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A FINITE ELEMENT MODEL OF A POST-TRAUMATIC VENTRICULAR SEPTAL DEFECT IN ASYMPTOMATIC AND SYMPTOMATIC HEARTS

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Abstract

Post-traumatic Ventricular Septal Defect (VSD) is described in 5.5% of severe blunt chest trauma cases. It occurs mostly in the muscular part of the septum, near the apex. One mechanism explaining the defect would be a compression of the heart between the spine and the sternum, increasing the intracardiac pressure in either an isovolumetric systole or by the end of a diastole. However, the level of strain on the heart when compressed during the impact is still understudied. The objective of this study is to develop a detailed finite element model of the heart assessing the von Mises strain to which the septum is subject to during a car crash.

From an existing simulation database, two real car crash cases representative of 46 crash scenarios were analyzed. The von Mises strains on the heart elements are extracted to select the worst-case scenario. The force applied on the heart nodes of model (H1) by the external organs are saved and applied to a second numerical model (H2) as nodal forces. The nodal coordinates are also used to match the two hearts' (H1&H2) nodal forces. A detailed numerical heart model (H2) previously developed in the laboratory includes the 4 cavities of the heart and simulates realistic heart contractions. It was adjusted to assess the morphological and material parameter which could influence a post-traumatic VSD: the septum as a component on its own in two sub-models (H2a&H2b), and a thinner circle in the septum in one of the sub-models (H2b). The thin part replicates a fragile area, simulating a preexisting congenital VSD in the muscular part of the septum, that has closed on its own. The myocardium is modeled with elastic material. Two types of boundary conditions were simulated: 1) the physiological contraction of the heart as an internal pressure load, and 2) the impact, imposed during peak left ventricular systole, modeled with the nodal forces extracted from the model (H1).

The FE model, showing a strain increase during the systole, presented a cumulative strain peak when the impact occurs. The thin part created in H2b did have an impact on the maximum strain values. Interestingly, the peak was concentrated in the muscular part of the septum.

This model is a first step toward numerically simulating a full beating heart during a car crash. The concentration of strain on the septum during the crash could induce a post-traumatic VSD.