

Development and Parametric Study of a Parametric Pediatric Head Finite Element Model for Impact Simulations

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ABSTRACT

Currently, only a few pediatric head FE models are available, and each of them only represents a head at a single age with single head geometry. The objective of this study is to develop a parametric pediatric head model capable of simulating head responses for children with different ages and head geometries, and conduct a parametric study on the effects of material property and geometry on pediatric head impact responses. In this study, a statistical cranium geometry model, including cranium size and shape, suture size, and skull/suture thickness, for 0-3 month-old children was developed based on CT images from 11 subjects using principal component analysis and linear regression. An automatic mesh morphing method based on radial basis function was used to morph a baseline FE child head model into three pediatric head geometries, representing newborn, 1.5-month-old, and 3-month-old infant head. The models were validated against cadaver tests from Duke University in compression and drop conditions. A parametric study was conducted on age and 7 material parameters by 81 near-vertex drop simulations. Elastic modulus of skull and suture were statistically significant on head maximal acceleration ($P=0.000$). Elastic modulus of skull was significant on maximal strain of the skull ($P=0.030$), while age ($P=0.044$), elastic modulus of suture ($P=0.000$) and scalp ($P=0.001$) were significant on maximal strain of the suture. Compared to newborn head, in average the 3 month-old head predicted higher suture maximal strain (105% higher), but lower skull maximal strain (61% lower) and maximal head acceleration (9% lower). The method developed in this study make it possible to investigate the age effect from skull and suture geometry and thickness changes on pediatric head impact responses. The parametric study showed that it is important to consider the material property and geometric variations when estimating pediatric head responses and predicting head injury risks.