Jet and Counter Flow Structures in Branching Tubal Systems and Human Respiratory Systems

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308, Mathematics Research Center Building (ori. New Math. Bldg.)

Two unique flow structures observed in idealized branching tubal systems and realistic human respiratory systems in an oscillatory (breathing=inspiration+expiration) setting are investigated numerically. One jet-like structure is observed on expiration, under normal tidal volume and oscillatory frequency, when air is flowing from daughter to parent branches. The other counter-flow structure is observed on flow reversal when changing respiratory phases, under low tidal volume and high oscillatory frequency. High frequency oscillatory ventilation (HFOV) is considered an efficient and safe respiratory technique to ventilate (that is, improve mixing in) neonates and patients with acute respiratory distress syndrome. A better understanding of these two structures can shed light on the structure and function (e.g airway resistance and mixing) relationship in the human lungs. Two types of geometrical models are employed: idealized tubal branching models and realistic computed-tomography (CT)-based airway models. Under the normal breathing condition, flow visualization reveals that viscous dissipation at both inspiration and expiration occurs in the boundary layer as well as in the core region where free shear jet-like flows are present. Furthermore, viscous dissipation is found to be greater at expiration than at inspiration because jet flows are more dissipative and more prevalent on expiration. Under the HFOV condition, in the straight-tube model, coaxial counter flow with opposing fluid streams is formed around flow reversal, agreeing with an analytical Womersley solution. However, counter flow yields no net convective mixing at end cycle. In the single-bifurcation model, counter flow

at high Reynolds number (Re) is intervened with secondary vortices in the parent (child) branch at end expiration (inspiration), resulting in an irreversible mixing process. For the CT-based airway model three cases are considered, consisting of the normal breathing case, the high-frequency-normal-Re case, and the HFOV case. It is found that the counter-flow structure is more evident in the high-frequency-normal-Re case than the HFOV case.

- For material related to this talk, click here.