Multiscale Analysis of Electrically Stimulated Vascularised Tumours: A Patient-Specific Theoretical and Computational Approach

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Abstract:
Electroporation-based therapies such as electrochemotherapy (ECT) hold great promise for improving cancer treatments. While highly effective for superficial tumours, its application for deep-seated malignancies is challenged by complex microstructural properties, and current models often lack a multiscale theoretical framework to capture those phenomena. Here, we develop and solve a novel system of coupled partial differential equations of Darcy-Laplace type obtained by applying the asymptotic homogenisation technique. We study the tumour response stimulated by an electric field, deriving effective macroscale equations for pressure, velocity, and electric potential while incorporating both hydraulic and electric microscale tissue heterogeneities.
Our coupled multiscale approach bridges the gap between the tumour microstructure and macroscale dynamics, offering a more comprehensive understanding of how tumour size, morphology, and hydraulic-electrical interactions influence interstitial flow. Using patient-specific data, we further investigate how the shape of the microscale cell inclusion affects the macroscale domain, specifically the pressure profile and electric field distribution. We present a parametric analysis of the hydraulic conductivity tensor and macroscale numerical simulation results for pressure and velocity fields, highlighting the role of the electric field in modulating fluid flow. Our findings provide meaningful insights toward advancing ECT protocols.