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Guest editorial

Cardiovascular Oscillations: from methods and models to clinical applications

The European Study Group on Cardiovascular Oscillations (ESGCO) is an interdisciplinary group for scientific exchange between theoretical and clinical physicians, biomedical engineers, and natural scientists. It was created during an Educational Training Course of the European Society of Cardiology on new methods to analyze and cross-analyze heart rate and blood pressure variability in the European Heart House in 1998 by T. Griffith, A. Malliani, P. Persson and B. Swynghedauw. The goal of the ESGCO is to promote basic research on linear and non-linear analysis of cardiovascular oscillations, including heart rate and blood pressure variations, contractility changes, oscillations in microcirculation, calcium waves and ion movements.

Previous ESGCO meetings took place in Cardiff (2000), Siena (2002), and Leuven (2004).

The ESGCO 2006 Conference and Meeting, Jena, May 15–17, 2006 focused on interdisciplinary evaluation of basic medical and engineering research, clinical application of enhanced univariate and multivariate signal analysis, and signal interpretation methods, as well as model-based signal analysis in different scales. The state of the art, trends, and challenges in the analysis of cardiovascular signals such as HRV, BPV, BRS, and HRT in practical medicine were critically discussed in a clinical and engineering expert round table.

ESGCO 2006 was organized by both Jena universities. Associated scientific societies were the Federation of European Physiological Societies (FEPS), the Engineering in Medicine and Biology Society of IEEE (IEEE EMBS), the German Society of Biomedical Engineering (DGBMT), and Collegium Europaeum Jenense (CEJ).

The main topics of the conference were:

- Cardiovascular oscillations in cardiovascular diseases
- Clinical risk stratification
- Cardiovascular oscillations modulated by central nervous system disorders (e.g., bipolar disorders)
- Investigation of autonomic nervous system
- Cardiovascular oscillations on a molecular and cellular scale
- Heart rate variability
- Blood pressure variability
- Baroreflex sensitivity
- Heart rate and blood pressure turbulence
- Alternans phenomena (blood pressure, T wave), QT dispersion and prolongation
- Linear and non-linear univariate and multivariate methods of signal processing and interpretation
- Statistical signal analysis
- Interaction analyses, coupling and synchronization
- Linear and non-linear modeling of experimental physiological and clinical data
- Related topics.

The ESGCO 2006 Conference and Meeting brought together scientists from universities, research institutions and industry. They were all invited to participate in this outstanding forum with plenty of opportunities for discussion and the exchange of ideas.

In total more than 100 scientists from 18 countries registered, and they presented 49 papers, 29 posters and eight industrial exhibits.

This Special Issue on Cardiovascular Oscillations aims to provide an update of international research work on the detection, analysis, interpretation and modeling of cardiovascular oscillations and their clinical impact.

In the first group of papers focused on the topic *Clinical investigations*, Stein et al. describe “Circadian and ultradian rhythms in heart rate variability”, rhythms that are not sufficiently considered in the HRV literature so far. Honzikova et al. investigate in their work “Influence of age, body mass index, and blood pressure on the carotid intima-media thickness in normotensive and hypertensive patients” relevant physiological aspects leading to cardiovascular dysfunction. The importance of considering several physiological parameters and their interactions for clinical risk stratification are described by Voss et al. in “Multivariate and multidimensional analysis of cardiovascular oscillations in patients with heart failure”.

This type of comprehensive signal analysis was also applied in *Further fields of Cardiovascular Oscillations*, such as sleep in “Multivariate and multiorgan analysis of cardiorespiratory variability signals: the CAP sleep case” by Bianchi et al. The influence of autonomic functions on non-linear dynamics of HRV was validated by Porta et al. in “Role of the autonomic nervous system in generating non-linear dynamics in short-term heart period variability”.

Representative papers reflecting relevant and innovative *Methods of signal analysis and their application* are as follows. Fractal indices are considered in “Non-linear dynamic analysis of the cardiac rhythm during transient myocardial ischemia” by Gomis et al.; autonomic information flow (AIF) is addressed in “Complex autonomic dysfunction in cardiovascular, intensive care, and schizophrenic patients assessed by autonomic information flow” by Hoyer et al.; compression entropy is the focus in “Low HRV entropy is strongly associated with myocardial infarction” by Lau et al., “Revisiting the potential of time-domain indexes in short-term HRV analysis” by Balocchi et al., “Fractal dimension in health and heart failure” by Beckers et al., and “Spatiotemporal correla-

tion analyses: a new procedure for standardisation of DC magnetocardiograms" by Goernig et al.; and detrented fluctuation analysis is the topic in "Changes in heart rate variability of athletes during a training camp" by Baumert et al.

Under the heading *Methods and modelling*, Dössel et al. present a review on "The missing link between cardiovascular rhythm control and myocardial cell modeling", Grudziński et al. a "Model of the sino-atrial and the atrio-ventricular nodes of the conduction system of the human heart", Leite et al. "Modelling long-term heart rate variability: an ARFIMA approach", Maestri et al. "Clinical correlates of non-linear indices of heart rate variability in chronic heart failure patients", Maier and Dickhaus "Recurrence analysis of nocturnal heart rate in sleep apnea patients", and Raab et al. "Normalized correlation dimension for heart rate variability analysis".

New fields in which cardiovascular oscillations have become clinically relevant are presented with regard to *Autonomic and neural disorders and fetal development*. Frank et al. introduce "Complexity of heart rate fluctuations in near-term sheep and human fetuses during sleep", Bär et al. "Differences between heart rate and blood pressure variability in schizophrenia", Castiglioni et al. "Influence of sympathetic vascular regulation on heart-rate scaling structure: spinal cord lesion as a model of progressively impaired autonomic control", Van Leeuwen et al. "Increase in regularity in fetal heart rate variability with age", and Schneider et al. "Fetal heart rate variability in growth restricted fetuses".

The following papers reflect contributions dealing with *Interaction/Uni- and multivariate analysis*: Zhong et al. "Frequency modulation between low- and high-frequency components of the heart rate variability spectrum", Faes et al. "Mixed predictability and cross-validation to assess non-linear Granger causality in short cardiovascular variability series", Corino et al. "Assessment of spatial organization in the atria during paroxysmal atrial fibrillation and adrenergic stimulation", Schmidt et al. "Attenuated autonomic function in multiple organ dysfunction syndrome across three age groups", Stojičić et al. "Central vasopressin V_{1a} and V_{1b} receptors modulate the cardiovascular response to air-jet stress in conscious rats", and Guzik et al. "Heart rate asymmetry by Poincaré plots of RR intervals".

In the *Round table discussion* "Analyses of cardiovascular oscillations for enhanced diagnosis and risk stratification in cardiac diseases and disorders", the clinical value of the above-mentioned methods was discussed by distinguished researchers and clinicians, namely by Solange Akselrod, Sergio Cerutti, Natasa Honzikova, Marek Malik, Phyllis Stein and other conference participants, leading to an outline of the state of the art and future challenges presented at the end of the present issue.

An overview of the remaining presentations of the conference is given in the *Abstracts*.

This Special Issue covers most of the important aspects regarding cardiovascular oscillations. The editors were primarily seeking high-quality research papers presenting methods evaluated against state-of-the-art solutions. From all contributions, the best 29 were selected for publication in this journal following a critical peer-review process whereby every manuscript submitted was evaluated by at least three prominent reviewers.

We wish to thank all the authors for their contributions, the members of the scientific board of ESGCO 2006 for their valuable advice and all the additional reviewers for supporting us to help make ESGCO 2006 a success. Finally, we wish to thank Dr. Gunda Stöber for her tireless assistance and patience in preparation of this Special Issue.

We hope that this Special Issue will contribute to enhance our knowledge in this challenging area of research, will support the application of promising methods into clinical practice and will help our young scientists in their daily work in this field.

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