Creating a Digital Twin to Investigate AV Block: Insights from a Validated Electromechanical Full-Heart Model

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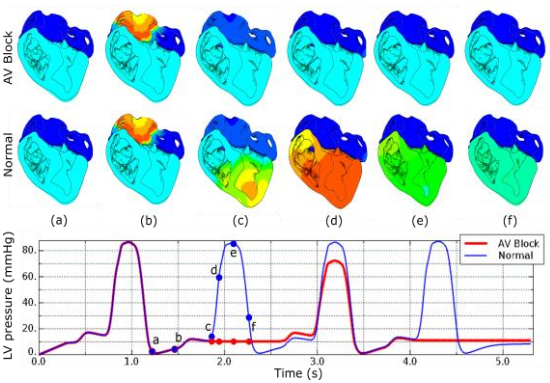
Introduction: Advancements in computational techniques will soon enable the use of anatomically realistic virtual models to contribute towards regulatory evidence. In this study we introduce methods to construct and validate a subject-specific four-chamber porcine heart model suitable to investigate coupled electro-mechanical phenomena from in vivo data.

Methods: Detailed geometric segmentations of the atria and ventricles at end diastole were created and meshed from CT scan data. Ventricular and atrial myofiber orientations were defined using rule-based and manual assignment respectively in accordance with literature values. The calcium transients for 4 consecutive cycles of activation at 55 BPM (based on experimentally recorded HR) were exported from the cell models to drive the timing of atria and ventricular contraction. Our electromechanical four-chamber heart is coupled to a closed-loop circulatory model adapted from lumped parameter representations of different compartments in the cardiovascular system and was mechanically calibrated to match the experimentally recorded LV pressure-volume loop. Surfaces of the LV and RV from the *in silico* model were validated against surfaces extracted from *in vivo* CT scans, which correlated well (R^2=0.94) over all phases. Validated model function is compared with simulations of AV block in the same subject.



Triggering activation in the normal (top) and AV block (middle) electromechanically coupled full heart model with corresponding left ventricle pressures (bottom).

Results: Our findings show that in addition to interrupted flow, AV block creates elevated stress and strain throughout the heart during diastole following the missed ventricular beat. The ventricles, unable to unload, are subjected to increased pressures and volumes which peak during the atrial kick. At this point mean ventricular stress were elevated by 50% (3.0 vs. 4.5 kPa, normal vs. AV block).

Conclusion: Our study validates an electromechanical four-chamber heart model and demonstrates model utility to investigate pathology using a "digital twin".