

Predicting Acute Cardiac Resynchronisation Therapy Effects through Patient Specific Modelling

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ABSTRACT

Dyssynchronous heart failure occurs when blocked or delayed electrical conduction results in mechanical dyssynchrony of the heart's ventricles. Cardiac resynchronisation therapy (CRT) is a potential surgical option where an implanted device re-synchronises the ventricular contraction through targeted electrical impulses. However, up to 50% of patients do not respond when selected by the current clinical criteria. Thus, there is a need to further refine patient selection, as reflected by the abundance of literature on clinical and engineering metrics which may predict a patients response to CRT.

Previous research has shown that the change in the haemodynamic quantity dP/dt_{max} from the dyssynchronous contraction to a CRT paced contraction has significant correlation with a patients long term response. Although this metric has much higher sensitivity than other commonly used quantification of dyssynchronous heart failure it is an invasive measurement only available during implantation of a CRT device. On the surface, this disqualifies changes in dP/dt_{max} as a pre-surgical metric, however with advances in patient specific modelling this quantity can be non-invasively estimated to aid patient selection.

We present a patient specific computational modelling pipeline that starts with non-invasive imaging data and ends on the virtual surgical table where biventricular simulations are used to determine the change in dP/dt_{max} . To start, MRI data provides personalised geometries and cardiac tissue deformation. This data is then assimilated using finite element mechanics and reduced-order unscented Kalman filtering to uniquely parametrise a passive constitutive law and extract an activation curve for the patient. Echo derived data is integrated to personalise a lumped-parameter model of the atria and circulation system, which gives the simulations boundary condition. Finally, ECG derived electrical activation maps allow simulation of the patients baseline dyssynchronous and CRT paced activation timings.

This pipeline, demonstrated with validation patient data, emphasises robustness and reliability while balancing the reality of surgical time lines. It is designed to process patients in a two week time frame and is currently being used with a large patient cohort, both retrospectively and prospectively. In addition to predicting CRT response, the robustness of this pipeline allows for the comparison of underlying mechanical bio-markers between responders and non-responders, which may give rise to new computationally derived metrics.