Computational Modeling Related to Blast Exposure

Scaling Ocular Blast Exposures: Development of a Scaling Equation Based on Computer Modelling

A common concern in animal models of blast injury has been how to translate the blast loading conditions experienced by humans into corresponding loading for experimental models (*Jean et al. 2014, Panzer, Wood, and Bass 2014*). Animal models for blast research typically include mice, rats, or rabbits, all of which are obviously smaller than blast-exposed Service members. Additionally, each animal model has dissimilar ocular anatomy, which will likely alter ocular mechanics and therefore injury predictions. Scaling equations have been developed for blast-related lung injury and traumatic brain injury, but no corresponding equation exists for ocular injury (*Bowen, Fletcher, and Richmond 1968, Jean et al. 2014*).

Based on previous experimental research, researchers at the University of Utah (Salt Lake City, Utah), developed a quarter-symmetry finite element model (FEM) of the rat eye under blast loading (*Shedd et al. 2018*). The model was validated using intraocular pressure measured in vivo during blast exposure. A total of six geometries were evaluated in the model that varied ocular anatomy, including combinations of rat- and human-sized globes, with varying sizes of the cornea and lens (Figure 1(A)). The pressure-time history used to define the blast loading was taken from a single shock tube recording. A total of five different blast pressure profiles were applied to each model geometry, representing ±2 standard deviation in each the pressure and duration (Figure 1(B)).

Sensitivity analyses indicated the peak intraocular pressure from each of the 30 simulations was primarily dictated by blast pressure, globe diameter, and lens-to-globe size ratio. These variables were, therefore, used to generate a scaling equation to predict intraocular pressure based on ocular anatomy and loading

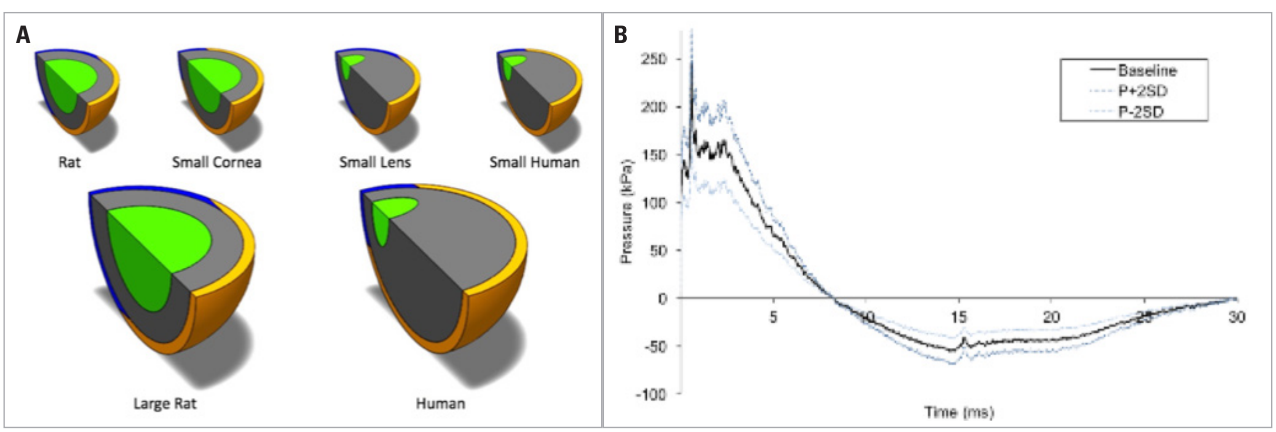

FIGURE 1: (A) Baseline quarter-symmetry rat model (top left) compared to the five varied model geometries. (B) Peak blast overpressure was scaled by ±2 standard deviation relative to baseline. Positive phase duration was similarly varied (not shown). (Figure used with permission from the authors)

overpressure. An additional geometry with the dimensions of a rabbit eye was used to test the predictive capability of the formula. The scaling equation was found to predict FEM intraocular pressure for all anatomical and size variations with a coefficient of determination (R-squared) of 0.92.

This equation can be applied to experimental animal studies to determine relative blast severity in humans. Using this relationship, the researchers estimate that the 228 kilopascals blast pressure applied to rats in previous studies is equivalent to a 312 kilopascal blast pressure in humans, representing a 37 percent higher blast pressure than originally anticipated without scaling (*Shedd et al. 2018*). This scaling equation, although validated against computer models, still needs further validation against experimental models. However, the equation will be an important tool to compare experimental ocular blast trauma data across multiple studies. Combining these data sets will allow more powerful and clinically relevant conclusions to be drawn from existing and future blast research.

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