The mechanics of traumatic brain injury

Blunt impacts and rapid angular accelerations—due to traffic collisions, sports accidents, falls, or other incidents—can cause traumatic brain injuries, a leading cause of death and disability. From a mechanical perspective, such injuries occur when the local mechanical load exceeds certain tolerance levels of the brain tissue. Establishing what those levels are requires not only realistic models of the brain's dynamic response, but also accurate determinations of the tissue's material properties under realistic loading conditions.

Adding further complications are the brain's complex geometry and significant inhomogeneities at macroscopic and microscopic levels. For example, the brain's gray matter, made up of neuron cell bodies, is essentially isotropic. In contrast, white matter—which consists of bundles of axons, or nerve fibers, that carry signals to other neurons—can be highly oriented, as shown in this electron micrograph. For many types of accidents, axons are particularly vulnerable to injury, especially at the grey matter–white matter boundary.

In recent studies of porcine brain tissue, which mechanically resembles human brain tissue, Badar Rashid, Michel Destrade, and Michael Gilchrist of University College Dublin and the National University of Ireland Galway have performed detailed dynamic stress measurements and simulations under impact conditions: compressive strains up to 50% and strain rates up to 9% per millisecond, corresponding to velocities of 450 mm/s. Their results on specimens of mixed gray and white matter show that nonlinear, so-called hyperviscoelastic models are well suited for simulating real-world impacts, and the researchers extracted several mechanical parameters needed for such models to have high biofidelity. (B. Rashid, M. Destrade, M. D. Gilchrist, *J. Mech. Behav. Biomed. Mater.* **10**, 23, 2012; image submitted by Badar Rashid.)

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