RESEARCH TOPIC PRIME4

Hybrid Physics-Based and Data-Enhanced Computational Models for Patient-specific Simulation of Glioma Growth and Lumbar Spine Mechanics

Thematic field of the project

Numerical analysis

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Main field of interest

Computational neurosciences

Abstract

Personalized physics-based and data-driven models are increasingly shaping the development of digital twins in medicine and neuroscience. In the context of glioma growth and lumbar spine disorders, several challenges arise in computational modeling, including the representation of complex and heterogeneous geometries, the multiscale and multiphysics nature of the underlying processes, and the identification of patient-specific physical parameters. Hybrid approaches combining physics-based modeling with data-driven techniques offer a promising framework to address these challenges. By integrating patient-specific clinical data with biomechanical and biological knowledge, such models enable the simulation of disease progression and the assessment of potential treatment outcomes. By coupling mechanistic understanding with data-informed learning, these frameworks can generate digital representations of individual patients, supporting improved diagnosis, therapy planning, and outcome prediction. This integrated paradigm highlights the potential of personalized digital twins as clinical decision-support tools and their role in advancing precision medicine in cranial and spinal neurosurgery.

Main technical approaches

Development, analysis and implementation of physics-based multiscale and multiphysics computational models.

Development and integration of data-driven methods (e.g., computational learning paradigms).

Model validation, verification and simulation-based analysis.

Scientific references

1. Urits I, Burshtein A, Sharma M, et al. “Low back pain, a comprehensive review: pathophysiology, diagnosis, and treatment”. Current pain and headache reports. 2019;23(3):23

2. Capo G, Calvanese F, Tahhan N, et al. Prediction of MRI in intra-operative findings for spinal meningeal diseases. Neurochirurgie. 2025;71(3):101661

3. Sun, Y., Wang, X., Zhang, D.Y. et al. Brain-wide neuronal circuit connectome of human glioblastoma. Nature 641, 222–231 (2025)

4. Bogdańska MU, Bodnar M, Piotrowska MJ, et al. “A mathematical model describes the malignant transformation of low grade gliomas: Prognostic implications.” PloS one 2017; 12.8:e0179999

Type of contract

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