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CHALLENGES IN VALIDATING HUMAN HEAD MODEL

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Traumatic brain injury (TBI) is observed to be one of the leading causes of disability in the war fighters returning from battlefield. While the exact mechanism describing the occurrence of TBI is yet to be determined, it is often sustained during the interaction of blast with the head. Accurate modelling of this interaction can improve the understanding of TBI and aid in developing mitigating strategies by providing insights on the biomechanical measures like stress, strain and pressure experienced by the tissue during such loading. Essential components of such accurate models include high fidelity geometric models, and material models calibrated with appropriate experimental data. In addition to the aforementioned necessary components, computational models require to be validated against experimental data involving post mortem human subjects (PMHS) for increasing confidence in their predictive capability. However, due to inherent nature of PMHS experimentation studies, often the complete information regarding the experimental conditions is missing for performing one to one comparison with computational model. For example, the exact boundary conditions on the PMHS during the testing, location of measured responses, orientation of sensors for such measurements, are not available for many studies. These missing details in experimental data allow significant flexibility in applying boundary conditions, and comparing responses post simulation. In light of these limitations and implications, it is essential for any validation effort to be descriptive in its methods and shortcomings, for both accurate representation of predictive capability and to serve as a guide for future PMHS experiments on the necessary inputs for validating computational models.

This paper presents details on challenges in validating the head model developed at the Naval Research Laboratory (NRL). The head model itself was developed using a 1-mm resolution magnetic resonance imaging of a human head, and incorporates all the major macro scale components and topological features (see Figure 1). The material model for each component is calibrated using the latest available data over the loading regime of interest (quasi-static to 1000/s). 4The material model choice for brain and corresponding calibration deserves special attention due to its importance in the context of TBI. The hyper-viscoelastic functional form was found to capture both hyperelasticity and rate-dependence observed during testing of brain tissue.

The validation is performed against four different PMHS studies in literature (1-4). The chosen studies included force, velocity, and acceleration inputs. Compared responses included intracranial pressures, accelerations and force/displacement curves. For each study the uncertainties on interpreting experimental data are described, and steps taken to perform a one to one comparison are provided. The model is observed to predict major trends observed in all four studies under reasonable assumptions. However, the strong effect of possible variations resulting from uncertain boundary conditions is also observed (see Figure 2). Subsequently, the work discusses the implications of available flexibility and its effect on validation performance for the four cases.

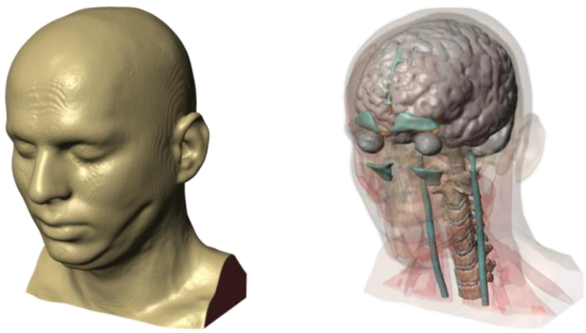

Figure 1: High fidelity geometric model.

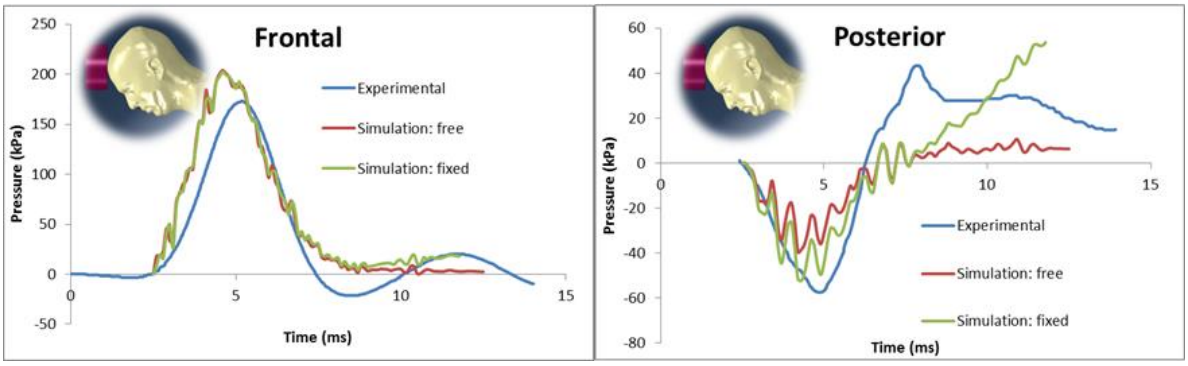

Figure 2: Effect of neck boundary condition on validation comparison for Nahum's experiments at two locations [1].

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