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Title: A comparison of reduced-order computational models for central blood pressure estimation

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INTRODUCTION.

Clinical studies have shown that central blood pressure (CBP) is a better cardiovascular risk indicator than brachial pressure [1]. However, the gold standard to measure CBP is an invasive catheter. We propose a non-invasive approach to estimate CBP from magnetic resonance imaging (MRI) data, coupled with a non-invasive peripheral pressure measurement, using reduced-order 0-D/1-D computational models of arterial haemodynamics. The objectives of this study were: (a) to develop methods for estimating model parameters in two clinical scenarios; and (b) to compare the performance of 0-D and 1-D models for estimating CBP waveforms and landmark values.

METHODS.

Three models for the estimation of the CBP waveform were used: two-element and three-element Windkessel 0-D models and a 1-D model of the aorta (Figure 1). Virtual (computed) healthy populations were generated from these 0-D models and from a 1-D model of the systemic arteries based on [2]. The values of each model's cardiovascular parameters were chosen according to the clinical literature for healthy humans. The pressure and flow waveforms from these populations were used as reference data to develop and test different methods for the estimation of the following vascular parameters: outflow vascular pressure, arterial compliance, characteristic aortic impedance and aortic pulse wave velocity. Two common clinical scenarios were considered depending on the pressure data: (a) when the peripheral pressure waveform is available; and (b) when only diastolic and mean pressure values are available. The optimal parameter estimation methods were identified based on the errors between the reference and estimated values of systolic, mean, diastolic and pulse pressure for each virtual population. These optimal parameter estimation methods were tested on a clinical population of 8 post-coarctation repair patients whose invasive CBP measurements were available.

PRELIMINARY RESULTS. Outflow vascular pressure was best estimated by fitting an exponential function to the pressure waveform during diastole. Average relative errors for pulse and systolic CBP were, respectively, <5 and <2 mmHg for the post-coarctation repair population and <1 mmHg for the virtual populations (Figure 2).

CONCLUSION. Reduced-order computational methods for the estimation of CBP using MRI data and a peripheral pressure measurement have been assessed and compared. Modelling strategies which account for the variety of available clinical data have been developed. The performance of reduced-order models for the estimation of systolic, mean and diastolic blood pressure was comparable. However, when analysing space-dependent features of the pressure waveform, the 1-D model was found to be the superior method.

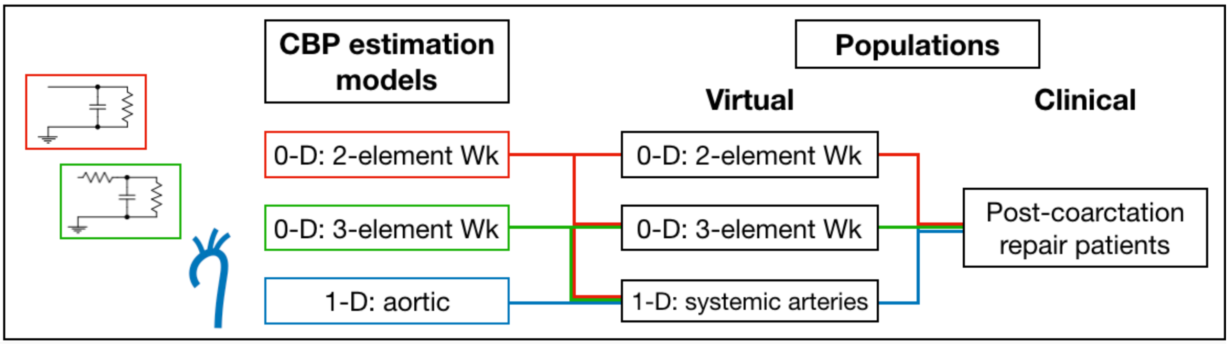

Figure 1 - Reduced-order models for CBP estimation.

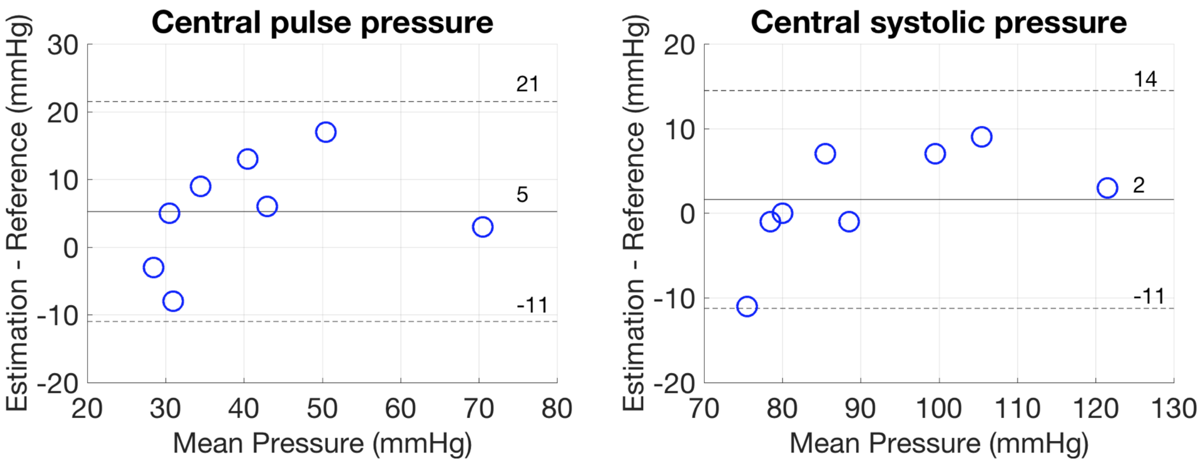

Figure 2 - Bland-Altman plots of pulse (left) and systolic (right) CBP. The bias (solid line) and limits of agreement (dashed lines) are shown.

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[2] DOI: 10.1007/s10439-015-1313-8