Exploring the mechanical complexity of the interface between gray and white matter in the brain

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Abstract

Diffuse axonal injury is one of the most common causes of morbidity after traumatic brain injury (TBI). Due to its significant differences in composition and mechanical properties, it is often localized at the junction between gray and white matter in the brain. White matter is generally stiffer and more viscous than gray matter and responds less quickly to mechanical strains, making the interface particularly vulnerable to shear forces and inhomogeneous deformation under dynamic loading conditions (1, 2). Computational models predict the highest acceleration and shear forces at this interface, highlighting its critical role in injury mechanisms (3). Microstructural studies also show that alterations in the transition zone correlate with post-concussive symptoms and adverse long-term outcomes, highlighting their potential as biomarkers for mild TBI (4). Despite its importance, the biomechanical properties of this interface are still poorly understood.
To address this gap, we conducted an extensive experimental investigation of gray matter, white matter, and the transition zone. Using cubic tissue samples subjected to different shear loading protocols, we assessed and compared the nonlinearity, hysteresis, and peak stress responses of the regions. Shear loading to failure also allowed us to evaluate the rupture strength and failure characteristics. Using digital image correlation, local strain distributions were visualized and fracture points were precisely identified. Our investigation provides new insights into how this interface behaves under dynamic loading conditions, a crucial aspect for the development and calibration of brain tissue TBI models.

References

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