Sensitivity Analysis of a Mathematical Model Simulating the Post-Hepatectomy Hemodynamics Response

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PARTIAL HEPATECTOMY HEMODYNAMICS DIGITAL TWIN: A SENSITIVITY ANALYSIS STUDY

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1. Introduction

Liver surgery is one of the only curative treatments for primary or secondary liver tumours. Partial hepatectomy is a partial resection of the liver allowing for tumour removal. The main risk of hepatectomy is the occurrence of Post-Hepatectomy Liver Failure, which may occur due to post-operative portal hypertension (PHT) [1]. This abstract presents a global sensitivity analysis (SA) study of a mathematical model simulating the hemodynamics response to partial hepatectomy to better understand the main drivers of the clinical outputs of interest.

2. Materials and Methods

Recently a lumped-parameter model of the cardiovascular system was proposed to simulate the whole-body hemodynamics before and after a partial hepatectomy and evaluate the risk of PHT due to this surgery [2]. The input parameters of this mathematical model $\mathcal{M}$ considered for the SA study proposed are:

- the heart elastances of the right atrium and left ventricle ($E_{a,RA}, E_{b,RA}, E_{a,LV}, E_{b,LV}$);
- the resistances to the flow within the portal vein, hepatic artery, hepatic vein, total digestive organs, and other organs ($R_{pv}, R_{ha}, R_{hv}, R_{DO}, R_{OO}$, respectively);
- the fraction of the total liver mass to be resected during the surgery (Hpx).

Motivated by the clinical needs to evaluate the patient state during hepatectomy, the pre-operative (pre-hpx) and post-operative (post-hpx) quantities of interest for this study are: (i) the portal vein pressure (P_{pv}), (ii) the portocaval gradient (PCG) that is the pressure difference between the portal vein and the vena cava, (iii) the systemic arterial pressure (MAP), (iv) the cardiac output (CO), and (v) the blood flows in the hepatic artery (Q_{ha}) and (vi) in the portal vein (Q_{pv}). While performing the SA using the Sobol indices method, the model outputs required to be constrained to physiological ranges. Thus, an innovative approach [3] that exploits the features of the polynomial chaos expansion method has been applied to generate a metamodel $\mathcal{M}_{pce}$, reducing the overall computational cost to complete a physiological global SA.

3. Results

Fig. 1 shows the most sensitive parameters (red), the fairly sensitive parameters (pink) and the insensitive parameters (white) to the studied quantities of interest.

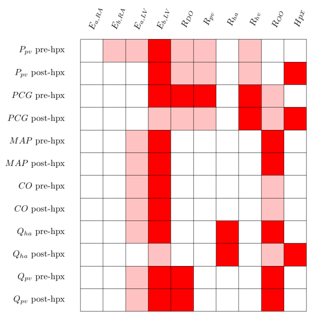

Figure 1: Sensitive (red), fairly sensitive (pink) and insensitive (white) input parameters for each quantity of interest suggested by the SA performed with the surrogate model $\mathcal{M}_{pce}$.

4. Discussion and Conclusions

The results suggest which parameters are more important for this hemodynamic model targeting surgical actions, identifying which measurements can be negligible (e.g.Q_{ha}) and which require good accuracy (e.g. Q_{pv}) to provide solid predictions. Moreover, these outcomes give new insights on how to improve the calibration of some model parameters to be more patient-specific.

5. References

1. Allard MA et al., *Annals of surgery*; 2013.
2. Golse N et al., *Journal of Hepatology*; 2021
3. Sala L et al., *Annals of Biomedical Engineering*; to appear. DOI:10.1007/s10439-022-03098-6.

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