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PREDICTIVE CONSTITUTIVE MODELING OF ARTERIES BY DEEP LEARNING

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The microstructure and macroscopic mechanical properties of soft tissues like arteries are closely related. While substantial efforts have been made to quantify this relation, it has yet remained impossible so far to predict the macroscopic mechanical properties of soft tissues from microstructural information with satisfactory accuracy.
To overcome this problem, we introduce a novel machine learning framework that combines advanced theoretical concepts with deep learning [1]. Once trained, this framework can predict the macroscopic mechanical properties of arterial tissue from microstructural information collected by histological analyses and imaging. The incorporation of substantial prior knowledge from continuum mechanics and materials theory enables our architecture to learn already from small amounts of data (10^1 - 10^2 samples) to predict the stress-strain curves of arterial tissue with high accuracy ($R^2 > 0.9$). To the authors' best knowledge, this is the first time that macroscopic mechanical properties of soft tissues are predicted with such high accuracy from the tissue microstructure. Moreover, our framework can also help to understand the role of different microstructural features for the macroscopic mechanical properties using concepts of explainable artificial intelligence.
The machine learning framework we present bears promise to be transformative for our understanding of soft tissue mechanics and to provide new insights into the changes of soft tissues during aging and various diseases.

REFERENCES

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