THE COMBINED USE OF AGENT-BASED MODELING (ABM) AND SYSTEM DYNAMICS MODELING (SDM) FOR TISSUE ENGINEERING: A RAW EXAMPLE OF INTERACTION AT DIFFERENT SCALES

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Background. ABM can be used to model individual structures as cells, organs, systems, and their interactions, considering factors such as cell migration, proliferation, and differentiation. SDM can then help capture the overall dynamics of the tissue and organ system, incorporating factors like nutrient distribution, oxygen levels, and growth factors. By combining both models, researchers can comprehensively understand how cells/tissues/organs behave and interact. This paper explores how ABM and SDM can benefit tissue engineering, uncovering the potential for future models.
Materials and methods. The NetLogo integrated development environment (IDE) is used for this research. The "regular" part of this IDE is used to showcase some cell interactions and dynamics, and the system dynamic modeler serves to represent the interaction of three systems: (a) maternal, (b) fetoplacental system, and (c) the fetus.
Results. A hybrid model that combines ABM and SDM was created using the NetLogo programming environment. The ABM component visualizes the behavior of cells (i.e., erythrocytes) at the placental level. The SDM component consists of three subsystems: (a) the maternal system (primarily, elements that determine oxygen transport), (b) the fetoplacental system, and (c) the fetal system (with emphasis on the elements that determine oxygen delivery to the fetus, $D_{fetus}O_2$). The $D_{fetus}O_2$ value is influenced by the dynamics of the physiological parameters, which are the foundation of the three subsystems and can be monitored using traditional methods. Modifying specific parameters within each subsystem directly impacts $D_{fetus}O_2$, the central element of the model's graphical interface. In this way, one can continuously monitor oxygen delivery to fetal tissues. The demo version of the created model includes several scenarios: (a) state of anesthesia, (b) maternal pathology (e.g., anemia, heart failure, etc.), and (c) fetoplacental pathology (e.g., abruptio placentae). The model is available at https://modelingcommons.org/browse/one_model/6688#model_tabs_browse_info
Conclusions. This example demonstrates the successful integration of ABM and SDM that can serve as leverage for tissue engineering research, enabling a more comprehensive understanding of cell/tissue and system behavior and prediction of complex biological processes. By combining the strengths of both modeling approaches, researchers can gain deeper insights into tissue dynamics and design more effective interventions.
Keywords: agent-based modeling, system dynamics modeling, tissue engineering, oxygen delivery, maternal system, fetoplacental system, fetus.