Protecting Children Against Commotio Cordis in Baseball by Understanding the Effects of Impact Locations Over the Heart

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Background

Commotio cordis is the second leading cause of sudden cardiac death in young athletes. Currently available chest protectors on the market are shown ineffective in preventing cases of commotio cordis in young athletes that play baseball. The new NOCSAE (National Operating Committee on Standards for Athletic Equipment) regulations specify force limits at three loading cells over the chest, with one upper and one lower loading cell, and one over the heart.

Objective

This study focused on understanding the effects of baseball impact locations to the heart. By understanding such effects and then identifying vulnerable locations, we may design and develop chest protectors that can effectively provide protection to prevent commotio cordis in young athletes.

Methodology

Simulation cases were run using the validated CHARM-10 chest model, a detailed finite element model representing an average 10-year-old child's chest. A baseball model was developed in company with the chest model, and then used to impact the chest at different locations. An 8x7 impact location matrix was designed with 56 unique simulations. Eight locations in the transverse plane, seven locations in the sagittal plane. The baseball was moved by half of the ball's radius (18.75 mm) in the transverse and/or sagittal plane in each individual case. An initial velocity of 17.88 m/s was chosen based on previous studies suggesting this to be the most dangerous impact speed. A standard baseball stiffness level was chosen for all impacts. Left ventricle strain and pressure, contact force between the baseball and chest, and rib deformations were analyzed.

Results

Left ventricle strain was highest from baseball impacts directly over the left ventricle (0.34) as well as impacts slightly lateral and superior to the cardiac silhouette (0.34). Left ventricle pressure was highest with impacts directly over the left ventricle (82.9 kPa). For impacts close to the upper and lower positions as specified by NOCSAE, left ventricle strain and pressure were 0.24 and 29.5 kPa (upper loading cell) and <0.04 and <4.0 kPa (lower loading cell).

Conclusion

This study systematically analyzed the effects of impact locations on left ventricle responses. Interestingly, we have identified the most dangerous impact locations not only to the left ventricle but also to the upper, left side of the heart. Impacts to the NOCSAE lower-loading-cell position was of minimal concern in inducing left ventricle strain or pressure. This novel study provided evidence through computational modeling of where to emphasize protective materials for establishing effective chest protectors that will minimize instances of commotio cordis in young baseball athletes.