H103 Biomechanics of Blunt Ballistic Impacts to the Head and Fracture Specific Injury Criteria Development

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After attending this presentation, attendees will be presented with a unique set of data regarding the biomechanics behind depressed comminuted skull fractures and blunt ballistic impact to the head. Engineering parameters responsible for the response and tolerance of the skull to blunt a ballistic impacts will be discussed with focus on the development of a new injury criteria for use in forensic case work.

This presentation will affect the forensic community by offering leading-edge scientific data set on skull fracture from blunt ballistic impact and of the depressed, comminuted fracture type. Investigators will gain insight into biomechanics of skull fracture and the development of unique injury criteria for application in forensic reconstruction of skull trauma.

Forensic applications of injury biomechanics is a unique and emerging field. Forensic biomechanics deals with reconstructing events that led to a documented injury. Skull fractures are forensic evidence that may be related to direct contact to the head by an external object and can assist in recon- struction of the impact conditions leading to the trauma. Circumstances leading to skull trauma may not always be known due to the lack of witnesses, inability of the patient to recall or articulate the events that led to the trauma or patient death. A forensic biomechanist may be brought in to work with a forensic pathologist or a forensic anthropologist to relate the mechanics involved with causing particular types of skull fractures. He/she may perform evaluations of various impact scenarios using biomechanical surrogates and injury criteria to assess the likelihood of producing fractures that match the physical evidence. Unfortunately, the current injury criteria and biomechanical surrogates developed by automotive safety researchers fall short of providing necessary information for the reconstruction of specific fracture types. Head injury criteria and biomechanical surrogates are currently needed for fracture-specific risk assessment. The primary goal of this research was the advancement of fracture-specific head injury criterion for the assessment of blunt ballistic lateral head impacts.

Experimental impact testing was performed on eight (8) isolated, unem- balmed postmortem human subjects. Specimens were impacted laterally in the region of the squamosal temporal bone with a 38 mm diameter rigid impactor, launched via a ballistic air cannon. Specimens were instrumented with a nine-accelerometer array to document global head response. Local bone response was measured by three Rosette-style strain gages attached to the outer cortical layer surrounding the impact site. Soft tissue was left intact at the impact site. Impact force was calculated from a 20,000 g accelerometer mounted to the rear aspect of the impactor. High speed video captured the impact at 10,000 frames per second. Post-test CTs were obtained along with detailed autopsies documenting resulting fracture patterns. Fracture criteria were explored through logistic regression analysis of measured parameters and compared with previously developed head injury criteria. Goodness of fit was evaluated by the chi-squared statistic, p-value and Nagelkerke R^2. Significance levels were set at $p < 0.05$.

Sixteen impacts were performed resulting in fractures to eight specimens with an average peak force of 5,079 ± 1572 N. Fractures were primarily depressed comminuted in nature. Acceleration from the array conditions which limits the ability to utilize the nine-accelerometer array for estimating center-of-gravity acceleration. Deformation-based measures should be investigated further in future experimental studies.

Logistic regression results indicate that strain-based measures were statistically significant predictors of fracture followed by acceleration of the head ($P < 0.05$). While impact force demonstrated increase risk of fracture with increasing force, this was not a statistically significant predictor of fracture ($P=0.054$).

Technical limitations currently exist for developing strain or defor- mation-based criterion for use with biomechanical surrogates. Current biomechanical models are not equipped to measure skull deformation or strain. These measures are currently most effectively measured through finite element models. The basic biomechanical data from this study will first and foremost serve as validation for advancement of finite element models of the head to the blunt ballistic impact environment. Additional efforts can then be put forward into development of an advanced fracture-prediction model. The current results indicate that effort should begin with strain-based criterion for blunt ballistic temporo-parietal skull fracture.

Biomechanics, Skull Fracture, Ballistic Impacts

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