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An Investigation of Left Ventricular Valve Disorders and the Mechano-Electric Feedback Using a Synergistic Lumped Parameter Cardiovascular Numerical Model

Nicholas F Pearce, Eun-jin Kim
Coventry University, UK

Cardiac diseases and failure make up one of largest contributions to global mortality and significantly detriment the quality of life for millions of others. Disorders in the valves of the left ventricle are a prominent example of heart disease, with prolapse, regurgitation, and stenoses—the three main valve disorders. It is widely known that mitral valve prolapse increases the susceptibility to cardiac arrhythmia. Here, we investigate stenoses and regurgitation of the mitral and aortic valves in the left ventricle using a synergistic low-order numerical model. The model synergy derives from the incorporation of the mechanical, chemical, and electrical elements. As an alternative framework to the time-varying elastance (TVE) method, it allows feedback mechanisms at work in the heart to be considered. The TVE model imposes the ventricular pressure–volume relationship using a periodic function rather than calculating it consistently. Using our synergistic approach, the effects of valve disorders on the mechano-electric-feedback (MEF) are investigated. The MEF is the influence of cellular mechanics on the electrical activity, and significantly contributes to the generation of arrhythmia. We further investigate stenoses and regurgitation of the mitral and aortic valves and their relationship with the MEF and generation of arrhythmia. Mitral valve stenosis is found to increase the sensitivity to arrhythmia-stimulating systolic stretch, and reduces the sensitivity to diastolic stretch. Aortic valve stenosis does not change the sensitivity to arrhythmia-stimulating stretch, and regurgitation reduces it. A key result is found when valve regurgitation is accompanied by diastolic stretch. In the presence of MEF disorder, ectopic beats become far more frequent when accompanied by valve regurgitation. Therefore, arrhythmia resulting from a disorder in the MEF will be more severe when valve regurgitation is present.

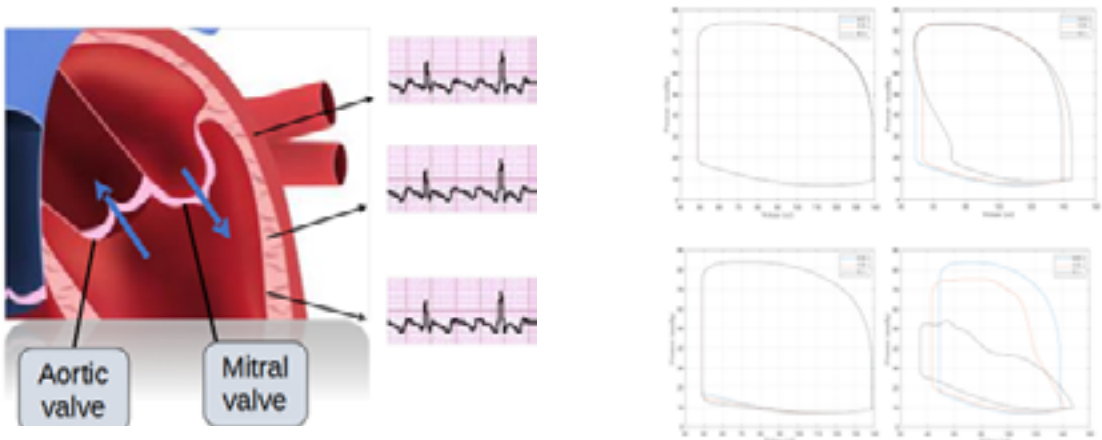

Figure 2: Effect of opening time (left) and closing time (right) of the Aortic valve on the pressure-volume loop of the left ventricle

Biography

Nick Pearce graduated from Warwick University with a PhD in Engineering in 2013. Continued working there briefly as a Research Associate before moving into industry. Continued working for multiple engineering companies until 2020, before joining Coventry University as a Postgraduate researcher in Bioengineering focusing specifically on cardiac modelling and research.