

# Finite Element Analysis of the Injury Potential of Shock-Induced Compressive Waves on Human Bone

Ann M. Bailey<sup>1</sup>, Sourabh Boruah<sup>1</sup>, John J. Christopher<sup>1</sup>, Mehdi Shafieian<sup>1</sup>, Robert S. Salzar<sup>1</sup>,  
Duane S. Cronin<sup>2</sup>

<sup>1</sup>University of Virginia

<sup>2</sup>University of Waterloo

## ABSTRACT

*Recent military conflicts have provided evidence of a new mode of lower extremity injury as a result of under-vehicle blasts. Extreme vehicle design elements have decreased the frequency of hull breach into the occupant compartment, yet catastrophic injuries to the lower extremities continue to occur. Previous studies of shock wave-induced injuries, such as blast lung, have highlighted acoustic impedance mismatch as a potential injury mechanism, and in the under-vehicle blast scenario, a similar situation appears to exist. In under-vehicle blast, the lower extremities, with high acoustic impedance, are loaded by a high speed compression wave (caused by the shock wave from a blast) through the low impedance vehicle armor. This mechanism loads the lower extremities faster than its respective speed of sound. Numerical analysis of this steel plate/lower extremity interaction reveals the potential for the accumulation of stresses in the high-impedance bone, which has potential to induce injuries separate from the more traditional inertia-based injuries. To prove the concept of acoustic impedance mismatch as an injury mechanism for this scenario, a series of finite element simulations were developed examining the injury potential of a high speed compression wave traveling from a low impedance material into a higher impedance bone material. By varying both the amount of energy input and the amount of impedance mismatch between the armor material and the bone, the potential for significant energy accumulation is shown. Additional analysis of this phenomenon also reveals the importance of capturing the strain-rate dependent material properties of bone. The results of this study provide a foundation for understanding the nature of underbody blast injuries as well as insight into potential lower extremity injury mitigation strategies.*