

Patient-Specific Multiscale Modelling of Glioblastoma: Targeted Modulation of Interstitial Fluid Flow Using Electric Field

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Glioblastomas are aggressive, highly heterogeneous brain tumours with poor prognosis and limited treatment options. Their complex microenvironment, characterised by elevated interstitial fluid pressure (IFP) and irregular microstructure, presents major barriers to effective therapeutic delivery. We present a novel, patient-specific, multiscale, and multi-compartment computational model that simulates interstitial fluid flow, pressure, and electric field distributions, incorporating realistic MRI-derived brain geometries and histopathology-informed tissue microstructures. Using asymptotic homogenisation, we derive effective transport properties that bridge macroscale anatomy with microscale heterogeneity. Each tissue compartment, necrotic core, tumour, oedema, and white matter, is assigned distinct dielectric and hydraulic properties. We solve homogenised Darcy and Laplace-type equations to compute physiologically relevant distributions of pressure and velocity. Our simulations show elevated IFP in tumour and peritumoral oedema regions, with outward fluid flow limiting drug penetration. We demonstrate that applying an external electric field can reverse and redirect this flow, promoting inward transport and improving drug uptake. This electrokinetic modulation offers a promising strategy to overcome transportation barriers. To our knowledge, this is the first model to combine patient-specific geometry and multiscale physics in the context of electric field-driven glioblastoma treatment, establishing a new computational framework for personalised therapy planning.