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BLAST INJURY RESEARCH PROGRAM
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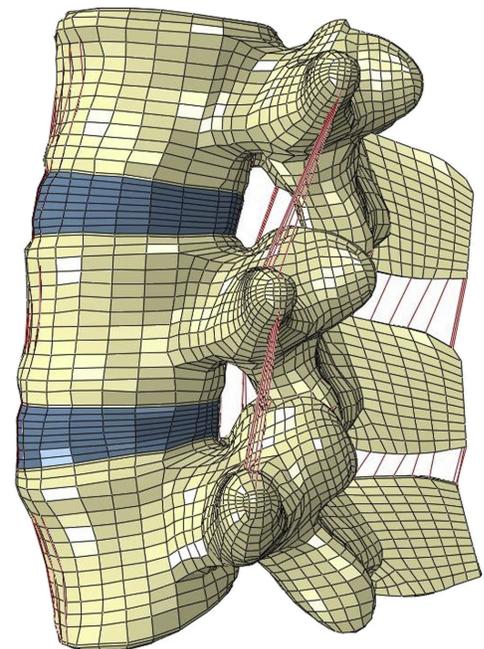
Injury Models

Development and Characterization of In Vivo Models of Explosive Blast-related Spinal Column Injury

In the recent overseas conflicts, Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), the incidence of traumatic orthopedic injuries is only secondary to that of traumatic brain injury (TBI). Of the total number of patients sustaining wartime orthopedic injuries, 78 percent have been caused by an explosive blast. Among orthopedic injuries, Joint Theater Trauma Registry data show that spinal injuries represented about 9 percent of all combat related injuries in OIF between 2002 and 2006. In addition, 10 percent of patients treated for TBI at the National Naval Medical Center and Walter Reed National Military Medical Center (WRNMMC) have also been diagnosed with spinal column injuries; more than 50 percent of these injuries were due to blast. The use of body armor is likely to affect the pattern of spinal injury, as we see a unique concentration of lower lumbar burst fractures in the ongoing military conflicts. However, it is difficult to systematically characterize these injuries and the associated complications without a reproducible animal model.

The Spine Blast Program at the Uniformed Services University of the Health Science (USUHS) was established through funding from the Defense Medical Research and Development Program (DMRDP) managed by the Congressionally Directed Medical Research Program (CDMRP) to develop animal models to investigate the effects of non-penetrating blast trauma on the spinal column including the neurologic, osseous, cartilaginous, and soft tissue components (Figure 1). To accomplish this goal, the program developed a rat animal model of blast-related non-penetrating spinal column injury with the objective to explore the impact of blast on spinal column integrity in order to aid in the characterization of injury and refinement of treatment options. Briefly, rats were exposed to free field primary blast of various intensities to define injury thresholds for mild, moderate, and severe orthopedic trauma. A specialized blast wave generator tube that had been previously constructed and validated using a swine model was scaled down to a rodent model and used to generate the free field blast.¹² Rats were provided a Kevlar shield that protected the axial skeleton from direct blast trauma. After BOP exposure, the rat spinal column was

FIGURE 1: Diagram of the Articulated Lower Lumbar Spinal Column



- 1 Bauman, R. A., Ling, G., Tong, L., Januszkiewicz, A., Agoston, D., Delanerolle, N., ... Parks, S. (2009). An introductory characterization of a combat-casualty- care relevant swine model of closed head injury resulting from exposure to explosive blast. *Journal of Neurotrauma*, 26(6), 841–860. <https://doi.org/10.1089/neu.2008.0898>
- 2 Long, J. B., Bentley, T. L., Wessner, K. A., Cerone, C., Sweeney, S., & Bauman, R. A. (2009). Blast overpressure in rats: recreating a battlefield injury in the laboratory. *Journal of Neurotrauma*, 26(6), 827–840. <https://doi.org/10.1089/neu.2008.0748>





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harvested for biological evaluation using Luxol fast blue and hematoxylin and eosin (H&E) histology for signs of disc degeneration. No fractures were seen as the spine was not likely to have fractured from primary blast with a rigid structure for exposures used in this model. Analysis of the samples is currently in progress and includes: measurement of the expression profiles of cytokines such as interleukin (IL)-1b, IL-6, IL-8, matrix metalloprotease (MMP)-1, MMP-3, MMP-13, and Aggrecan in intervertebral discs using quantitative polymerase chain reaction (qPCR) to identify signs of early degenerative disc disease; completion of myelin staining of the spinal cord to determine if there was any noticeable damage to the spinal cord; chromosome sequencing to create genomic signatures; and collection of the final qPCR and luminex data. Together, these data sets suggest that inflammatory pathways are activated in and about the spinal column that may influence overall performance of healing and recovery providing highly unique insights into the events occurring early after blast injury. Additional work has been completed employing a Finite Element Model (FEM) and a Mounted Blast Scenario in order to provide insight into the effect of different blast scenarios on the spinal axis and potential improvements in blast resistant vehicle design. Understanding the injury biomechanics and biology associated with blast will assist in the development of early diagnostic and therapeutic strategies to improve clinical management of the blast-related spinal injury.

