Bridging the Gap between Theory and Clinical Utility -Parameter Estimations of a 4-chamber 0D Cardiovascular Model for the Purpose of Finding Novel Biomarkers.

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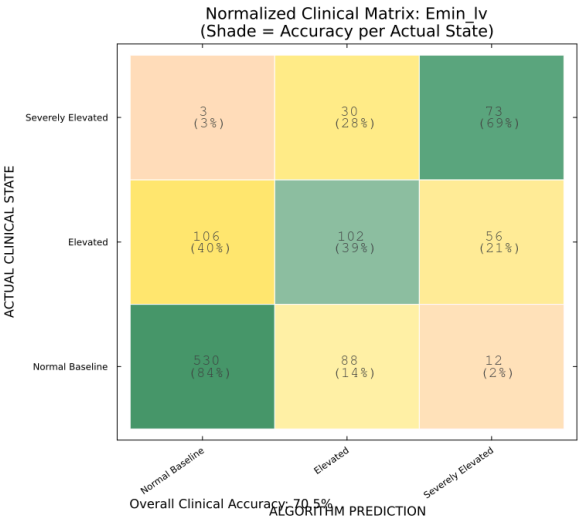
Introduction: Cardiovascular models require calibration to individual patients for clinical utility, yet many parameters remain unobservable, and larger models face identifiability issues. Building on successful estimations in a 1-chamber 0-dimensional model using a modified Unscented Kalman Filter (UKF), we aimed to personalise a 4-chamber, 33-parameter model of the cardiovascular circulation. Our modified UKF approach transforms a state-tracking algorithm for the purpose of control into a parameter estimation tool to find unique solutions for high-dimensional models. We focus on recovering four left heart elastance parameters, which describe passive diastolic filling and active systolic pumping. They could be considered as potential biomarkers for left ventricular function, from recent literature that deduced left atrial strain as a biomarker for left atrial filling pressure.

Methods: We utilised synthetically generated replicas of 30 Hz cardiovascular MRI left heart chamber volumes sampled over one cardiac cycle, alongside a 2 Hz brachial cuff pressure measurement. We tested the algorithm on 1000 sample sets of synthetic parameters representing diverse underlying pathophysiologies. These samples included parameters with over 100% divergence from normal physiological values, testing robustness beyond typical estimation attempts that are often in the order of 10%.

Results: The algorithm correctly identified that 97% of samples with severely elevated minimum left ventricle elastance (the highest numerical tier) belonged to an elevated category, with only 3% incorrectly predicted as baseline. Conversely, it misclassified only 16% of cases with normal elastance (the lowest tier) into higher categories. These metrics demonstrate high classification performance despite an overwhelming proportion of baseline left ventricular physiology within the 1000-sample set.



Conclusion: The high specificity and recall of this algorithm are encouraging. It demonstrates potential for incorporating model-derived elastance biomarkers into the prognostic stratification of cardiovascular disease. This technology is also in its embryonic stages of development, so the clinical potential could be significant.