AGENT-BASED MODELING OF FLUID DYNAMICS IN LUNG TISSUE ENGINEERING

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Introduction: In tissue engineering for lung applications, understanding and controlling fluid dynamics within engineered constructs is paramount. Agent-based modeling (ABM) offers a powerful framework to simulate complex physiological systems, yet its application to pulmonary edema (PE) in this context remains underexplored. This study presents an innovative ABM, built in NetLogo, to simulate cardiogenic PE (CPE) by modeling extravascular lung water dynamics under hydrostatic pressure (HP) and oncotic pressure (OP). This model can serve as a tool to inform the design of tissue-engineered lung constructs by providing insights into fluid management strategies.

Materials and Methods: The ABM was developed using NetLogo, employing a simplified Starling equation: Q = k (HP - OP). The model's spatial environment includes capillary, alveolar-capillary membrane (ACM), and alveoli, with agents representing water molecules and macromolecules. Two scenarios were simulated: (1) Normal: HP = 18 mmHg, OP = 25 mmHg, (2) CPE: HP = 22 mmHg, OP = 24 mmHg.

Results: In the normal scenario, the model achieved a physiological balance with approximately 200 ml of extravasation cleared. In the CPE scenario, there was significant fluid accumulation (>400 ml by ~40 ticks). Adjusting parameters, such as reducing OP, amplified the edema, demonstrating the model's flexibility. The model is available at:
https://modelingcommons.org/browse/one_model/5103#model_tabs_browse_info.

Conclusions: This ABM provides a valuable platform for tissue engineers to understand and manipulate fluid dynamics in lung constructs. By simulating the effects of different pressure gradients and permeability, it can guide the development of biomaterials and scaffolds that optimize fluid handling in engineered lung tissues. The model's extensibility allows for future incorporation of additional complexities, such as gas exchange and variable tissue properties, enhancing its utility in both research and practical applications.

Keywords: Tissue engineering, Agent-based modeling, Pulmonary edema, Fluid dynamics, Hydrostatic pressure, Oncotic pressure.