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EXPERIMENTAL INVESTIGATION OF THE FLOW DYNAMICS IN A LEFT VENTRICLE DURING A BLUNT CHEST TRAUMA

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ABSTRACT

Blunt chest trauma is a significant complication arising from high-speed Motor Vehicle Crashes. Cardiac injuries following Blunt Chest Trauma (BCT) vary in severity and emergency stage. They can range from minor myocardial contusions to life-threatening cardiac ruptures. However, investigations into ventricular and blood flow responses during BCT remain relatively scarce. The objective of this study is to develop an in vitro cardiac simulator subjected to a direct compression and to induced flow dynamics using time-resolved Particle Image Velocimetry (PIV).

The setup consists of a left heart simulator, combining elastic silicone models of the left atrium, the left ventricle (LV) and the aorta. The silicone used is optically transparent and compatible with PIV measurements. The mitral valve and the aortic valve used are both bioprosthetic valves. The working fluid is a mixture of distilled water and glycerol (60-40% by volume). The higher compartment of the box contains the left atrium, being passively filled by an upper container linked to the four pulmonary veins. The lower compartment encases the LV in a hydraulic chamber filled with the same fluid. A piston-cylinder assembly activates the contraction and relaxation of the ventricle, through an electromagnetically driven precision linear motor. Two syringes of 10 mL each are inserted perpendicularly to the lower compartment's wall, linked from one side to a 3D printed impactor facing the LV, and from the other side to another linear motor inducing the impact. A plexiglass wall is added at the back of the ventricle to limit its motion after the impact, simulating the presence of the spine. The flow inside the circulatory system is seeded with polyamide particles. A double-pulsed laser illuminates the particles in a plane formed between the center of the apex and the center of the valves. A high-speed camera captures the LV flow domain. But right after the impact, the flow experiences significant changes including in the vortex formation in the LV and in the magnitude of the aortic flow velocity.

This study simulates and shows the effect of an acute cardiac compression during a blunt chest trauma on the flow dynamics inside a model of a left ventricle. This represents an important step toward a better understanding of the causes that might lead to some cardiac injuries during car crashes.