# Modelling of Vascular Influence on Brain Tissue Mechanics

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## Summary

The mechanical properties of brain tissue exhibit noticeable variations when measured *in-vivo* versus *ex-vivo*. We hypothesize that the vascular system and its associated blood pressure significantly influence *in-vivo* measurements, contributing to these discrepancies. To investigate this, we simulate a material embedded with blood vessels to assess how vascular structures and internal pressure cycles affect tissue behavior. Using magnetic resonance elastography techniques, we evaluate the material in a way that mimics *in-vivo* testing conditions. This approach allows us to explore the relationship between blood flow and the effective mechanical properties of brain tissue in greater detail.

## Introduction

The discrepancies in measured mechanical properties of brain tissue *in-vivo* versus *ex-vivo* are often attributed to variations in testing modalities and experimental conditions. However, a key factor that may contribute to these differences is the role of the brain's vascular system and the influence of blood pressure on tissue mechanics.

## Methods

To investigate this hypothesis, we develop a continuum-mechanics-based model implemented in C++ using the deal.II library. The material is assumed to exhibit either linear elastic or viscoelastic behavior and is subjected to dynamic loading conditions. To incorporate vascular structures, a 3D-1D Lagrange multiplier coupling approach [1] is used.

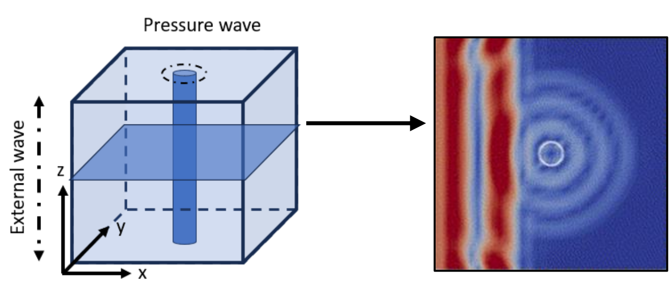


**Figure 1**: Shear wave and blood pressure wave interaction

To mimic a magnetic resonance elastography testing setup, shear waves are applied to the material, and the resulting displacement fields are extracted for further analysis. These displacements serve as input for the inversion process, where the direct inversion scheme [2] is utilized to re-extract the mechanical properties of the simulated system. A similar procedure is applied with an embedded vascular inclusion and (Figure 1) shows the wave interaction so produced. By comparing the re-extracted properties between models with and without vasculature, we assess the impact of blood pressure on the observed mechanical behavior.

## Results and Discussion

The simulation of a material without an embedded inclusion, combined with the direct inversion loop, allows us to re-extract the material properties with less than 7% relative error. This validates the accuracy of our modeling and inversion approach.

The presence of a constant blood pressure within the vessel does not significantly alter the extracted material properties, indicating that static pressure alone has minimal influence on the overall mechanical response.

However, when cyclic blood pressure is introduced, a noticeable stiffening effect on the material properties is observed. This effect is strongly dependent on several factors, including the magnitude of pressure fluctuations, the geometry of the vessel, and its orientation within the material. These findings suggest that dynamic vascular pressure forces contribute to the effective mechanical behavior of brain tissue.

## Conclusions

Our study highlights the significant influence of vascular structures and dynamic blood pressure on the effective mechanical properties of *in-vivo* brain tissue.

## Acknowledgments

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## References

[1] Belponer C. et al. (2023). *arXiv, math.NA*.
[2] Hirsch S. et al. (2017), *Magnetic Resonance Elastography*, Wiley-VCH.