# Ultrasound Measurement Validation Under High-Rate Rotational Motion

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**Background**

It has been well-established that motor vehicle crashes are a leading cause of head injury. Previous studies that have worked to quantify brain motion as a head injury metric have been limited to quantifying deeper brain motion, and no studies have yet non-invasively measured relative motion between the cortical surface and meningeal layers during trauma level loading. The selection of high-speed, high frequency, B-mode ultrasound has served as a means to measure relative motion between surface level brain tissue and the meningeal layers at rotational accelerations and velocities up to 3200 rad/$s^2$ and 26 rad/s, respectively. Efforts to validate the use of a stationary ultrasound transducer to measure high-rate motion has been accomplished, but the use of an ultrasound transducer undergoing high-rate rotational motion has not yet been validated. Therefore, the objective of this study focused on comparing the displacement obtained from tracking an ultrasound image to the displacement measured directly by instrumentation.

**Methodology**

In order to validate ultrasound as a viable measurement technique, a custom validation fixture was fabricated. The validation fixture is comprised of a metal cup mounted to a shaft, with a spring installed on the shaft in order to limit the amount of displacement of the cup along the shaft. A 3D printed surrogate was created to be imaged by the ultrasound system, which fits into the metal cup and consists of triangular peaks of varying heights that are spaced 1 mm apart. The validation fixture was then installed in a custom rotation fixture, followed by the placement of the ultrasound probe. Images of the 3D printed piece were collected using an ultrasound probe rotating under high-rate motion with the validation fixture. Images were collected at 693 frames per second at an image width of 4.08 mm and a focal depth of 6 mm. The rotation shaft and both sides of the cage were instrumented with angular rate sensors to measure rotational velocity about the Y-axis. Uniaxial accelerometers were fixed to the anterior and posterior cage for calculation of rotational acceleration about the Y-axis. Video sequences were collected by B-mode ultrasound and analyzed using a commercial video tracking software and a temporospatial correction was applied to the ultrasound data. Multiple points on the ultrasound image were tracked semi-automatically and the time-histories were compared to direct measures of displacement made by a linear potentiometer. Both prograde (the leading edge is installed such that it captures images in the same direction of the motion of the imaged object) and retrograde (leading edge facing the opposite direction of motion of the imaged object) orientations of the ultrasound probe were investigated.

**Results and Discussion**

Preliminary results indicate a difference in agreement of less than 8% and 5% between the linear potentiometer data and the ultrasound data that was tracked in the prograde and retrograde orientation, respectively. This indicates that an ultrasound transducer, even when rotating at high rates of acceleration and velocity, is a suitable measurement technique for quantifying surface level brain motion.