Transport modeling of radial flow bioreactors packed with hollow cylindrical porous construct for bone tissue engineering: effect of external resistances to transport on solutes distribution

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Radial flow perfusion of osteogenic cells seeded onto 3D hollow cylindrical porous scaffolds in radial flow packed bed bioreactors (rPBB) may help realize engineered tissue substitutes for the treatment of large-size bone defects. Control of dissolved oxygen, nutrients and waste metabolites concentration throughout the construct is essential to enable long-term cell survival and to guide cell differentiation. Models of momentum and mass transport across the rPBB compartments may help obtain it provided they are validated against experimental results. In existing transport models of rPBBs, the effect of external resistance to solute transport establishing from the bulk medium to the porous construct surface are generally neglected. Such resistance depends on construct morphological properties and rPBB operations. Under conditions typical of bone tissue engineering, they may cause poor dissolved oxygen and nutrients supply to the cells and culture under sub-physiological nutrient and oxygen concentrations. This may yield to incorrect prediction, and thus monitoring, of dissolved oxygen, nutrients and metabolic wastes concentration profiles at the cell surface. In this study, it is proposed a model of momentum and mass transport in rPBBs accounting for external solute transport resistance aimed to ensure adequate dissolved oxygen and nutrients supply to, and metabolic wastes removal from, large-size construct of given geometry and permeability. Steady-state transport across the rPBB compartments was described according to a pseudo-homogeneous approach. Momentum and mass transport in the inner hollow cavity, the peripheral annular space and the isotropic porous construct was described according to the Navier-Stokes, the Darcy-Brinkman and the convection-dispersion-reaction equations. Dimensionless analysis yielded to the identification of the most relevant dimensionless groups determining rPBB performance. Model predictions, expressed in more apt parameters to bone tissue engineering, suggest how to reduce the effect of external resistances to transport on the solutes concentration profiles and how to ensure adequate culture conditions for osteogenic cells survival and differentiation throughout the construct.