# Re-establishing Impact Speed Requirements for Inducing *Commotio cordis*

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## I. Introduction

*Commotio cordis* (CC) is a sudden death mechanism involving pump failure of the heart from impacts over or near the cardiac silhouette [1] and has garnered heavy publicity due to the sporting incidences involving American football player Damar Hamlin and ice hockey player Chris Pronger. While these events took place 25 years apart, they are both unique in the sense that CC occurred in two professional athletes with moderate to high-velocity impacts to the heart. It has been established that CC requires impacts to the chest ranging from 30 to 50-mph [2]. This study investigated the re-establishment of impact speed requirements to induce CC with older age groups and developed bodies.

## II. Methods

We used the Total Human Model for Safety (THUMS), a finite element model of an adult male to recreate CC inducing impacts. This model is extensively validated and use for impact recreation. An anonymous survival case of CC involving a 19-year-old male collegiate baseball player was reconstructed and analyzed. Based on recollections and witness analysis, the player was struck directly over the heart with a 90-mph pitch and was not wearing a chest protector. To further understand what was happening to the heart during this impact, we used the AM50 (Adult male 50$^{th}$ percentile) model with a regulation sized baseball aimed directly over the heart at speeds of 90-mph and compared it with the 10YO (10-year-old) model under a 40-mph identical impact. Left ventricular strain values from impact, which are a surrogate measure of determining CC, were measured.

## III. Results

Strain dispersion seen throughout the adult left ventricle showed large portions of tissue elements experiencing max principal strain upwards of 25%. Approximately 40% of the left ventricular tissue was engulfed in these strain levels (Fig. 1). Left ventricular strain was highest in the epicardium of the left ventricle, suggesting that the electrically disturbed cardiac tissue would likely be found in this region.

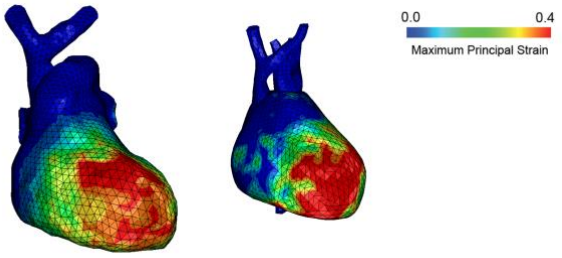


Fig. 1 Comparison of AM50 heart during 90-mph baseball impact (left) and 10-year-old heart during 40-mph baseball impact (right), showing peak strain values of the left ventricular region of the heart.

## IV. Discussion

Currently, the established requirements for inducing CC state the impact speed must be in the range of 30 to 50-mph. When comparing the strain values from the AM50 model with 90-mph impacts to previous studies using a child 10-year-old model [3] with 40-mph impacts, we can see that the strain levels and distribution are strikingly similar (Fig. 1).

This study provides evidence that CC impact speeds of 30 to 50-mph may be specific to youth, and as individuals age with a larger and stiffer thoracic cavity, the impact speed requirements for CC increase with age. Therefore, CC may be reliant on age, weight, and stiffness of the individual, and should be seen as a spectrum regarding induction impact speeds, rather than absolute values. This is an important consideration for re-establishment of the required speeds for inducing CC and should influence chest protector design and regulations across all sports regarding the prevention of CC. Future work will consider various morphologies and speeds.

## References

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