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Modelling Realistic Inhalation in Large-scale Lung Airway

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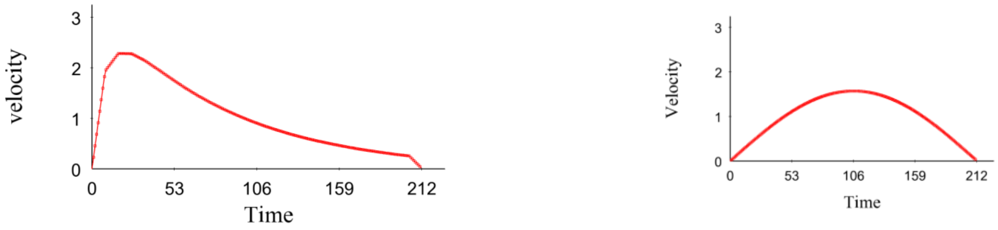
The flow fields in lung airway are quite complex mainly due to the geometrical and unsteady breathing effects. Multiple bifurcations and nonplanarity are the main attributes of the lung airway geometry. The secondary flows, mainly in form of vortices, are present in lung airway due to the curvature of the bifurcating tubes. Particle deposition in bronchial tubes is strongly affected by these secondary flows. The temporal variations in inlet velocities during inhalation further complicate the flows and contribute towards unsteady breathing effects. The harmful effects of inhalation of particles from environment can be better understood by modeling airflow with particle transport in lung airway using computational methods. Also, it may contribute to the development of novel more effective approaches for pulmonary drug delivery either to treat localized health condition in respiratory system or as a systemic delivery to the entire human body.

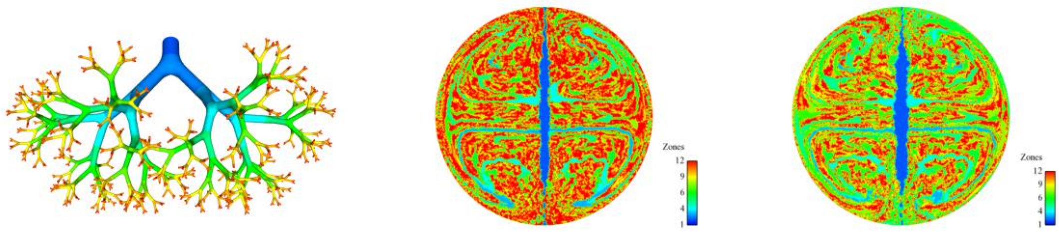
An idealized sinusoidal inhalation profile has been a broadly accepted choice among many researchers, while examining unsteady breathing effects in lung airway. The realistic breathing profiles may vary based on the person’s age, health condition, physical activities, etc. In addition, since there is a limited accessibility and high degree of difficulty involved gaining realistic inhalation data; consideration of idealized inhalation profile has served as a practical alternative for preliminary studies. In our recent efforts we study the effects of temporal variation in inhalation velocities on particle deposition in ten-generation lung airway model employing sinusoidal idealized inhalation profile [1]. The results demonstrated significance of unsteady breathing effects on particle deposition when particles initiated at different times of the inhalation phase of a breathing cycle. In our current study, we advance a step further and continue to examine the unsteady breathing effects on particle transport employing the realistic inhalation profile [2].

In this paper, we try to recognize the importance of employing realistic breathing profile as opposed to the idealized sine-wave form. To accomplish this, we compare particle deposition results for both the realistic and sine-wave form of breathing profiles. We simulate the unsteady flows and particle deposition in an idealized large-scale lung airway geometry consisting of a ten-generation, nonplanar, bronchial tube model using our hybrid (finite element/finite volume), matrix free, parallel CaMEL solver [3]. Particles were released at different inhalation times to investigate the unsteady effects for both cases. The results showed discrepancy in particle deposition in terms of particle destination maps and particle deposition efficiencies. Fig. 1 shows the realistic and sine-wave form of inhalation inlet velocity profiles that were employed in this study. In Fig. 2, particle destination maps for particles released at the peak of realistic and sine-wave inhalation profiles are shown. Significant differences in particle destination maps for both cases are apparent from figures 2(b) and 2(c). Particle destination map demonstrates colored particle release locations based on the particle deposition sites in the lung airway. The color code for the particle destination maps are shown in fig. 2(a).



(a) (b)

Fig. 1. (a) Realistic inhalation profile, (b) Sine-wave form of inhalation profile



(b) (b) (c)

Fig. 2. (a) Color code for particle deposition maps, (b) Particle deposition map at peak of sine-wave form of inhalation profile, (c) Particle deposition map at peak of realistic inhalation profile.

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