

## Development of a laboratory of excellence in the cardiovascular field

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Located in the Italian city of Latina, near Rome, the LABoEx certainly represents a one-of-its kind concentrate of know-how and advanced research in the field of Cardiovascular disease.

Conceived during a meeting between cardiologists and bioengineers, LABoEx was created in reply to the shared needs for an in-depth understanding of the many variables and parameters of the cardiovascular system and of their interaction with mechanical assist devices (such as the oxygenator, the intra-aortic balloon pump, centrifugal pump, the ventricular assist device, the ventilatory assistance etc).

The initial idea, brought forth by the bioengineers, was to develop a *tool* of diverse numerical models that could simulate the behaviour of the cardiovascular system in presence of different mechanical cardiac or ventilatory assist devices. The concept was then extended by the cardiologists who suggested to extend its application in predicting, starting from few cardiovascular variables (measured non invasively), the trend, or better, the behaviour of those variables that cannot be directly measured on the patient. The successive step was use numerical models ad hoc for patients affected by specific pathologies, hence providing the physician a *tool* for deciding the most appropriate strategies for the patient.

From there, the group developed the idea of orienting the cardiovascular numerical models also towards other applications, such as a commercial device that monitors the correct functioning of a 24-hr blood pressure Holter.

Indeed, the laboratory of the Institute of Clinical Physiology of the Italian National Research Council (C.N.R.) has already started working towards the realization of a *software tool* (CARDIOSIM©) aimed at simulating the behaviour of the cardiovascular system. This modular software was developed by Italian researchers together with colleagues from the Institute of Biocybernetics and Biomedical Engineering, IBIB-PAN Warsaw, Poland, of the Iwate Prefectural University in Japan, the Biomedical Engineering and Cardiothoracic Surgery of the University Medical Center Groningen in Holland, and the N.I.H in the USA.

The *software* implements on a PC platform a family of lumped parameter circulatory models designed to be used in clinical, research, and educational applications.

The family of the circulatory models represents the circulation at the level of large vessels and allows to evaluate the global effects of external disturbances (pathologies, therapies, mechanical assistance, special environments or surgery) on the circulatory system.

The *software tool* simulates different mechanical heart assist devices, like left and right Ventricular Assist Device (VAD) and Intraaortic Balloon Pumping (IABP): both pulsatile and continuous flow VAD can be used inside the tool. Also the mechanical ventilatory assistance is implemented.

The main features of CARDIOSIM© are basically:

- Capability to reproduce volumetric phenomena of the circulation and artero-ventricular interaction;
- Possibility to assemble the model in different ways, according to the specific circulatory condition to be reproduced;
- Exhaustive data presentation and storing of simulation results;
- Possibility to set the values of circulatory parameters *on-line*.

These principles led to the development of a lumped parameter model of the circulation completed by two variable elastance models to reproduce the Starling law of the heart for both ventricles.

Modular organization of the *software*, which allows planning different experiments.

CARDIOSIM© runs on a personal computer (under Windows operating system). Among its calculations, it includes ventricular energetics. It is an easy to use software compatible with other software packages. Moreover, it is useful to physicians, students, clinicians, anaesthesiologists, researchers and surgeons for studying and analyse the most important cardio-circulatory phenomena in physiological and pathological conditions and during mechanical circulatory assistance and/or mechanical ventilation as well.

LABoEX was born within the U.O.C of Cardiology of the University "La Sapienza" - Polo Pontino (Latina) directed by Prof. Alessandri Nicola.

The first studies undertaken were performed on patients affected from arterial hypertension and cardiocirculatory lack of balance. The same cardiovascular variables were measured in patients affected by these pathologies and were later used to simulate the patients' conditions. The use of CARDIOSIM© allowed to simulate the effects induced by different drugs used to solve the patient pathology, which helped the cardiologists to choose the most suitable drug protocol of for each patient.

The LABoEX experience allowed to put together a know-how, useful in the organization of continual medical education (ECM) courses (accordingly to the educational policy of the Italian Ministry of Health <http://www.ministerosalute.it/ecm/ecm.jsp>) addressed to the general practitioners, as well as to students of the School of Medicine of the "La Sapienza" University.

Recently LABoEX has launched a project for the design of an inexpensive device for controlling the functioning of a 24-hr blood pressure Holter. The device based on the numerical models of the

cardiovascular system will reproduce during 24h different physiopathological arterial systemic pressure waveforms. These numerical waveforms will be converted using a pump in hydraulic pressures that will be measured by the Holter under investigation. In this way it is possible to check if the numerical pressure reproduced by the numerical simulator is equal to them measured by the device during the 24-hr. The next future is likely to see the development of a monitor for Intensive Care unit able to show simultaneously measured and calculated variables, using modular numerical model of the circulation. This should simulate in real time the effects of the somministrations of drugs (or different manoeuvres) on patients.

The CARDIOSIM© *software* is currently used by researchers in different countries (Germany, England, Turkey, Japan, France and Poland).

Further information on the *tool* CARDIOSIM© are available and on the book “Modelling Cardiovascular System and Mechanical Circulatory Support”, Edited by Claudio De Lazzari and published by Consiglio Nazionale delle Ricerche (2007) and on the Italian web-site <http://www.progettoattila.it/brevetti.aspx>.

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