ANALYSIS OF THE EFFECT OF COMBINED EXTRACORPOREAL LUNG AND KIDNEY SUPPORT USING A CARDIOVASCULAR MODEL

Jan-Niklas Thiel (1), Ana M. Costa (2), Bettina Wiegmann (3), Jutta Arens (2), Michael Neidlin (1)

1. Department of Cardiovascular Engineering, Institute of Applied Medical Engineering, Helmholtz Institute, RWTH Aachen University, Aachen, Germany; 2. Department of Biomechanical Engineering, Engineering Organ Support Technologies Group, University of Twente, Enschede, Netherlands ; 3. Department of Cardiothoracic, Transplantation and Vascular Surgery and Lower Saxony Center of Biomedical Engineering, Implant Research and Development (NIFE) and German Center for Lung Research (DZL), BREATH, Hannover Medical School, Hannover, Germany

Introduction

Extracorporeal membrane oxygenation (ECMO) is commonly used in intensive care to support cardiac and respiratory failure, yet up to 70 % of these patients also suffer from acute kidney injury. The treatment for this complication, which involves connecting continuous renal replacement therapy (CRRT) to the ECMO circuit, lacks a gold standard and its connection configuration varies depending on the operator's practice and proficiency.

Aim of this study is to develop a cardiopulmonary model to investigate the effect of different CRRT connection schemes (see Figure 1 a)-c)) on large ECMO cohorts. As a first step, this abstract focuses on the application to a veno-venous-ECMO (VV-ECMO) patient. A Global Sensitivity Analysis (GSA) using Sobol indices is conducted to identify most crucial model parameters for fitting, reducing the number of function evaluations (NFE) and thus its computational cost. Different solvers are compared with regard to performance and quality of the results.

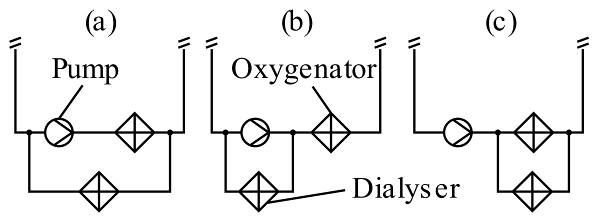

Figure 1: Some of the possible combinations of ECMO and CRRT.

Methods

A computational cardiovascular model has been extended by a pulmonary system and an ECMO system with an external pump, oxygenator, and additional cannulae. This model was fitted to an ARDS patient with Influenza A Pneumonia (f, 28y, sedated) using different state-of-the-art solvers. A GSA was conducted using the Sobol method to identify the model parameters most relevant for the fitting. The Saltelli extension of the Sobol sequence was used to generate 512 samples that served as inputs for the GSA.

Results

Left part of Figure 2 shows the Total Sensitivity Index, which measures the total effect of each model parameter on the output of the system, including interactions between them. Model fitting was performed using the intersection of the two most important parameters for each output. These parameters were the resistances $R_{s,\,arterial}$, $R_{p,\,arterial}$, $R_{cannula,\,inlet}$, $R_{cannula,\,outlet}$, $R_{oxygenator}$, the compliance $C_{p,\,arterial}$ and the maximum elastance $E_{max,\,left\ ventricle}$.

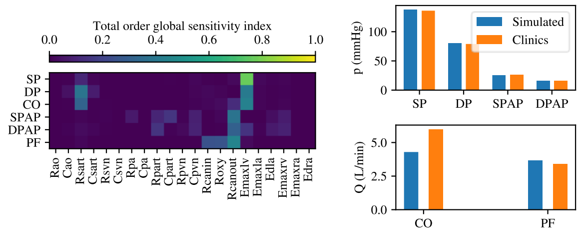

Figure 2: Left: total effect of each model parameter on the outputs. Right: comparison of model output for fitted model parameters. SP, DP, SPAP, DPAP: systolic and diastolic pressure of aorta and pulmonary arteries. CO: cardiac output. PF: pump flow.

Table 1 shows the results of different solvers for minimizing the root-mean-square error between simulated and clinical data, as well as the NFE required for convergence. The Sequential Least Squares Programming *SLSQP* algorithm was chosen for its low error value and computational cost. Its results are compared to clinical data on the right of Figure 2.

Solver	BFGS	CYBOLA	Powell	SLSQP
Error	0.31	0.047	0.020	0.019
NFE	96	500	2861	176

Table 1: Error and NFE for different solvers.

Discussion

A cardiovascular model including VV-ECMO was analyzed using GSA, which revealed that fitting the model using only a subset of important model parameters reduces computational cost while maintaining the quality of the fit. This framework will now be extended to a more comprehensive model that incorporates different CRRT strategies and phenotypes from larger patient cohorts.

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