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Mechanical characterisation of brain tissue up to 35% strain at 1, 10, and 100/s using a custom-built micro-indentation apparatus

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Abstract

Understanding the behaviour of soft tissues under large strains and high loading rates is crucial in the field of biomechanics in order to investigate tissue behaviour during pathological processes such as traumatic brain injury (TBI). It is, therefore, necessary to characterise the mechanical properties of such tissues under large strain and high strain rates that are similar to those experienced during injury. However, there is a dearth of large strain and high rate mechanical properties for brain tissue. This is likely driven by the lack of commercially available equipment to perform such tests and the difficulties associated with developing appropriate custom-built apparatus. Here, we address this problem by presenting a novel, custom-built micro-indentation apparatus that is capable of characterising the mechanical properties of brain tissue up to 35% at 100/s with a spatial resolution of 250 µm. Indentations were performed on the cortex and cerebellum of five-week-old mouse brains up to 35% strain at 1, 10, and 100/s. Three hyperelastic models were fitted to the experimental data that demonstrate the strong rate-dependency of the tissue. The neo-Hookean shear modulus for the cortex tissue was calculated to be 2.36 ± 0.46, 3.64 ± 0.48, and 8.98 ± 0.66 kPa (mean ± SD) for 1, 10, and 100/s, respectively. Similarly, the cerebellum shear modulus was calculated to be 1.12 ± 0.26, 1.58 ± 0.32, 3.10 ± 0.70 kPa for 1, 10, and 100/s, respectively. Student's t-tests were used to show statistically significant differences between the cortex and cerebellum at each strain rate. Furthermore, we discuss the apparent strain-softening effect in the 100/s force-displacement curves for both regions after approximately 30% strain.