Analysis of the Mechanisms that Lead to Blunt Aortic Rupture

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Blunt traumatic aortic injury following road traffic accidents accounts for approximately 20% of vehicle related deaths. The majority of victims sustain immediate and catastrophic aortic failure with exsanguination and death at the site of trauma. Despite the range of trauma scenarios, the injury profile is very similar with the majority of the tears being continuous and in the circumferential direction (i.e., transverse to the aorta axis) at the isthmus region between the end of the aortic arch and beginning of the straight thoracic aorta. The aortic wall is damaged from inside to outside, from the intima towards the adventitia, and ranges from limited laceration of the intima (which results aneurysm) to complete transection of the aorta, depending on the morphological structure of the aortic wall and the strength of forces causing the trauma. In this study we assumed the direct collision between cars generates an impact of acceleration along the aorta that instantaneously drives the column of blood towards the heart. We further assume that the aortic valve withstands the thrust of this impact, and as a result, a huge step of pressure is generated at the aortic root, which in turn drives large wave downstream the aorta. Here, we modeled the aorta as fluid-filled elastic tube with a length of L=50 cm, inner diameter of D=2 cm, and wall thickness of h=0.2 cm. We assume that the aortic wall behaves as a linear and isotropic elastic material with elastic modulus of E=2 MPa and Poisson's ratio of ν=0.5. At the aortic root (i.e., the tube inlet) we tethered the tube from axial motion and allow only radial translation. At the tube outlet we assumed a fixed support for tube wall and zero traction for the fluid. For the pressure impulse at the aortic root we assumed a sinusoidal impulse with an amplitude of P_{max}=20 kPa and duration of T_r=0.02 s. The model was solved using the ADINA, which is commercial finite-element software for dynamically solving problems of fluid-structure interaction. Representative results of the circumferential and longitudinal strains which are generated within the aortic wall due to the pressure impulse at its root are shown in Figs. 1 and 2. A clear wave of elongation is propagation downstream the aorta, and depending on the local mechanical characteristics of the isthmus region, it may generate a transverse tear that will eventually lead to immediate loss of huge amount of blood and death. This model can now be used to analyze protecting requirements to avoid the immediate damage to the aorta at the relatively weak wall in the isthmus region.

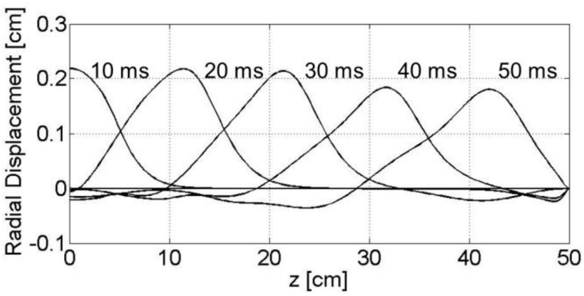

Fig. 1. Distribution of radial displacement along the aortic wall.

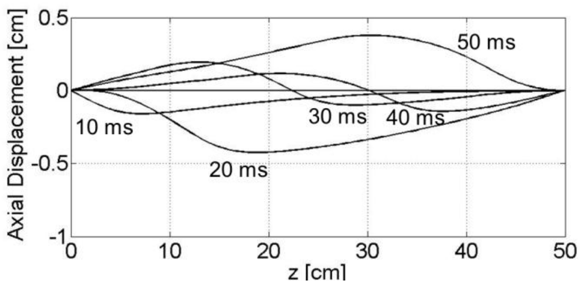

Fig. 2. Distribution of axial displacement along the aortic wall.