Quantifying Relative Brain Motion in a *Post Mortem* Human Subject

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Due to increased vulnerability in the older population, occupants over the age of 54 are more likely to sustain head injuries resulting in intracranial bleeding. Among the most lethal of bleeding head injuries are acute subdural hematomas (ASDH), with mortality rates cited up to 50%. ASDH from torn bridging veins are believed to result from motion of the brain relative to the dura and skull. In order to develop an age-tolerance relationship from whole brain testing, a first step is to determine the relationship between gross head kinematics and motion between the brain and the skull. Previous studies have attempted to quantify relative motion, but these studies lacked resolution to quantify meningeal motion, were limited by the invasive nature of the test series, or were limited by post mortem degradation.

The objective of this study was to quantify relative brain motion between the skull and the brain in a post mortem human subject using high frequency B-mode ultrasound.

To limit degradation, brain temperature was targeted at a range of 6-12°C throughout preparation and testing, a preservative solution of antibiotics and sodium bicarbonate was introduced, and post mortem time was minimized. The head-neck complex was separated at the C6-C7 vertebral level, and artificial cerebrospinal fluid with preservatives (aCSF+) was introduced into the subarachnoid space. An ultrasound-viewing window was cut through the skull 3 cm posterior to the bregma and 3 cm lateral to the midline and the head-neck complex was positioned in a custom rotation cage so that the center of rotation was 8 cm from the dura surface at the viewing window. The cage rotated in an anterior-posterior direction. Two accelerometers and two angular rate sensors (ARS) were placed on the cage to obtain kinematic data. The ultrasound probe was mounted directly to the cage so that it would move with the skull in contact with the dura. Three rotational severities were tested and two-dimensional brain motion images were collected using high-speed, high frequency B-mode ultrasound (VisualSonics VEVO 2100). Testing was completed within 72 hours post mortem.

Kinematic analysis of the cage indicated good repeatability (CV <5%). The following points were tracked through the entire motion sequence using a commercial motion tracking software (TEMA) in order to calculate displacement relative to the skull: cortical surface, 1 mm deep in cortex, 2 mm deep in cortex. Maximum anterior-posterior displacements of these points relative to the ultrasound probe are summarized in Table 1.

Table 1: Summary of results for three severities of rotation testing

	Rotational velocity (rad/s)	Rotational acceleration (rad/s^2)	Cortical surface (mm)	1 mm deep (mm)	2 mm deep (mm)
Low-severity	2.2	133	0.012	0.105	0.126
Medium-severity	3.8	477	0.058	0.178	0.226
High-severity	28	3800	2.001	3.283	3.414

These results provide new insight on the relationship between gross head kinematics and motion between the between the brain and skull at severities up to 3800 rad/s^2 using multiple strategies to minimize post mortem degradation. These strategies can be applied in future works to define this relationship at injury-level severities and across age groups.