11.8.6. Cycle-Induced Flow And Transport In An Alveolus Partially Filled With Liquid

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The flow and transport in an alveolus are of fundamental importance to partial liquid ventilation, surfactant transport, pulmonary drug administration, and gene therapy. When the thickness of the liquid layer is thin compared to the size of the alveolus, we have developed an asymptotic theory in small film thickness and stretching amplitude to describe the flow pattern and surfactant transport. Non-zero cycle-averaged flows are shown and their turning directions near the end wall depend on the parameters of the system. We also model the case when the liquid is partially filled in the alveolus and has a comparable thickness to the size of the alveolus. The surfactant-free case is first investigated. By assuming a spherical interface due to small capillary number, we solve the Stokes flow analytically in the toroidal coordinate system. For small liquid volume, the flow field is dominated by the normal velocity component. However for large liquid volume, the flow shows a vortex structure near the alveolar opening. For the transport of macromolecules, the Peclet number is large and the corresponding mass transfer is discussed.

Posters

Respiratory Systems Engineering Posters

P11.1. Pulmonary Surfactant Physicochemical Behavior During Oscillation And Progression In A Narrow Tube

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Infants born before the seventh month of gestation may suffer from respiratory distress syndrome (RDS) due to an immature surfactant system. A lack of surfactant will elevate reopening pressures due to high surface tension causing airway damage. This study investigates the role of combined steady progression and oscillation of a finger of air in the reduction of surface tension in a model of an occluded airway in the presence of surfactant. The airway model consists of a long, narrow tube, containing an atelectic region, through which a finger of air is forced toward an end tank reservoir. Progression of the finger of air is defined by a specified flow rate of the form $Q(t)=Qs+Qo*\sin(\omega*t)$. Variations in surface tension will be recorded as changes in bubble pressure as the finger progresses. We propose that progression with an oscillatory component will be more effective in reducing surface tension at the bubble interface than progression alone due to the physicochemical properties of surfactant. Decreasing surface tension, as described in this model, reduces the pressure required to reopen an occluded airway thereby reducing airway damage.

P11.2. A System For Analyzing Aerosols Produced By Humans During Respiratory Maneuvers

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It has long been known that the spread of aerosols from person to person is one of the leading causes of respiratory disease. In order to characterize aerosols produced by humans, a system was constructed which measured the number and size of aerosols produced during voluntary coughs and forced exhalations (FE). The measurement system was enclosed in a chamber and maintained at 37 degrees C to minimize alterations in aerosol characteristics due to condensation-evaporation. Air expired through a disposable mouthpiece entered a spirometer which measured the flow and volume of the maneuver. A particle analyzer, used to characterize the aerosols, pulled air from the spirometer. Aerosol size distributions between 0.3-20 um were determined using an optical particle counter. Custom software was developed which acquired the data and ensured the validity of the maneuver in real-time. In order to evaluate the system, volunteer subjects performed coughs and FE's after breathing HEPA filtered air. Characteristics of aerosols produced during coughs and FE's produced similar size distributions in terms of counts and mass. Results indicate a mass mode appeared at 6 um. This project is supported in part by FAA IAG 97-11.

P11.3. Air-Interfaced Lung Epithelial Cell Monolayers Characterization Of Large Light Polymer Aerosols

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Large and light polymer aerosols may improve the duration and effectivene: drugs delivered via the lung due to their easy aerosolization, contrc degradation properties, and ability to resist phagocytic clearance mechani: However, optimization of these new particulates for pulmonary drug delivery been greatly limited by the inadequacy of standard characterization methods (complete immersion methods) in mimicking the thin fluid layers found in lung. To closely mimic the lung environment, we have cultured Calu-3 c under air-interface conditions and shown that they form tight monolayers w excellent barrier properties. Tight monolayers were indicated by transepithe electrical resistance (TEER) values in excess of 300 Ω· cm² and via staini experiments indicating regular expression of tight junctional proteins betwe cells. Cell monolayers were grown on permeable membranes that separated t apical cell surface (cell-air interface) from an underlying receptor reservoir, th enabling quantitative transport studies with model drugs. Monolayers grov under air-interfaced conditions exhibited no significant change in fluorescein-N flux or in TEER following particle aerosolization using a liquid impinge suggesting that monolayer barrier properties were not altered. Differences i microparticle degradation rates and drug transport between this new system an conventional "complete immersion" studies will also be discussed.

P11.4. Limitation Of Expiratory Flow In Liquid Ventilation

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Liquid ventilation involves filling the lungs either partially or totally with perfluorocarbon liquids, and can be used as a vehicle for the delivery of medications or genetic material to the lungs. The flow limitation, which occurs when airway pressures become low enough (due to flow) that airways collapse, is an impediment to liquid ventilation. We examine flow limitation in a rabbit model of liquid ventilation. Perfluorocarbon was instilled into the tracheas of intact rabbits with a filling volume of either 20 or 40 ml/kg. Perfluorcarbon was then removed from the lung by flow-driven expiration. Tracheal pressure and flow were measured, as was the volume of perfluorocarbon remaining in the lungs. The effects of perfluorocarbon characteristics on flow limitation were examined. J.L. Bull is a Parker B. Francis Fellow in Pulmonary Research. This research is funded by NIH grant HL64373.

P11.5. A Multiple-Path Particle Deposition Model For Cystic Fibrosis Patients.

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In cystic fibrosis (CF), apical lung regions are poorly ventilated and hence difficult to treat with inhaled therapeutics. We have developed a multiple-path particle deposition model. Our current model divides the lung into quadrants, separated at lobar bronchi, representing apical and basal lung regions. Model predictions were compared with observed patterns of coarse particle (5um MMAD) deposition in ten CF patients. Quadrantal volume and ventilation were experimentally determined from xenon equilibrium and multi-breath washout, respectively. A patient's custom lung morphology was then calculated based on their lung volume and quadrantal ventilation. Deposition calculation input parameters were morphology, breathing pattern, and particle size. Regional deposition (RDep) was computed as the fraction deposited in a quadrant normalized to volume and classified as tracheobronchial (TB) or pulmonary (PU). Consistent with experimental data, the model predicted greater RDep(PU) in basal than apical regions of all patients. RDep(TB) was greater in the apex than base in 9 patients and modeled as such in 7. In one patient, both experimental and modeled RDep(TB) were greater in the base than the apex. This model may be useful for predicting a patient's breathing conditions and particle size for optimal drug delivery. Funded by U.S. EPA CR824915.

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