Mini-Symposia Title:

Recent Advances on Cuff-Less Blood Pressure Measurement I

Mini-Symposia Organizer Name & Affiliation:

Ramakrishna Mukkamala, University of Pittsburgh

Mini-Symposia Speaker Name & Affiliation 1:

Ramakrishna Mukkamala, University of Pittsburgh

Mini-Symposia Speaker Name & Affiliation 2:

Josep Sola, Aktiia

Mini-Symposia Speaker Name & Affiliation 3:

Arik Eisenkraft, Biobeat Technologies

Mini-Symposia Speaker Name & Affiliation 4:

Martin Baruch, Caretaker Medical

S Mini-Symposia Speaker Name & Affiliation 5:

Yuan-Ting Zhang, City University of Hong Kong

Mini-Symposia Speaker Name & Affiliation 6:

Theme:

- ○ 01. Biomedical Signal Processing
- ○ 02. Biomedical Imaging and Image Processing
- ○ 03. Micro/ Nano-bioengineering: Cellular/ Tissue Engineering &
- ○ 04. Computational Systems & Synthetic Biology; Multiscale modeling
- ◉ 05. Cardiovascular and Respiratory Systems Engineering
- ○ 06. Neural and Rehabilitation Engineering
- ○ 07. Biomedical Sensors and Wearable Systems
- ○ 08. Biorobotics and Biomechanics
- ○ 09. Therapeutic & Diagnostic Systems and Technologies
- ○ 10. Biomedical & Health Informatics
- ○ 11. Biomedical Engineering Education and Society
- ○ 12. Translational Engineering for Healthcare Innovation and Commercialization

Mini-Symposia Synopsis— Max 2000 Characters

Cuff-less blood pressure (BP) monitoring is expected to improve hypertension awareness and control rates and may now be feasible due to recent technological advances in, e.g., wearable sensing. As a result, cuff-less BP monitoring devices are being widely pursued around the world. This topic is of great interest to the attendees of the IEEE EMBC. We have organized multiple mini-symposia on the topic at each of the past seven IEEE EMBCs. The in-per sessions have always been filled to capacity with 100 people or more (when the room was large enough) in attendance from academia and industry. We now propose two mini-symposia on recent advances on cuff-less BP measurement for the Guadalajara meeting. Our proposal includes ten outstanding speakers in the field from companies and universities. Half of these speakers would be attending the Guadalajara meeting for the sole purpose of participating in the proposed mini-symposia. This particular mini-symposium represents part one and covers PPG waveform analysis methods presented by three industrial and two academic speakers.

Is PPG Waveform Analysis a Viable Approach for Cuff-Less Blood Pressure Measurement?

Ramakrishna Mukkamala, University of Pittsburgh

***Abstract*—Ramakrishna Mukkamala is a blood pressure measurement researcher and will propose evaluation methods for, and present human study results on, photo-plethysmography (PPG) waveform analysis for cuff-less blood pressure measurement.**

Ramakrishna Mukkamala is a Professor in the Department of Bioengineering and Department of Anesthesiology and Perioperative Medicine at the University of Pittsburgh. In recent years, the principal aim of his research program has been to innovate technologies to advance blood pressure (BP) measurement. His group has developed oscillometric algorithms for more accurate cuff measurement of brachial BP [1] and for indirect measurement of aortic BP via a standard arm cuff device [2]; the oscillometric finger pressing method for cuff-less and calibration-free BP monitoring via a smartphone [3, 4]; and methods and systems based on pulse transit time for continuous and non-invasive tracking of BP changes without a cuff (e.g., [5, 6]). He has also recently published reviews and book chapters on cuff-less BP measurement [7-9].

Photo-plethysmography (PPG) waveform analysis is being increasingly investigated for ultra-convenient blood pressure (BP) monitoring (typically in between cuff calibrations). However, the accuracy of this approach, especially in terms of added value over other available information, and the useful features and models for converting the features to BP is still unclear. It is particularly important to understand the features given that a supporting theory for the approach may be lacking. In this talk, I will first describe how PPG waveform analysis techniques for BP measurement should be evaluated. I will then present a study of human physiological data in which easy-to-understand models relating PPG waveform features to intervention-induced BP changes were developed and then evaluated to conclusively determine whether they provide added value or not in BP measurement accuracy [10].

REFERENCES

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Monitoring the effects of antihypertensive drugs using the Aktiia optical device: a four-month case report

Josep Sola, Aktiia

Abstract— **This talk will present real world evidence on the use of cuffless devices in the longitudinal monitoring of hypertensive patients.**

Dr Sola completed his Master's Thesis in 2004 at the Catalonia Polytechnic University (UPC) in the field of biosignal processing. In 2012 he obtained his PhD thesis at the Swiss Federal Institute of Technology in Zurich (ETHZ) with a dissertation entitled "Continuous blood pressure monitoring". Between 2004 and 2018 Dr Sola performed basic and clinical research at the Swiss Center for Electronics and Microtechnogy (CSEM) in Neuchâtel (Switzerland) in the field of non-invasive cardiovascular monitoring. For 14 years he explored multiple sensing modalities and signal processing algorithms to facilitate the widespread of use of cuffless blood pressure devices in the real world. He's inventor of +20 international patents, author of +60 peer-reviewed publications and book chapters, and since 2019 the editor and author of the book "The Handbook of Cuffless Blood pressure Monitoring - A practical guide for clinicians, researchers, and engineers" published by Springer.

The reduction of Blood Pressure (BP) is associated with a significant reduction of cardiovascular events and all-cause mortality. After lifestyle interventions, antihypertensive drugs are routinely administrated to lower BP. The optimization of antihypertensive therapies requires the identification of the best adapted drug for each patient, followed by the titration of dosages. Automated cuffless BP monitoring devices based on optical sensors have the potential to provide new insights in the monitoring of the effectiveness of antihypertensive therapies over weeks. This talk will describe the technology implemented into the CE-marked Aktiia Bracelet optical device, and will illustrate its use for the monitoring of a 39-year-old male subject for four months while different drug therapies were administrated.

J. Sola is with Aktiia SA, Switzerland; e-mail: josep@aktiia.com.

Using a PPG-based remote patient monitoring platform to monitor subjects with suspected acute respiratory illness

Prof. Arik Eisenkraft, Chief Medical Officer, Biobeat Technologies Ltd.

Abstract—**Using the PPG-based Biobeat remote patient monitoring platform, subjects were continuously monitored during the flu season, aiming to detect and define physiological changes due to acute respiratory illness.**

Prof. Arik Eisenkraft is the Chief Medical Officer at Biobeat Technologies Ltd. Prior to joining Biobeat, Prof. Eisenkraft served in the Israeli Ministry of Defense as the Head of the CBRN Protection Division, leading national R&D efforts on the development of medical countermeasures and preparedness for mass casualty events, focusing on first responders and hospitals. He has 25 years of experience in conducting pre-clinical and clinical studies, and working with regulatory agencies around the world for the approval of multiple therapeutics and devices.

121 healthy volunteers were recruited for a study aimed to detect and define physiological changes when developing acute respiratory illness. Subject were monitored using the Biobeat wrist-monitors for a period of up to 3 months during the flu season, while living their regular everyday life. The following physiological parameters were automatically collected every 5 minutes and transmitted to the Biobeat web application, for a retrospective analysis: respiratory rate, SPO2 , heart rate, heart rate variability, cuffless non-invasive blood pressure (including systolic blood pressure, diastolic blood pressure, mean arterial pressure, and pulse pressure values), cardiac output, cardiac index, stroke volume, systemic vascular resistance, temperature, and Early Warning Score values. These parameters were matched with subjects' complaints of acute respiratory illness (cough, sore throat, running nose, and fever/chills), and with serological tests of multiple respiratory pathogens. We will elaborate on our PPG-based technology, the remote patient monitoring platform, discuss the results of our analysis, and share challenges of analyzing 2 million data points of physiological parameters crossed with clinical data from this study.

Hemodynamic Monitoring using Pulse Decomposition Analysis

Martin C. Baruch, PhD, Caretaker Medical

Dr. Baruch has been involved in physiological research for over 25 years and has managed over $7M in research contracts awarded by DOD, NIH and DARPA, published over 50 publications, and received over a dozen patents related to non-invasive physiological monitoring, brain injury assessment, neuro-feedback, gait assessment and other application areas. He has spent the last 10 years developing the technology that is the basis of the Caretaker physiological monitor for the continuous non-invasive monitoring of blood pressure and other hemodynamics parameters, Pulse Decomposition Analysis.

Currently in its fourth generation, the CareTaker™ physiological monitor has demonstrated compliance with the ANSI/AAMI/ISO 81060-2:2013 standard and received FDA (K151499, K163255, K181196) and CE clearances for the noninvasive and continuous monitoring of blood pressure, heart rate and respiration rate. Current development efforts seek to expand the platform's capability to include hemodynamic parameters such as stroke volume, cardiac output and ejection time, as well as to provide predictive tools for impending hypotension.

Wearable MINDS: Cuffless Blood Pressure Estimation Using Machine Learning Approaches

Yuan-Ting Zhang, City University of Hong Kong

This talk will present firstly some aspects of the Miniaturization, Intelligence, Network, Digitization, and Standardization (MINDS) design of wearable and flexible devices with their applications for the unobtrusive, cuffless measurements of arterial blood pressure (BP). Secondly, machine learning approaches will be discussed and compared with physiological modeling methods for cuffless BP estimation. Finally, using the atherosclerotic plaque assessment as an example, the talk will attempt to illustrate the integration of the wearable BP sensing with other technologies across multiple scales in the biological hierarchy from molecular, cell, organ to system for the early prediction of acute cardiovascular diseases. A multi-Centre clinical trial on Myocardial Infarction & Stroke Screening Of Nations (MISSION) will also be introduced at the end of talk.

Dr. Yuan-Ting Zhang is currently the Director of Hong Kong Center for Cerebro-Cardiovascular Health Engineering (COCHE), and the Chair Professor of Biomedical Engineering at City University of Hong Kong. He was the Sensing System Architect in Health Technology at Apple Inc., California, USA, and the founding Director of the Key Lab for Health Informatics of Chinese Academy of Sciences (CAS) and the Founding Director of the CAS-SIAT Institute of Biomedical and Health Engineering. Dr. Zhang dedicated his service to the Chinese University of Hong Kong from 1994 to 2015 in the Department of Electronic Engineering, where he served as the first Head of the Division of Biomedical Engineering.

Dr. Zhang was the Editor-in-Chief for IEEE Transactions on Information Technology in Biomedicine and the first Editor-in-Chief of IEEE Journal of Biomedical and Health Informatics. He served as Vice Preside of IEEE EMBS. Dr. Zhang is currently the Editor-in-Chief for IEEE Reviews in Biomedical Engineering, and Chair of the Working Group for the development of IEEE 1708 Standard on Wearable Cuffless Blood Pressure Measuring Devices.

Dr. Zhang was selected as a Most Cited Chinese Researcher by Elsevier for the past 6 consecutive years since 2014. He was elected to be IAMBE Fellow, IEEE Fellow and AIMBE Fellow for his contributions to the development of wearable and m-Health technologies in 2006 and 2007 respectively.