Understanding the Role of Fluid-Structure Interactions in Traumatic Brain Injury

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This project focuses on understanding the mechanisms of the fluid-solid interface damage in blast traumatic brain injury. The challenge of this project is capturing the physics intracranially with experimental observations of blast interactions and their aftermath. The experimental framework will be carried out in an open field facility at the New Mexico Tech - Energetic Materials Research and Testing Center (EMRTC). Measurements will be carried out over simplified simulated heads fully instrumented to use diagnostics such as time resolved Particle Image Velocimetry (PIV) and X-ray microscopy.

Experimental Analysis

Our approach will focus on the dynamics of the intracranial solid-fluid interfaces by exposing simple test-objects (TO) to blast waves. These TOs will be of comparable mass, volume, and mechanical properties to the human head. During exposure to blast we will monitor for the presence of cavitation bubbles, measure skull deformation with high-speed strain gauges, and measure intracranial strain and strain-rates with PIV markers. This study is unique because of: (1) the inclusion of a vascular model in our test objects, (2) direct comparison between the dynamics and damage of TOs scaled to humans and common animal models, (3) close collaboration of experimentalist, computational modeler, and practicing neurologist to design and interpret experiments, and (4) a novel post-blast analysis of TOs. This post-blast analysis includes filling the TO with a radio-contrast dye and following blast using high resolution computed tomography (CT) radiography to look for evidence of extravasation of fluid from the channels and cavities into the surrounding brain model. Additionally, microscopic analysis of the TO will be performed to look for microscopic evidence of damage at these interfaces. This approach will likely be successful because other computational and experimental studies have demonstrated the presence of cavitation intracranially when blast waves impinge upon skulls (Gross, 1958; Moss *et al.*, 2009). Cavitation has been implicated in the specific periventricular damage found in a swine model (DeLanerolle *et al.*, 2011) and has been suggested to cause microvascular damage in human kidneys exposed to shock wave lithotripsy (Freund, 2008; Zhong *et al.*, 2001, 1998). Additionally, the density mismatch of brain matter and Cerebrospinal Fluid / blood interface is expected to cause interface damage during blast wave exposure (Cernak & Noble-Haeusslein, 2010). The success of this study will be measured with available diagnostic tools such as radio-contrast and CT radiography. If present, we expect that vascular damage will manifest with extravasation of contrast into surrounding gel material. The use of radio-contrast and CT radiography with review by practicing neurologist and vascular neurologist is expected to be highly sensitive for any compromise of the model vascular space, as it is in detection of intracranial blood in human patients in clinical practice (Perry *et al.*, 2011). Furthermore, the post-blast microscopic analysis of the specimen should provide a further increase in the sensitivity of our study for fluid-solid interface damage.

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