Editor's Page

# Recent Advances in Cardiovascular Diagnosis: The "Revolution" in Biomedical Engineering

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Cardiovascular diseases, as the foremost health care problem in the developed countries, impose a tremendous economic, social and emotional burden on societies. Biomedical engineering aims at contributing to a better understanding of the mechanisms of cardiovascular diseases and promoting innovative technologies for cardiovascular diagnosis, rehabilitation and therapy.

**Biomedical engineering** is a multidisciplinary field, which integrates mathematical, physical, chemical, computational and engineering sciences to study biology, medicine and health. Biomedical engineering has a particularly wide spectrum of applications in almost every medical field. In cardiovascular medicine the term "cardiovascular engineering" is commonly used. Applications of cardiovascular engineering include bioelectrical and neural engineering, biomedical imaging, biomaterials, biomechanics, biofluid mechanics, biomedical devices (i.e. artificial organs), instrumentation, molecular, cellular and tissue engineering, computational systems and bioinformatics, as well as mathematical and experimental modelling.

**Numerical and hydraulic modelling,** often termed mock circulation, has been a traditional research approach in cardiovascular engineering and medicine for the study of pathophysiological phenomena. Artificial hearts, valves, stents, grafts, contrast agents, catheters, have been primarily studied and optimised by using numerical and hydrodynamic analogues (models) prior to their *in vivo* application. Advances in mathematics and computer science have significantly improved the validity of these models, strengthening their usefulness and applicability.[1]

**Cardiovascular imaging.** Although imaging diagnostics have been in use for decades (the X-ray has been used for more than 100 years), it is in the last 40 years that there has been an explosion in their use due to technological developments in imaging modalities, such as ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography, and single photon emitted computed tomography. Advances in cardiovascular CT imaging have dramatically changed the way we evaluate cardiovascular diseases, mainly through the improved spatial and faster temporal resolutions of the newer scanners.[2] Technological developments in cardiac MRI, such as MRI at 3 Tesla,[3] have improved assessment of cardiac function, metabolism and perfusion, definition of anatomy, evaluation of the ventricular mass, regional and global ventricular function, and detection of congenital heart and aortic disease. Software and hardware developments in ultrasonography have expanded its diagnostic ability, with major advances being tissue harmonic imaging and three-dimensional imaging. Miniaturised probes (i.e. MRI and ultrasound) have now enabled intravascular imaging, providing an in-depth analysis of atherosclerotic plaque function and composition.[4] Finally, the introduction of contrast agents (microbubbles) has provided a boost to cardiovascular imaging by improving the signal to noise ratio of the acquired images.[5] Contrast enhanced imaging (e.g. MRI or ultrasound) has expanded our diagnostic capabilities by improving the assessment of tissue perfusion and the imaging of atherosclerotic plaque neovascularisation.

**Signal processing** consists of various tasks such as acquisition, filtering, prediction, enhancement, coding, analysis, compression, modelling, or display of data. Signal processing has played a key role in blood pressure and flow wave analysis, with applications in the non-invasive assessment of aortic blood pressures, impedance, wave reflections and the mechanical arterial properties, as well as in the analysis of ECG signals. During the last decade the introduction of non-linear dynamics and chaos theory has attracted increasing research interest in cardiology. Complex physiological dynamics enable an organism to respond rapidly to internal and external perturbations. Continuous interplay among the electrical, chemical, and mechanical components of biological systems ensures that information is constantly exchanged, even at rest. These dynamic processes are evident in the complex variability of physiological control systems, such as blood pressure and heart rate, when they are measured on a moment-to-moment or beat-to-beat basis. It is now believed that it is important to measure and analyse the continuous behaviour of these systems, rather than their average value over some time period. Previous studies have indicated that a loss of complexity in heart rate dynamics is associated with aging and disease. Additional evidence has indicated the prognostic value of these nonlinear, "chaotic" features of variability and their association with mortality, while pharmacological effects on heart rate and blood pressure "complexity-predictability" and irregularity are under investigation.[6]

Finally, progress in **nanotechnology and biotechnology**, which is expected to explode over the next few decades, will bring advances in biomedical engineering that stretch the imagination. In the USA the proposed 2008 budget for agencies participating in the National Nanotechnology Initiative is $1.5 billion, more than triple the estimated $464 million spent in 2001. Latest news from the USA in the field of cardiology announced that "*The National Heart, Lung, and Blood Institute (NHLBI), National Institutes of Health (NIH), has awarded researchers from Georgia Institute of Technology and Emory University $11.5 million to establish a new research program focused on creating advanced nanotechnologies to analyze atherosclerotic plaque formation on the molecular level and detect plaques at its early stages.*"

It should be acknowledged, though, that the rapid technological developments in the biosciences raise scepticism in the medical world regarding the ability to assimilate the new technologies, to comprehend their clinical necessity and to afford the financial cost of these increasingly sophisticated innovative technologies.

## References

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