3-Dimensional Simulation of Unsteady Airflow in a Realistic Airway Model of a Severe COPD Patient

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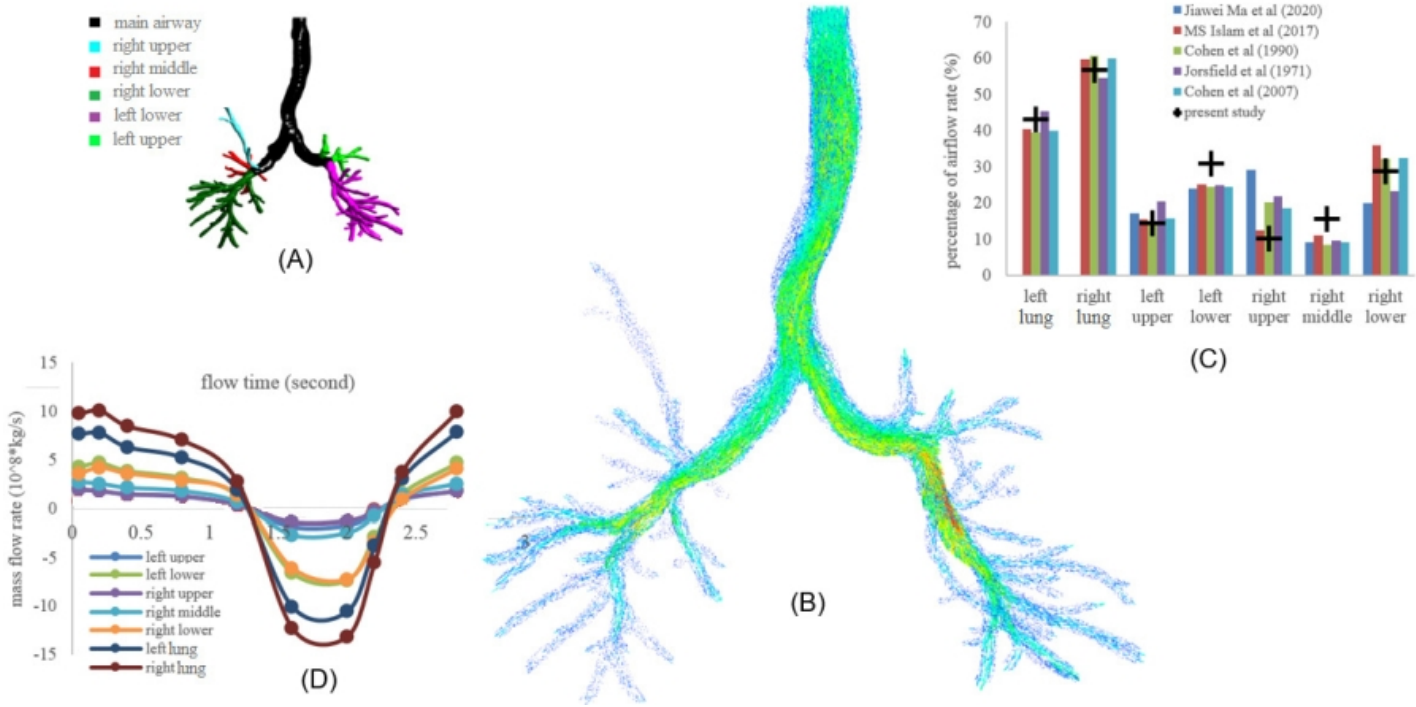
Rationale: Chronic obstructive pulmonary disease (COPD) is the third leading cause of death in the world and has a great impact on patients and societies in terms of cost and life expectancy. In order to better understand the pathophysiology of COPD development and exacerbation, it is important to have a good understanding of airflow in airways of these patients and to compare it with the healthy controls. In this study, 3D unsteady simulation of the airflow in the respiratory airway of a patient with severe COPD obtained with computed tomography (CT) scan, has been performed (Fig. 1A). Furthermore, the breathing cycle and the transient inhaled/exhaled air-flow rate are determined based on real breathing model of the patient. Methods: CT scans images with a cut size of 0.3 mm, were used to construct the realistic geometry of the airway of a patient with very severe COPD. A hybrid mesh, including 6 layers of prism cells and tetrahedral elements, was generated for the fluid region using ANSYS ICEM-CFD. The SIMPLE algorithms were used through ANSYS-FLUENT commercial codes to solve the airflow equations numerically. A real time-dependent patient's mass flow rate (obtained from spirometry) was set on the inlet trachea and a constant outlet pressure of the atmospheric pressure was set as the outlet boundary condition (Fig. 1B). Results: Results show that the air flow in some parts of the patient's airway does not change significantly (Fig. 1C). However, in some locations, such as the left lower and right middle lobes, the high airflow velocity is observed locally. Figure 1D also illustrates that the amount of flow rate in the right lung is more than the left lung. It also demonstrates that the peak airflow rate under unsteady breathing conditions is significantly higher than the steady state conditions specially in exhalation. Additionally, the time-dependent velocity distribution is also confirmed as a result of a variable inhalation/exhalation air flow rate under unsteady breathing cycles. Conclusions: The analysis results of the airway in very severe COPD are strongly dependent on the flow pattern and the modeling of the airway real geometry. Through our 3D case study, the realistic airway model proposed in this study, will be able to provide fundamental and quantitative information for health risk assessments in COPD patients.



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