

# Cardiovascular modelling for medical device testing

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## Organisation

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## SCOPE OF THE METHOD

<b>The Method relates to</b>	Human health
<b>The Method is situated in</b>	Basic Research, Education and training, Translational - Applied Research
<b>Type of method</b>	In vitro - Ex vivo
<b>Specify the type of cells/tissues/organs</b>	Cardiovascular system

## DESCRIPTION

### Method keywords

Cardiovascular modeling

Lumped parameters model

in vitro

in silico

## Scientific area keywords

Ventricular assist device  
Total artificial heart  
Heart valves  
Exercise physiology  
cardiovascular

## Method description

The cardiorespiratory model reproduces human physiology with a high level of fidelity. It is a lumped parameter model including a representation of atria, ventricles, pulmonary and systemic circulations, autonomic controls, metabolic peripheral control, ventilation and gas exchange in tissues and lungs.

The simulator is developed in LabVIEW language and is organized in several modules:

- Physiological model: this is the internal core representing the circulation as described above. It reproduces flow and pressure profiles in the heart and in the vessels.
- Diseases: this module consists in a set of parameters values to be fed into the physiological model for the representation of one or multiple diseases with different levels of severity. These diseases were validated using the ACCF/AHA medical guidelines so to make sure the output (cardiac output, wedge pressure, arterial pressure etc.) was in the correct range.
- Therapies: this modules permits to simulate the effects of pharmacological and device therapies.
- Self-tuning module: this module automatically tunes the simulator to a patient's specific condition. The user inserts patient's data and a recursive algorithm tunes the simulator to the desired hemodynamic condition.
- Exercise module: it reproduces exercise physiology both in healthy and heart failure conditions in terms of chronotropic and inotropic response, vasodilation, increase in ventilation.

The laboratory of cardiac surgery is also equipped with a "hybrid" simulator (HS), developed in cooperation with the Nalecz Institute of Biocybernetics and Biomedical Engineering of the Polish Academy of Sciences. This is an innovative type of simulators that combines computer modeling and mock loop connected each other

in LabVIEW real time. This simulator is largely used in the pre-clinical test of medical devices as: ventricular assist devices, vascular grafts, heart valves, total artificial hearts etc.

### **Lab equipment**

- Home made high fidelity models Computer running specific softwares: Matlab, LabView ;
- Pressure and flow sensors, hydraulic components, pumps, valves ;
- Cardiovascular medical device used to support circulation.

### **Method status**

History of use

Internally validated

Published in peer reviewed journal

## **PROS, CONS & FUTURE POTENTIAL**

### **Advantages**

Reduced number of animals to be used for the preliminary tests of a medical device ;  
Evaluation of the complex hemodynamic interaction of a medical device with the cardiovascular system ;  
Study of complex pathophysiological conditions, in particular concerning exercise physiology ;  
Tests of the efficacy of different therapeutic strategies for specific cardiovascular diseases.

### **Future & Other applications**

The simulator can be adapted to tests other types of medical devices such as extracorporeal membrane oxygenators and to reproduce complex pathophysiological conditions such as Fontan circulation.

## **REFERENCES, ASSOCIATED DOCUMENTS AND OTHER INFORMATION**

### **References**

Fresiello L et al. Exercise physiology with a left ventricular assist device: Analysis of

heart-pump interaction with a computational simulator. PLoS One. 2017 Jul 24;12(7):e0181879.

Fresiello L et al. A Model of the Cardiorespiratory Response to Aerobic Exercise in Healthy and Heart Failure Conditions. Front Physiol. 2016 Jun 8;7:189.

Fresiello L et al. A cardiovascular simulator tailored for training and clinical uses. J Biomed Inform. 2015 Oct;57:100-12.

Fresiello L et al. Reproduction of continuous flow left ventricular assist device experimental data by means of a hybrid cardiovascular model with baroreflex control. Artif Organs. 2014 Jun;38(6):456-68.

## Links

[Cardiovascular Hybrid Simulator](#)

[Short pitch simulator MD testing](#)

[Pitch Use of a cardiovascular hybrid simulator as a support decision system for...](#)

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