Point-of-Care Technologies for Health Care

THE increasingly global focus on health care issues continues to underline the importance of point-of-care technologies and their ability to provide cost-effective solutions that address many unmet health care needs. Further, the current crisis in health care costs has critically underscored the need for research and development into highly effective, but low cost means of delivering health care. With a focus on providing clinically actionable information at or near the patient, point-of-care devices provide clinicians with information that is critical to the management of patient care while they are still with the patient. Rapid information results in various advantages for POC testing in different kinds of health care settings. In primary care settings in developed countries, the shortened timeline between testing and availability of results reduces the need for extra office visits or follow-up phone calls to convey testing results and adjust clinical intervention. This strategy can reduce cost and increase access of otherwise underserved populations to medical care. For diseases that are infectious, such as sexually transmitted infections or respiratory diseases, POC testing can facilitate treatment modalities quickly, thus preventing further spread of the infection for better and timely clinical management. In acute care settings, timely access to diagnostic information is most critical for providing an effective medical response. In disaster settings, POC diagnostics can speed triage and enable rapid establishment and delivery of medical services.

While in the developed world, POC testing is primarily designed as an adjunct to central lab testing, not as replacement, POC testing can enable local health care providers to deliver cost-effective care in developing countries or at rural locations with lack of access to central laboratory infrastructure. Further, a growing number of point-of-care technologies enable clinicians to remotely assess/monitor patients who are home bound or unable to meet the clinician in their clinical setting. The underlying theme is to multiply the effectiveness of physicians by providing better/faster information that enables timely delivery and management of health care.

I. Scope of the Special Issue

For this Special Issue of IEEE Transactions on Biomedical Engineering (TBME) LETTERS, we invited manuscripts highlighting highly innovative, novel, and exciting research activities in wearable sensors, remote health monitoring, e-Health, telemedicine, and health care information management for acute emergency care, clinical disease, and outbreak/disaster situations. As a result of the call, we received a record number of 73 submissions. These manuscripts were submitted by leading experts in their respective areas. From the many meritorious submissions, 24 manuscripts with high potential impact were selected to present a wide cross-section of the growing diversity of clinical needs where point-of-care technologies show a significant promise to improve the delivery of health care.

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II. Special Issue Papers

The papers in this Special Issue highlight some of the most exciting current research in the development of novel point-of-care technologies. Covering clinical applications that range from point-of-care testing for Chlamydia to remote monitoring of cardiac condition, the papers in this issue provide a snap shot of the broad range of unmet clinical needs that are being addressed at the point of need.

The papers have been loosely divided into two groups. Twelve papers highlighting advances in Sensors and Devices focus on advancements that improve aspects of the core technologies that underpin various point-of-care technologies. The second group of twelve papers focuses on Detection, Analysis and Monitoring in various clinical needs.

The following sections provide a brief highlight for each of the articles that make up this Special Issue on Emerging Technologies in Point-of-Care Health Care.

A. Sensors and Device

Linghua *et al.* describe a novel instrument for multispectral imaging. Their handheld device provides real-time operation at a cost that is suitable for home-based health care applications.

Jung *et al.* present a handheld point-of-care device for optical coherence tomography. The system provides a user-friendly interface that is capable of guiding the physician in real-time toward the identification of suspicious tissue regions that needed closer examination.

Motivated by the disparity in cardiac care between rural and urban health care delivery, Mandal *et al.* developed a point-of-care device specifically intended for delivery of heart care services to rural populations. Preliminary results confirm the applicability of the device as a pre-screening tool that provides indicative diagnosis of cardiac conditions.

D'Arcy *et al.* describe a noninvasive device that measured brainwaves (electroencephalography or EEG). In contrast to traditional EEG systems, their device is portable, user-friendly and includes a novel software algorithm that automates stimulation, data acquisition/analysis and reporting functions to enable evaluation of conscious awareness in brain damaged patients.

Pearce *et al.* have developed a Point-of-Care device for detection of *Chlamydia trachomatis*. Utilizing a novel electrochemical detection method, they are able to run their assay in less than 25 minutes while maintaining sensitivity and specificity of 98%.

Bercich *et al.* present a hand held plasma isolation device that utilizes a unique array of parallel fiber glass filters to produce

a plasma sample from a small quantity of whole blood. Their device is a critical enabling technology in the development of Point-of-Care technologies that analyze plasma.

Majerus *et al.* describe the design, fabrication and testing of a wireless bladder pressure sensor. The device is intended for chronic, ambulatory application, such as urodynmics or closed-loop neuromodulation.

Gao details the design of an integrated CMOS untra-wideband wireless telemetry transceiver for wearable and implantable medical sensor applications. A prototype implementation of the transceiver is then demonstrated in a capsule endoscopy device that is capable of *in vivo* transmission of 640 $\times$ 480 resolution images at a frame rate of 2.5 frames/second.

Beyette *et al.* demonstrate the performance of a device that quantifies bilirubin in hemorrhagic CSF. By identifying bilirubin even in the presence of hemoglobin, the device is able to differentiate bleeding associated with a subarachnoid hemorrhage from bleeding that is associated with a traumatic spinal tap.

Using diffuse reflectance spectroscopy, Alla *et al.* present results for a device that can noninvasively quantify bilirubin, hemoglobin, and hematocrit. The device is tested using an animal model for jaundice and human subjects.

Geddes *et al.* show their microwave accelerated metal enhanced fluorescence method for lysing *Chlamydia trachomatis* and then detecting the DNA released from the lysed cells. Their new "release and detect" method allows for detection of bacteria in less than 1 min.

Jabłónski describes work done to develop a mobile interrupter module for monitoring respiratory mechanics. Especially well suited for newborns, preschool children, and patients suffering from respiratory muscle impairment, this enhanced interrupter technology is well suited for home-based monitoring in telemedicine applications.

B. Detection, Analysis, and Monitoring

Chon and Lee present a particle filtering algorithm that combines both time variant and time invariant autoregressive models for accurate extraction of respiratory rates. The method is able to accurately measure respiration rates in the range from 6 to 90 bpm even when the respiration rate suddenly changed (both increase and decrease) by 24 bpm.

Giancardo *et al.* propose a technique that uses uncalibrated multiple-view fundus images to analyze swelling of the macula. The reconstructed images resulting from there method may enhance the performance of fundus cameras that are used in the diagnosis of various retinal diseases.

Pecchia *et al.* describe a platform to enhance effectiveness and efficiency of home monitoring through a method of data mining. The system is focused on early detection of indicators that a patient's condition is worsening.

Bearinger *et al.* present the development of a small footprint, disposable, fast and inexpensive device for pathogen detection. Utilizing a variation of Loop-Mediated Isothermal Amplification (LAMP) assay, their system provides a screening tool with PCR level sensitivity and specificity.

Youn *et al.* discuss a sensor integrated system model for metabolic syndrome prediction. Using their system, they show the possibility to evaluate the functionality of human mitochondria and analyze energy metabolism.

Barfield *et al.* report the development of a new lateral flow rapid test for Chagas disease. With sensitivity/specificity results that are comparable to reference tests, their new method shows promise as an improved and reliable tool for screening and diagnosis of Chagas disease.

Ruggeri *et al.* describe a novel system for vascular tree identification and the quantitative estimation of AVR clinical index in retinal fundus images. The system is organized as a client-server structure that enables utilization by clinicians and researchers from all over the world.

Poh *et al.* present a simple, low-cost method for measuring several physiologic parameters using a webcam. Their system, which quantifies blood volume pulse, heart rate, respiratory rate, and heart rate variability, has significant potential for advancing personal health care and telemedicine. This letter was intended to be part of the Special Issue, but was previously published in the IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, January 2011 issue.

Lahuec *et al.* propose a new metric for *in vivo* estimation of the lifespan for total knee replacement prosthesis. In contrast to current methods, which cannot be applied until years after knee replacement surgery, their method enables lifespan estimation of the prosthesis a couple of months after surgery.

Rico *et al.* report on a microfluidic chip-based hydrodynamic focusing approach that minimizes sample volumes required in the analysis of cell-surface interactions. Their system quantifies cellular surface coverage and aggregate size distributions as a function of time during blood-flow analysis and facilitates diagnosis of disease state and/or efficacy of drug treatment.

Bonato *et al.* describe a platform to enable home monitoring of patients with Parkinson's disease using wearable sensors. Performance analysis of the system suggests that their web-based technology is suitable for facilitating the titration of medications for patients in the late stages of the disease.

Hesse *et al.* evaluate the feasibility and performance of a new Point-of-Care test for detection of *Chlamydia trachomatis*. Rapid communication with the device manufacture of results from a small study that analyzed self-test utilization of the device compared to the gold standard physician collected cervical tests enabled rapid turnaround in the design modification.

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Dr. Beyette currently serves as an Associate Editor for the IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING. He is a member of the IEEE Engineering in Biology and Medicine Society, The IEEE Lasers and Electro-Optics Society, The IEEE Circuits and Systems Society, The IEEE Computer Society, Sigma Xi, and Eta Kappa Nu.

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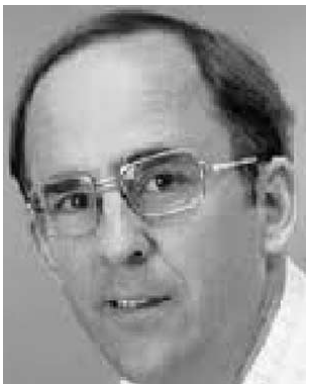
She has extensive laboratory expertise with more than 40 years of experience in microbiology, has authored 18 book chapters, more than 250 research articles, and more than 450 research abstracts and oral presentations. She has conducted clinical trials for new diagnostics for STIs and respiratory pathogens. She has developed DNA amplification tests for multiple organisms. An Internet project for home STI screening using self-administered genital swabs sipped dry for testing has been an effective outreach program. Her laboratory is the core diagnostic laboratory and reference laboratory for many international studies of STIs, respiratory diseases, and trachoma. She is Coinvestigator for the Diagnostic Core for the Mid-Atlantic Center of Excellence for Biothreat and Emerging Infectious Diseases. She is a recipient of an NIH Center grant to develop point-of-care tests for STIs. Her laboratory is Clinical Laboratory Improvement Amendments (CLIA)-licensed. She is a Professor in the Division of Infectious Diseases, Medicine, Johns Hopkins University, a member of the Center for Global Health, with joint appointments in Emergency Medicine, Epidemiology and Population, Family and Reproductive Health, School of Public Health. She is the Director of the International STD, Respiratory Diseases, and Biothreat Research Laboratory, as well as the Director of the North American Branch for the International Union Against Sexually Transmitted Infections (IUSTI). She serves on the National Chlamydia Laboratory Committee and on the Executive Boards of the American Sexually Transmitted Diseases Association (ASTDA) and International Society for Sexually Transmitted Diseases Research (ISSTDR).

Prof. Gaydos serves on the Editorial Board for the *Sexually Transmitted Diseases Journal*.



Gerald J. Kost studied in Venezuela. He received the B.S. degree in engineering from Stanford University, Standford, CA, in 1967, and the Master's degree in engineering-economic systems (EEP) from Stanford prior to entering the Medical Scientist MD-Ph.D. training program at the University of California (UC). He received the Ph.D. degree in bioengineering [NIH Bioengineering Traineeship] from the University of California, San Diego, and the MD degree from the University of California, San Francisco.

His clinical residency included training in internal medicine and neurology at the University of California, Los Angeles (UCLA), and Laboratory Medicine at the University of Washington, Seattle, where he was the Chief Resident and a Postdoctoral Researcher with Dr. Jim Bassingwaighte, Bioengineering Department, prior to becoming boarded in Clinical Pathology by the American Board of Pathology. At the University of California Davis (UCD) for more than 27 years, he has been the Director of Point-of-Care Testing and Clinical Chemistry for the UCD Health System. He is a tenured Professor in the Department of Pathology and Laboratory Medicine, the Quality Program Chair, and faculty in Biomedical Engineering. In 1995, he founded the Point-of-Care Testing Center for Teaching and Research (POCT•CTR) in the School of Medicine. He was elected to the National Academy of Clinical Biochemistry (NACB) in 2001 and has served on its Board of Directors. After promoting point-of-care testing (POCT) widely in the United States and Europe in the 1980's and 1990's, he lectured in Asia for several years, culminating in 2003 and 2004 with the receipt of a Fulbright Scholar Award in Demography, Economics, and Medicine at Chulalongkorn University, Bangkok, and subsequently, received UC Pacific Rim and UC Outreach and International Program grants to develop national resources in POCT and optimal health care delivery systems for Thailand and other Southeast Asian countries. He has contributed to the first global training course in POCT for low-resource nations. His Fulbright Scholar collaborations in Southeast Asia produced two foreign language monographs, POCT for Thailand (in the Thai language), and Gambaran Tentang Point-of-Care Testing-Sasaran, Pedoman, Prinsip Dan Jaminan Mutu (Overview of POCT: Goals, Guidelines, Principles, and the Assurance of Quality), in Bahasa Indonesia, both published in 2006. As Affiliate Faculty at Chulalongkorn University since 2004, his research team there has performed health care field surveys of the tsunami provinces, hill tribe villages, the Golden Triangle, and underserved Isaarn in Thailand; of pediatric hospitals in Cambodia; and of public hospitals in Vietnam. His recent field surveys focused on optimizing POC cardiac biomarker testing in the vicinity of the Mekong River along the Lao-Thai border in Northern Isaarn, and now, on needs assessment for disaster preparedness in Phang Nga Province where the 2004 tsunami hit.

Dr. Kost is the Editor of *Principles and Practice of Point-of-Care Testing,* published by Lippincott, Williams, and Wilkins (LWW) in 2002, and a Founding Member of the Editorial Board of the companion journal, *Point of Care: The Journal of Near-Patient Testing and Technology,* now in its ninth year of successful production by LWW. Prof. Kost provides peer review for several journals, including *Critical Care Medicine* and is currently developing the theory and practice of POCT in small-world networks and his current strategic missions include: a) the accuracy of POCT, revealed by "locally-smoothed median absolute differences curves," a math-statistical method co-invented by Dr. Kost for POCT evaluations worldwide; b) critical-emergency-disaster care under an NIBIB POC Technologies Center U54 Award ($8.6 million); c) rapid pathogen detection in sepsis using multiplex PCR, LATE-PCR, and other methods to perform rapid nucleic acid recognition in whole blood, with a clinical study published in Critical Care Medicine (2008;36:1487–92) with Richard Louie, Ph.D., POC Technologies Center Fellow as first author; d) harmonization of critical limits for urgent clinician notification; and e) "The Critical Human," a monograph in preparation.

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