Controlled blunt impact experiments on soft tissue simulants

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ABSTRACT

Traumatic brain injury (TBI) following blunt force impact to the head yields symptoms that include confusion, headache, dizziness, and speech problems. The mechanism of injury resulting in these symptoms is still not well understood, hindering the development of effective countermeasures. To increase our understanding of TBI (without skull fracture), we have designed an apparatus that can reproduce the blunt impact forces in a controllable and repeatable manner. The apparatus consists of a simplistic head system with tissue and fluid surrogates to represent the brain, cerebrospinal fluid (CSF), and skull. The head system (i.e. brain-CSF-skull apparatus) will facilitate research to identify the various frequencies and loading magnitudes that will yield a TBI. The results of the research will aid in the design of devices to damp or offset the frequencies experienced by the brain that may cause a TBI to occur.

A cylindrical head geometry was chosen for the brain-CSF-skull apparatus due to its simplicity. The head system consists of a low durometer rubber cylinder (i.e. brain) housed inside a skull surrogate fabricated out of a rigid cylindrical polyvinyl chloride (PVC) tube. The PVC tube (i.e. skull) was machined to provide a slight gap between the skull and brain, which was filled with an artificial cerebrospinal fluid. A dedicated shaker is coupled with the brain-CSF-skull apparatus to allow for controlled and repeatable testing of blunt loading scenarios with variable complexity. The shaker assembly works via imbalance to allow the brain to oscillate at specified frequencies. Resultant forces imparted on the outer layer of the skull are recorded using force transducers. A tri-axial accelerometer mounted on the brain and a laser vibrometer measured the acceleration and velocity, respectively.

The Severity Index (SI) scale, which is used to rate the severity of skull impact, guided the selection of the shaker's frequency and applied force needed to simulate a TBI, such as a concussion. According to the SI scale, an index of 700 corresponds to a concussion sustained by a National Football League (NFL) player during gameplay. The duration of the blunt impact event resulting in the concussion is 15 ms, which translates to an acceleration of 74 g-force. Our preliminary results show that when the shaker's period of oscillation was 15 ms, a maximum acceleration of 49 g-force and a measured resultant skull force of 196.6 N was recorded. The percent difference at 15 ms for the acceleration measured using our head system and 74 g-force reported by the SI scale is 41%. To ensure that a TBI event is being reproduced using the brain-CSF-skull apparatus, the mass on the unbalanced shaker tray will be increased until the

acceleration matches 74 g-force. The resultant skull force measurements and frequencies leading to TBI will then be reported. Our brain-CSF-skull apparatus may be used in experiments that will add to the limited knowledge of TBI mechanisms.