Mechanics of Head Injury

Structural Influence on the Mechanical Response of Swine Cranial Bone

In general, TBI studies that use impact and blast loading are conducted on animals rather than humans. However, the applicability of insight gained from non-human TBI impact and blast experiments relies on the ability to scale the animal injury thresholds to the human anatomy. The scaling relationship will depend on the mechanical response of the constituents of the human and animal head. The skull is particularly important since its mechanical response determines the transfer of deformation and stress to the brain during blast and impact loading.

The mechanical response of the skull, in turn, is dependent on its unique microstructure. Therefore, quantification of both the mechanical response and morphology of the animal skull will enable any critical injury thresholds identified in an animal TBI study to be scaled to other species, including human.

Ongoing investigations at the U.S. Army Research Laboratory (ARL; Aberdeen Proving Ground, MD) use the Göttingen minipig as a surrogate to better understand the mechanisms of TBI during mechanical loading. In FY18, the microstructure of cranial bone from adolescent (approximately six months old) Göttingen minipigs was quantified and related to the mechanical response.

Bone specimens were dissected from the crania of adolescent Göttingen minipigs. The microstructure of these skull specimens was quantified using micro-computed tomography (microCT). The skull microstructure demonstrated a clear porosity dependence on location along the skull thickness; the skull was highly porous near the skin side surface and became less porous as the location approached the brain side surface. The skull specimens were then slowly compressed to measure their mechanical response. The distribution of strain on the specimen surfaces was measured to derive the stress-strain response and depth-dependent elasticity at different layers of the bone. These mechanical properties were then linked to structural properties using high-resolution images to produce a model. The model enabled the prediction of local elasticity and also provided an estimation of the tissue elasticity of the cranial bone. This work provides an understanding of the effect of force on the head for development of novel head protection devices to mitigate blast and impact loading to the head of the warfighter.

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