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Poro-viscoelasticity of brain tissue: modeling and inverse parameter identification

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The brain is arguably the most complex human organ and modeling its mechanical behavior has challenged researchers for decades. There is still a lack of understanding on how this tissue responds to mechanical loading and how material parameters can be reliably calibrated. The Theory of Porous Media combined with finite viscoelasticity provides a theoretical framework to explore the underlying physical mechanisms, including interactions between solid matrix and free-flowing interstitial fluid and corresponding viscous and porous effects. By comparing finite element simulations with experimental data of cyclic compression–tension loading and compression–relaxation experiments, we show that the solid volumetric stress proves to be a crucial factor for the overall biphasic tissue behavior, as it strongly interferes with porous effects controlled by the permeability. An inverse parameter identification (PI) reveals that poroelasticity alone is insufficient to capture the time-dependent material behavior, but a poro-viscoelastic formulation captures the response of brain tissue well. Including the lateral displacement of specimens during testing into the inverse PI, results in more accurate parameters. Taken together, our analyses provide valuable insights into the individual contributions of viscous and porous effects. They can help identify more reliable poro-viscoelastic parameters for brain finite element simulations in the future.

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