A 0D-1D global, closed-loop model of the cardiovascular system

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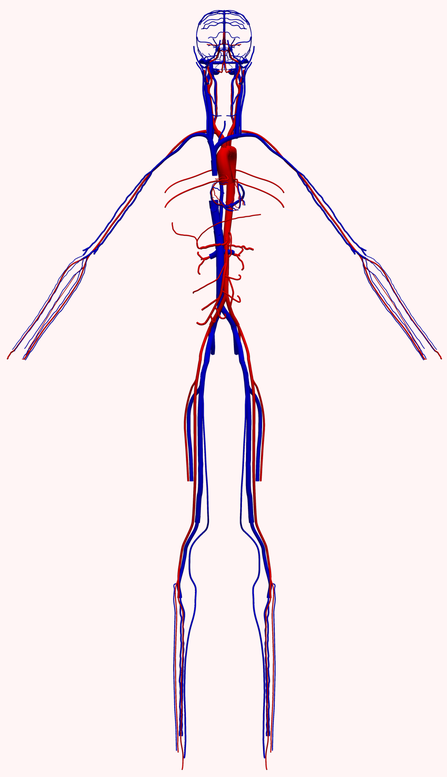
INTRODUCTION

How can **hemodynamic models**, despite their potential to **reduce invasive procedures** in patient care, be optimized to overcome their **high computational costs** and facilitate real-time adoption in medical settings?



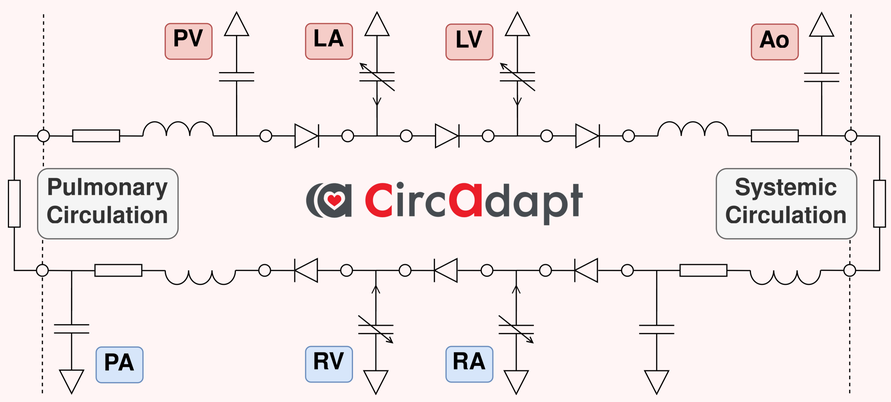
Arterial and venous vascular anatomy of the ADAVN model.

CONTEXT

Understanding the **complex interactions** between the heart and the arterial and venous networks remains a significant challenge in cardiovascular research.

In this work we coupled the **ADAVN model**, a 1D anatomically accurate model of the vascular system, with the **CircAdapt model**, a 0D model of the cardiac function and pulmonary circulation.

The coupled model enables an in-depth study of the interplay between the heart and the vascular system at a **reduced computational cost**.



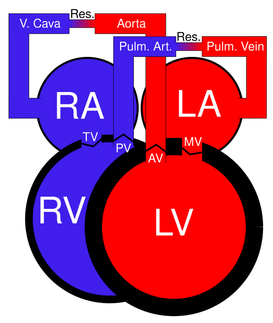
Electrical equivalent circuit of the CircAdapt model

CIRCADAPT

CircAdapt is a **0D hemodynamic model**, i.e., it simplifies the cardiovascular system to a set of ordinary differential equations.

It is **modular**, consisting of components for vessels, heart chambers, pericardium, sarcomeres, tubes, and valves.

This modularity allows it to be **easily coupled** with more detailed models of specific compartments.



Anatomy of CircAdapt.

ADAVN

"*ADAVN*" stands for **A**natomically **D**etailed **A**rterial **V**enous **N**etwork.

Several **boundary conditions** are used to couple vessels, and **high-order finite volume solver** are used to approximate the solution.

One-dimensional blood flow equations

$$\begin{cases} \partial_t A + \partial_x q = 0 \\ \partial_t q + \partial_x \left(\frac{q^2}{A} \right) + \frac{A}{\rho} \partial_x p = -\frac{f}{\rho} \end{cases}$$

ADAVN network

86 systemic arteries

23 coronary arteries

189 systemic veins

COUPLING

To enable this coupling we included the ADAVN model as an additional tube in the CircAdapt model.

At each time step, the flow from the aortic valve and the pressure in the right atrium are provided to ADAVN, which returns the pressure in the ascending aorta and the venae cavas to CircAdapt.

Before the coupling, the ADAVN model is pre-initialized to reach convergence.

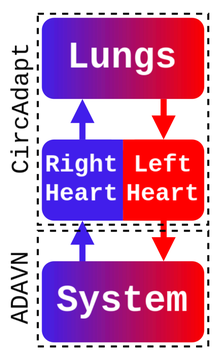
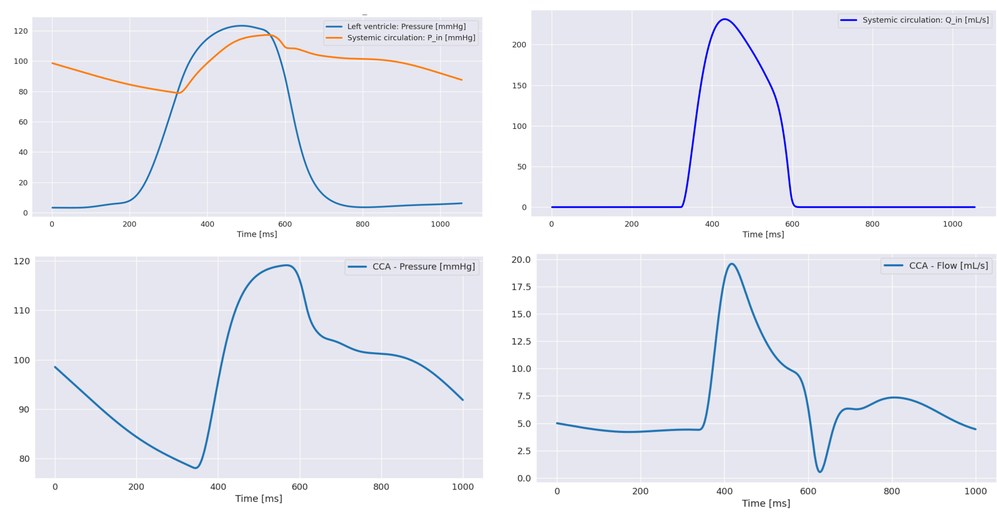


Diagram of the coupling.

RESULTS



CONCLUSION + FUTURE WORK

We obtained a 0D-1D model which provides insight into **cardiac biomechanics** thanks to the CircAdapt model and **wave propagation dynamics** thanks to 1D formulation for the vascular system.

In the future we want to apply the coupled model to several pathologies, e.g., system hypertension and pulmonary hypertension.

LET'S KEEP IN TOUCH

Personal website

st-costa.github.io

More on this work

bit.ly/3X0Y6Sn

AFFILIATIONS

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