-temporal deformation of the tongue under a sequence of movements which simulate the oral stage of swallow.