REGION-DEPENDENT MATERIAL PARAMETERS FOR FULL-SCALE HUMAN BRAIN SIMULATIONS

Emma Griffiths (1), Jan Hinrichsen (1), Nina Reiter (1), Silvia Budday (1)

1. Institute of Applied Mechanics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Introduction

An accurate finite element (FE) model of the human brain reliably predicting its response under loading offers great possibilities for brain injury prevention, disease prediction, and surgical guidance. However, the brain is an extremely complex organ and shows high structural heterogeneity, both on a macroscopic and microscopic level. This also results in heterogeneous mechanical properties. Therefore, the identification of material parameters accurately describing the region-dependent mechanical behavior of human brain tissue is crucial. While the division of the human brain into different anatomical regions is well established, knowledge about regions with distinct mechanical properties remains limited and their importance for full-scale human brain simulations remains mostly unknown – not least due the lack of corresponding data.

Methods

We perform multi-modal mechanical testing on human brain tissue from 19 anatomical regions and use an inverse parameter identification scheme based on a hyperelastic Ogden model to identify mechanically distinct regions and provide the corresponding material parameters [1]. In a second step, we investigate the importance of using region-specific material parameters when modelling the full human brain [2]. To this end, we simulate an indentation of the brain occurring during surgical procedures, e.g., due to needle insertion. We compare parameter sets based on unconditioned and conditioned experimental data as well as different Poisson's ratios.

Results

Our analyses show that we can assign the 19 anatomical regions to nine governing regions based on similar parameters and microstructures, as illustrated in Figure 1. Statistical tests confirm differences between the regions and indicate that at least the corpus callosum and the corona radiata should be assigned different material parameters in computational models of the human brain. The simulation results further highlight that accounting for region-dependent properties leads to significant differences in the predicted strain state compared to simulations assuming homogeneous material properties. Also, the Poisson's ratio and using unconditioned or preconditioned data sets significantly affects the results of full-scale brain simulations, emphasizing the importance of carefully selecting the material parameters used.

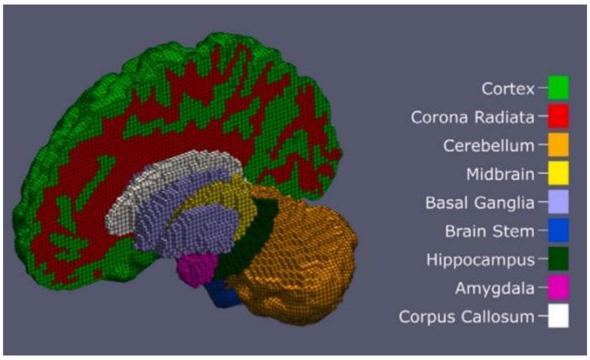

Figure 1: Brain finite element model with segmentation into nine governing regions with distinct mechanical properties [2].

Discussion

The presented analyses have important implications for choosing appropriate region-dependent material parameters for full-scale human brain finite element simulations in the future. The identified parameters will contribute to more precise computational models enabling spatially resolved predictions of the stress and strain states in human brains under complex mechanical loading conditions.

References

1. Hinrichsen et al, 2022 Preprint at https://www.biorxiv.org/content/10.1101/2022.12.19.521022v1.
2. Griffiths et al, European Journal of Mechanics / A Solids, 99: 104910, 2023.

Acknowledgements

We gratefully acknowledge the financial support by the German Research Foundation (DFG) through the grant BU 3728/1-1 and by the FAU and the STAEDTLER Stiftung through the Emerging Talents Initiative.