Cardiovascular modelling for medical device testing

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SCOPE OF THE METHOD

The Method relates to	Human health
The Method is situated in	Basic Research, Education and training, Translational - Applied Research
Type of method	In vitro - Ex vivo
This method makes use of	Human derived cells / tissues / organs
Specify the type of cells/tissues/organs	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, hudraulic 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.

Associated documents

Links

Cardiovascular Hybrid Simulator
Short pitch simulator MD testing

PARTNERS AND COLLABORATIONS

Organisation

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