Sensitivity Analysis and Parameter Identification of a Cardiovascular Model in Aortic Stenosis

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Context: Aortic stenosis (AS) is a narrowing of the aortic valve opening. Although left ventricular (LV) pressure curve is essential for the estimation of myocardial work indices (Owashi, 2020), its estimation remains difficult in AS. The objective of this study is to propose a model-based method, adapted to patients with AS, in order to reproduce LV pressure and volume from clinical invasive and non-invasive data.

Methods: The model of the cardiovascular system (CVS) is composed of i) cardiac electrical activity, ii) elastance-based mechanical activity, iii) systemic and pulmonary circulations and iv) heart valves. A sensitivity analysis of the proposed model was performed using the Morris elementary effects method (Morris, 1991) on stroke volume (SV) and transaortic pressure gradient (ΔP). Then, a patient-specific parameter identification was implemented with evolutionary algorithms on experimental LV pressure curve, volume curve, systolic and diastolic arterial pressures. The experimental dataset includes echocardiography and invasive pressures measured from 3 patients with severe aortic stenosis.

Results: The sensitivity analyses were applied on 80 parameters with ranges selected from previous work and literature $\pm 30\%$. The most influent parameters on ΔP were mainly related to the aortic valve, whereas most important parameters on SV are associated with LV systolic and diastolic properties. The parameters with the highest sensitivities were selected for parameter estimations. A close match was observed between experimental and simulated pressure and volume curves. The global root mean square error (RMSE) for pressure and volume curves are respectively $21.8(\pm 1.8)$mmHg and $14.8(\pm 9.4)$ml.

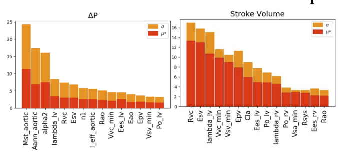

Figure 1: Sensitivity analysis on ΔP and SV

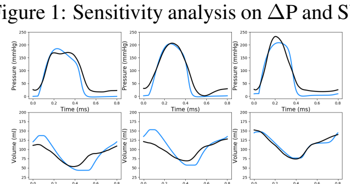

Figure 2: LV pressure and volume curves: i) simulated (blue) ii) experimental (black)

Conclusions: The model-based approach proposed shows promising results to generate accurate LV pressure in AS case. Further work will focus on patient specific identification in non-invasive data and integrate in the assessment of myocardial work.