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Biomechanical Implications of Bicuspid Pulmonary Valve Dynamic Deformation in Patients with Repaired Tetralogy of Fallot

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Abstract: Pulmonary valve stenosis (PVS) is one common post-operative problem in patients with tetralogy of Fallot (TOF) after repair. Congenital bicuspid pulmonary valve (BPV) is a condition of valvular stenosis, and the occurrence of congenital BPV is often associated with TOF. Compared with the biomechanical simulation model of the bicuspid aortic valve, the BPV is often neglected. In this study, we developed a dynamic biomechanical model of a simulated normal pulmonary root (PR) with tri-leaflet and a model of simulated PR with BPV in patients with repaired TOF in order to describe the effect of geometric structure with BPV on the stress and strain distribution. The geometry of PR included valvular leaflets, valsalva sinuses, inter leaflet triangle and annulus. Mechanical properties of PV leaflet were obtained from biaxial testing of human PV leaflet, and characterized by an anisotropic hyperelastic material model. Our model simulated complete cardiac cycles to observe valve leaflet dynamic stress/strain behaviors. Our results indicated that stress/strain distribution patterns of normal PV and the BPV were similar on pulmonary root and valve leaflets, but their values were different. When the valve was completely closed, maximum stresses were found leaflet attachment boundary, with their values at 17.1 kPa and 17.2 kPa respectively. When the valve was fully open, maximum stresses were found at the vicinity of commissures of sinus and leaflet, that is, near the annulus, with the values at 115.0 kPa and 143.0 kPa respectively. Compared with normal PR, the valve orifice area in the completely opened position in congenital BPV is significantly reduced. Our initial results demonstrated that geometrical variations with BPV may be a potential risk factor linked to occurrence of PVS in patients with repaired TOF. Computational models could be a useful tool in identifying possible linkage between valve disease development and biomechanical factors. Large-scale clinical studies are needed to validate these preliminary findings.

Keywords: Pulmonary valve stenosis, bicuspid pulmonary valve, tetralogy of Fallot.

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