Effects of Atrial Fibrillation on the Coronary Flow at Different Heart Rates: a Computational Approach

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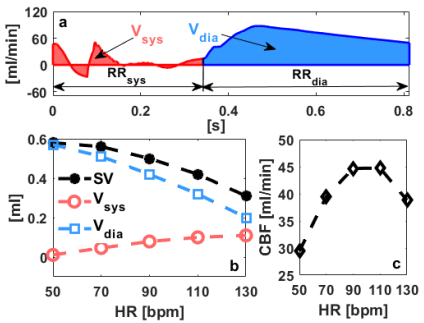
Aim: We investigate the flow alterations of the coronary circulation in atrial fibrillation (AF) at different (average) heart rates (HRs: 50-70-90-110-130 bpm), by focusing on the left anterior descending (LAD) arterial region.

Methods: A physically-based multi-scale model of the heart-arterial circulation, together with the left coronary circulation, is proposed. 2000 heartbeat periods, RR [s], are simulated for each HR, paying attention to reproduce the AF-related random component. Model outcomes provide the flow rate and pressure time series along the whole arterial network. Significant hemodynamic parameters are evaluated to characterize the LAD flow rate waveform at each heartbeat (Fig. a): the blood volumes V_{sys} and V_{dia} during the systolic and diastolic phases, the stroke volume (SV), which is the sum of V_{sys} and V_{dia}, and the coronary blood flow (CBF), which is SV divided by RR. These metrics are computed over 2000 beats for each HR to guarantee statistically stationary results.

Results: In the range 50-130 bpm (Fig. b), SV decades with HR, V_{sys} increases from 0.01 to 0.11 ml, and V_{dia} decreases from 0.57 to 0.20 ml. CBF (Fig. c) exhibits a non-monotonic behaviour: it grows of the 34% in the range 50-90 bpm, remains almost constant between 90 and 110 bpm, and reaches the maximum value (44.8 ml/min) at 110 bpm. For HRs higher than 110 bpm, CBF decreases up to 38.8 ml/min.



(a) Typical LAD flow rate waveform at 70 bpm. Trends of mean SV, V_{sys}, V_{dia} (b) and CBF (c) with HR.

Conclusions: Despite the absence of baroreceptor mechanisms, results indicate a peculiar frequency-dependent trend of CBF during AF. Moreover, the irregular and faster AF beating leads to an increasing data dispersion for higher HR, which itself can cause significant changes (e.g. recurrence of extreme hemodynamic values) at coronary level.