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Current and Future Challenges in Point-of-Care Technologies: A Paradigm-Shift in Affordable Global Healthcare With Personalized and Preventive Medicine

ATAM P. DHAWAN[1], WILLIAM J. HEETDERKS[2], MISHA PAVEL[3], SOUMYADIPTA ACHARYA[4], METIN AKAY[5], ANURAG MAIRAL[6,7], BRUCE WHEELER[8], CLIFFORD C. DACSO[9], T. SUNDER[10], NIGEL LOVELL[11], MARTIN GERBER[12], MILIND SHAH[13], S. G. SENTHILVEL[13], MAY D. WANG[14], AND BALRAM BHARGAVA[15]

[1]New Jersey Institute of Technology, Newark, NJ 07103 USA
[2]National Institute of Biomedical Imaging and Bioengineering, National Institutes of Health, Bethesda, MD 20817, USA
[3]Northeastern University, Boston, MA 02115, USA
[4]Johns Hopkins University, Baltimore, MD 21218, USA
[5]University of Houston, Houston, TX 77004, USA
[6]Stanford University, Stanford, CA 94305, USA
[7]Orbees Infolabs India Pvt. Ltd., Hyderabad 500081, India
[8]University of Florida, Gainesville, FL 32611, USA
[9]Baylor College of Medicine, Houston, TX 77030, USA
[10]Apollo Hospital, Hyderabad 500072, India
[11]University of New South Wales, Sydney, NSW 2052, Australia
[12]Medtronic, Mumbai 400093, India
[13]Medtronic India, Mumbai 400093, India
[14]Georgia Institute of Technology, Atlanta, GA 30332, USA
[15]All India Institute of Medical Sciences, Delhi 110029, India

CORRESPONDING AUTHOR: A. P. DHAWAN (dhawan@njit.edu)

ABSTRACT This paper summarizes the panel discussion at the IEEE Engineering in Medicine and Biology Point-of-Care Healthcare Technology Conference (POCHT 2013) held in Bangalore India from Jan 16–18, 2013. Modern medicine has witnessed interdisciplinary technology innovations in healthcare with a continuous growth in life expectancy across the globe. However, there is also a growing global concern on the affordability of rapidly rising healthcare costs. To provide quality healthcare at reasonable costs, there has to be a convergence of preventive, personalized, and precision medicine with the help of technology innovations across the entire spectrum of point-of-care (POC) to critical care at hospitals. The first IEEE EMBS Special Topic POCHT conference held in Bangalore, India provided an international forum with clinicians, healthcare providers, industry experts, innovators, researchers, and students to define clinical needs and technology solutions toward commercialization and translation to clinical applications across different environments and infrastructures. This paper presents a summary of discussions that took place during the keynote presentations, panel discussions, and breakout sessions on needs, challenges, and technology innovations in POC technologies toward improving global healthcare. Also presented is an overview of challenges and trends in developing and developed economies with respect to priority clinical needs, technology innovations in medical devices, translational engineering, information and communication technologies, infrastructure support, and patient and clinician acceptance of POC healthcare technologies.

INDEX TERMS Global healthcare, healthcare challenges, healthcare innovations, point-of-care technologies.

I. INTRODUCTION

The twentieth century witnessed a technology revolution in medicine and health through instrumentation, computer and information and communication technologies. This revolution has continued in the twenty-first century, with smart cross- and trans-disciplinary technologies and innovations directly impacting medical practice and healthcare delivery, which, in turn, have redefined the relationship between patients and healthcare providers. Technology innovations and globalization have brought the world together as one global community where developing and developed economies have become more dependent and well connected than in previous times. As the overall life expectancy across the globe has increased, the global community is now facing new challenges of improving quality of life and healthcare at an affordable cost. While the exponentially rising cost of healthcare, defined as total healthcare expenditure as a percentage of a nation's Gross Domestic Product (GDP), is a critical priority challenge in developed nations, providing minimal quality healthcare to all, specifically large and sparsely distributed communities living in rural areas, is the most vital challenge to developing nations.

A necessary component of affordable global healthcare is Point-of-Care (POC) healthcare technologies, and developing POC technologies will require continuous evolution of innovation in smart and portable bio-sensor, computing, information and communication technologies. A strategic study at the National Institutes of Health has noted (http:// report.nih.gov/NIHfactsheets/ViewFactSheet.aspx?csid=112) [1]: "With the development of miniaturized devices and wireless communication, the way in which doctors care for patients will change dramatically and the role patients take in their own healthcare will increase. Healthcare will become more personalized through tailoring of interventions to individual patients."

Though the challenges of providing high-quality healthcare in developing countries are different than those in developed countries, they share a common goal: to provide access to health monitoring and assessment technologies to people with limited or no healthcare facilities, or with geographically distant or difficult to physically access facilities. While developed countries may find POC technologies an effective means for reducing healthcare costs and improving efficiency, POC technologies are critical in the provision of diagnostic and monitoring healthcare needs in countries with large populations or rural areas. The developing countries in the eastern part of the globe, which account for more than two-thirds of the population of the world, face the basic challenge of providing minimal healthcare to all people living in adverse geographical or economic constraints, and also monitoring critical infectious diseases such as HIV/AIDS, TB, malaria, etc. The challenge becomes even more critical in potential epidemic situations.

Given the rapidly aging populations in both developed and developing nations, it is now more critical than ever to develop collaborative synergies to explore POC health monitoring, assessment and therapeutic technologies to significantly impact global healthcare for the "well-being" of a healthy society.

However, the implementation of POC healthcare technologies towards a tangible clinical impact poses formidable challenges in educating users. Not only must users and local support staff learn about technology usage, measurement techniques, data communication and compliance, patients and family members must undergo a behavioral change to understand and accept new roles and responsibilities in keeping themselves, family members, and others healthy. The concept of self-care must be a major flagship in this education process. POC healthcare technologies (including sensor- and biomarkers-based POC diagnostic technologies; therapeutic and rehabilitation devices; and information and communication technology (ICT) with mHealth, eHealth, and health monitoring with POC decision support systems) will directly impact patients, support staff, community center workers, and nurses, among others. All of these users will have to become comfortable, to varying degrees, with technology usage and local decision-making. In addition, physicians and business managers will also need to become conversant in the broad spectrum of data integration, mining and interpretation [2]–[12].

II. PROCEDURES AND METHODS

The EMBS conference on Point-of-Care Healthcare Technologies invited scientific researchers and innovators, industry leaders, clinical experts, and policy makers from the USA, Hong Kong, China, Japan, Europe and India as plenary, keynote and panel speakers. This white paper was developed out of those presentations, as well as panel discussions, data presented, and comments made during breakout sessions, using the following multi-step methodology. The conference's first day featured plenary and keynote talks by leaders and representatives from government agencies including Roderic Pettigrew, MD, PhD, Institute Director, National Institute of Biomedical Imaging and Bioengineering, National Institutes of Health (USA); senior leaders from global industries including IBM Life Sciences and Medtronic (USA and India); experts from clinical healthcare facilities including the Cardiology Department, Kyushu University Hospital (Japan) and Apollo Hospital (India); and biomedical researchers and innovators. These talks were followed by a panel discussion led by representatives from stakeholder groups from all over the globe. Both the plenary and keynote talks and the expert panel discussed current and future challenges in global healthcare. After these interactive panel discussions with over 176 researchers and stakeholders, the following steps were implemented to systematically collect insights from the various discussions generated by the conference program, including two additional panel discussions and three breakout sessions. Conference attendees represented a rich spectrum of clinical practitioners, industry experts and entrepreneurs, academic researchers, and policy makers (Table 1).

This paper represents the summary of discussions, data and comments made during the conference events.

1. A questionnaire was circulated after the first panel discussion to all attendees requesting them to identify

TABLE 1. Percentage of conference attendees representing major stakeholder groups.

Stakeholder Representation Type	Percentage
Clinical Practitioners	27%
Industry Representatives and Entrepreneurs	23%
Academic Researchers and Students	35%
Policy Makers, Federal and Funding Agency Representatives	15%

specific issues for discussion during the breakout sessions at the conference. These questions were categorized for three breakout sessions.

2. Three breakout sessions were held with detailed discussions on the following topics:
   a. Breakout Session 1: Priority Point-of-Care Healthcare Technology Areas and Global Collaborations
   b. Breakout Session 2: Patient Participation and Role: Expectation and Challenges
   c. Breakout Session 3: POCHT Implementation Strategies and Compliance: Challenges and Future Trends
3. Breakout discussions were summarized by the session leaders in consultation with designated note-takers who transcribed the sessions and presented to the entire group of conference attendees in the Panel Discussion 2: Reports from Breakout Sessions: Future Trends and Follow-up. The discussions were summarized further in the raw data.
4. The speakers from Panel Discussion 2 session formed a committee of authors and prepared a report that was transformed into the content of this paper. The paper went through three iterations to help ensure that it was an accurate record of the conference and that all points of view were included.

III. POINT-OF-CARE HEALTHCARE TECHNOLOGIES (POCHT): A PARADIGM SHIFT IN AFFORDABLE QUALITY GLOBAL HEALTHCARE

POCHT is a ***paradigm-shift*** in global healthcare. However, such technologies do not exist in isolation and must be integrated into and adopted by new or existing health service delivery models, be supported by sound business cases, and show demonstrated levels of improvement to patient health outcomes in terms of such metrics as quality-adjusted life years (QALYs) as a means of quantifying disease burden. Development, deployment and compliance issues related to affordable global healthcare have to be critically examined towards the creation of sound business models for their effective implementation such that they can be sustained with an economic impact.

What is striking about the concept of POCHT is its near universality of potential application. There is benefit to the management and treatment of most diseases – hence priorities mirror the prevalence of disease in each country. There is applicability to both wealthy and developing countries with cross-fertilization of design back and forth among all nations, with both simple and advanced technologies being of use to all [2]–[8]. Both rural and urban settings would benefit greatly from POC technologies. Perhaps most striking is the potential for widespread and localized screening for disease and health conditions. A simple vision of the technology might include:

(a) Increasingly low-cost diagnostic tests, including those modified from existing methods through the use of novel, low-cost micro-molecular-biochemistry technology;
(b) Inexpensive device-based imaging and first-level analysis (e.g., smartphones capable of pulse oximetry, blood pressure, EKG recording and analysis or image recognition of skin disease);
(c) Smart device / smartphone / computer communication of data to regional or central health centers;
(d) Communication back to the personal care site for treatment or feedback;
(e) Ability to engage sophisticated healthcare treatment and diagnostic information, either by accessing human experts or clinical decision support systems.

IV. POCHT CHALLENGES: TECHNOLOGY INNOVATION AND PRIORITY NEEDS

Within this broad framework there are many health areas that would potentially be impacted. Some of the global needs and challenges include:

(a) Chronic disease management and monitoring: Here, the major impact would come from the major chronic diseases, especially cardiovascular, pulmonary, neurological, geriatric, and early detection of the onset of and complications from diabetes.
(b) Therapeutic intervention: Rehabilitation medicine and therapy would be greatly assisted by the ability to locally monitor patient progress, condition, and exercise or other health management programs. In rural areas where transport to a rehabilitation facility is prohibitive, therapy could be administered by paramedical personnel. The same logic applies in developed countries where system cost is an over-riding issue.
(c) Prenatal monitoring: Special mention is made of the impact potential for POCHT in perinatal care; this would include routine physiological monitoring of hemoglobin, urine protein and blood pressure to detect problems at an early stage. POCHT could lead to major reductions in maternal mortality rate.
(d) Preventative medicine through behavioral change: There is a great potential for increased feedback to the individual of key health indicators. One can

imagine poor, rural areas where the introduction of paramedical personnel bringing more information coupled with simple monitoring measures of health (blood pressure, heart rate, blood physiology) would have significant impact on people's behavior and lives. At the other extreme, POCHT technologies are already in the hands of wealthy, educated people in the form of smartphone applications for monitoring exercise – there will be a continuing and rapid growth of monitoring capability for this population that already wants to change its behavior. Aggressive development – either private, profit-making or government – could bring these behavior-changing technologies to ever-wider populations [8], [12].

(e) Medical information: The ability to collect medical and healthcare information locally and aggregate centrally has strong implications for epidemiology and for planning the availability of medical supplies and resources (supply-chain management). A form of this already exists in the RFID of equipment for inventory within hospitals.

V. POC HEALTHCARE TECHNOLOGIES

There is strong consensus that several technologies are already having a huge impact on society at large, with impacts on healthcare to follow.

(a) Low cost sensor technologies: There are several prototypical examples.
   (i) Perhaps ubiquitous is the smartphone capable of a number of diagnostic measurements, including EKG / heart rate, breathing rate, blood pressure, blood oxygen saturation, image recognition for skin disease
   (ii) Low cost blood chemistry sensors, ranging from the more straightforward (blood glucose) to the highly sophisticated (detectors for dengue fever, on chip PCR)
   (iii) Reduced-cost versions of historically expensive technologies – an example is ultrasound machines whose cost now permits wide distribution

(b) Communications and computational technology: Smartphones put more computer power in the hands of a common person than a computer engineer dreamed of 50 years ago. Wireless and satellite communications have revolutionized the communications world. The development of these technologies is practically "for free" as other markets are driving the cost and availability faster than the medical applications would. The goal is to harness these technologies, not develop them.

(c) Modeling and simulation from physiology to behavior: As more point-of-care data become available, there will be increasing need for models of increasing complexity to assist in analysis. An example is modeling the daily activity patterns of the elderly to predict medical problems. More generally, the ability to use data to anticipate individual problems is a key component of personalized medicine.

(d) Automated decision-making and support: We have now seen more than a decade of on-line medical diagnostic information services, which will continue to grow in sophistication. There is tremendous potential for exploiting the spectacular medical research knowledge base, advancing the practice of evidence-based medicine on a world wide scale. The initial cost is very high, but the delivery cost is very low given the communications technology. This technology can scale for the use of the expert, the general practitioner, the nurse, and the paramedical professional.

(e) Accessible data structures: The delivery of the benefits of POCTH will be greatly assisted by enhanced accessibility of data to the broader medical community. There are a variety of competing issues to achieving this goal, including security and privacy of data, interoperability of data structures, and ownership of data.

VI. STRATEGIC ENABLERS

Some POC technologies are already either in place or developing rapidly. Others will need support from governments, either directly through education as well as research and development funds, or indirectly by incentivizing the private sector.

(a) Networking of practitioners: The encouragement of a growing leadership community is essential to the promulgation of POCHT practice. This should come in a variety of forms: publication in scholarly journals; publication in the medical trade press; workshops sponsored by national medical organizations; conferences; social media; and MOOCS (massive online open courseware; http://www.mooc-list.com).

(b) Medical and paramedical education: POCHT makes possible task shifting at all levels, putting expert knowledge in the hands of generalists and general medical knowledge in the hands of paramedical personnel. There will be tremendous need for education at all levels.

(c) Design for all: This maxim implies that designing for the cost constraints of the developing world impacts medical products in the developed world, and vice versa. This is especially relevant in the fast-developing POCHT area and a world in which innovation travels the globe nearly instantly.

(d) Entrepreneurship and financial support: POCHT is an especially open area for entrepreneurial development, as is evidenced by rapidly developing smartphone applications, tremendous spinoffs from biomolecular science, and strong support for global health from a variety of Western institutions and foundations. Still, much more is needed from all sectors of society.

(e) Standards and harmonization: This refers to a host of properties that enable data access, storage, transmission and use; standards for measurement and reporting of

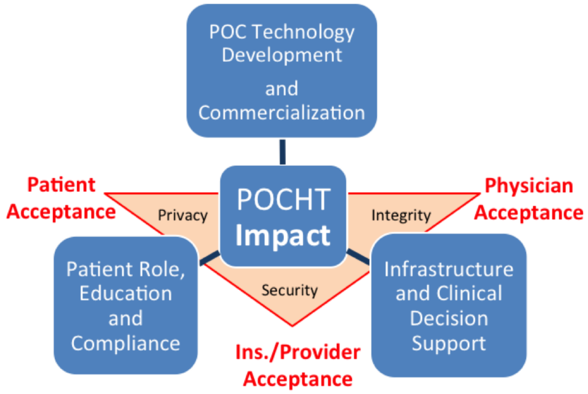

FIGURE 1. POCHT impact and paradigm with major infrastructure support and issues.

patient information; and access to expert information and to one's own records.

VII. POCHT CLINICAL IMPACT

Clinical impact can be realized in *preventive*, *therapeutic* and *surveillance* areas. In the preventive area, POCHT impact may be appreciable only after a few years. For example, a decline in the incidence of myocardial infarction after good control of diabetes, cholesterol and blood pressure will take years to realize. The impact in the therapeutic area can be more readily assessed after POCT implementation. For example, the Apollo Hospital in India uses cardio biomarkers in early diagnosis of myocardial infarction and early transfer to the ICU. It can be readily shown that POCT has a favorable impact on the hospital's cardiac mortality. Similarly, use of antenatal POCHT kits in diagnosing early eclampsia or anemia can be easily shown to reduce maternal mortality rate. Surveillance POCHT is similar to preventive POCHT where the actual clinical impact may be appreciable only after a few years. The major challenge would be in data acquisition, communication, and patient compliance, specifically in developing economies. The major challenge is in task shifting: shift of preliminary or pre-diagnosis responsibility at the point-of-care. Other challenges include developing pathways to provide [8]–[12]:

(a) Evidence-based personalized care;
(b) Patient centered precision medicine;
(c) Preventive healthcare;
(d) Short-term feedback with long-term benefits;
(e) Cost-effectiveness, specifically in mass screening (e.g., diabetes and hypertension monitoring);
(f) Easy and intuitive devices and decision support systems.

The medical devices and informational communication technologies at the point-of-care also face other societal challenges for acceptance and implementation. These issues include diverse demographic and cultural backgrounds, and differences in needs due to geographical, social, and economic factors. While it makes sense to be patient-centric, empowering ptaients with point-of-care decision support systems raises concerns about legal liability and potential reduction in sensitivity. It is not yet clear how POCT can be used to integrate family members and physicians into one effective healthcare team.

VIII. CONCLUDING REMARKS AND RECOMMENDATIONS

Though the challenges of providing high-quality healthcare in developing countries are different than those in developed countries, there is a common goal to provide access to health monitoring and assessment technologies to people with limited or no healthcare facilities. Large developing nations with fast economic growth such as India and China are committed to providing healthcare to all, but they still face major challenges in assessing rural and underserved patients' healthcare needs and in providing them with timely quality healthcare at the point-of-care. This is also a critical challenge in metropolitan areas where the hospital and primary healthcare facilities are overburdened. Major challenging priority areas where healthcare is most needed for people in India, as identified by WHO, are: hypertension and cardiac deaths, diabetes, cancers, women's health (specifically child birth) and infant mortality, and neurological disorders [13]. Use of advanced point-of-care technologies, including wearable sensors, biomarkers, and mobile-communications-based education, along with health data collection and analysis, is a viable and affordable way to reach larger populations for better healthcare and compliance. The impact on quality of life from better outreach, increased affordability of quality primary care, and increased patient compliance would be tremendously positive.

It is important to consider perspectives from all stakeholders, including patients, industry, healthcare providers, payers, policy makers and society as a whole (Fig. 1). In order for the POCHT paradigm shift to lead to transformational change, POCHT technologies must address critical issues in patient privacy, data integrity and security on one hand, but also infrastructure support and policies on the other hand. These infrastructure and policy supports will need to enable data and decision-support systems for all stakeholder groups in healthcare: patients at point-of-care, clinicians at healthcare facilities, and payers at the insurance or provider levels.

All of these stakeholder groups must be willing to accept the challenges and potential errors that might impact the sensitivity and specificity of healthcare processes. In addition, clinicians and community members, such as community health workers, will need to help patients accept responsibility and accountability for their own health as they are empowered to address their health issues, illnesses, and preventive care in order to remain healthy. Thus patients, families, and communities will need to learn to think in new ways about the use of technology and how to responsibly monitor their health when applying POC healthcare technologies and decision-support systems.

The transformational change in defining new roles and responsibilities for patients has to come through patient-centered design, local solutions, and sensitive patient-education on POC benefits, such as significant cost-savings, reduced hospitalizations, and better personalized and preventive healthcare. The outreach to patients for POC education and monitoring may incorporate specific innovative methods such as smartphone ICT and incentives from healthcare providers, payers and government. For example, many developing and developed countries are encouraging continuous monitoring of blood glucose and hypertension through innovative programs including educational camps and free or heavily discounted prices of monitoring systems. Of course, the economic aspects of such initiatives in developing countries can cause critical challenges in implementation involving social and political issues. Recent studies on the economic impact of using POC technologies in economically challenged nations presented in references [12]–[15] summarize that these socio-economic and infrastructure challenges may at first overshadow the benefits of POC technologies. Yet, in the long run, POC technologies with smart ICT hold tremendous hope for sustainably managing resources and improving healthcare delivery in rural and developing nations.

While the developed world provides quality healthcare, growing expense is a universal concern, perhaps most acutely in the USA with the most expensive healthcare system in the world. Mutual collaborative efforts and networking in both developed and developing markets will allow opportunities to learn the best technologies, research, innovation, and best practices that lead to better and more affordable global solutions for quality healthcare.

1) RECOMMENDATIONS

1. A collaborative meeting jointly hosted by NIH and NSF with invited technology, industry, and business leaders in Washington, DC to discuss resource development strategies (e.g., workshops) on future collaborative research, clinical translation, and implementation infrastructure issues.
2. Develop a web portal supported by NIH/NSF/EMBS as the resource for collaborative networking, research and development, research dissemination, workshop, and clinical translation information in POCHT with active participation from academia, industry, corporate sector, hospitals, and healthcare provider facilities.
3. An annual meeting with leaders and all stakeholders in technology innovation, development, commercialization, implementation, and clinical acceptance (including reimbursement) sectors should be pursued with an emphasis on the development, follow-up, and evaluation of strategic goals and global milestones.

APPENDIX

Minutes of the breakout sessions are available for download as a supplementary file on http://health.embs.org.

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ATAM P. DHAWAN (F'78) received the bachelor's and master's degrees from IIT Roorkee, and the Ph.D. degree from the University of Manitoba, all in electrical engineering. From 1985 to 2000, he held faculty positions with the Electrical and Computer Engineering Department and the Radiology Department, the University of Houston, the University of Cincinnati, the University of Texas, the University of Texas Medical Center, Dallas, TX, USA, and the University of Toledo.

He is currently a Distinguished Professor of Electrical and Computer Engineering and the Vice Provost of Research with the New Jersey Institute of Technology, where he serves as the Executive Director of the Interdisciplinary Design Studio. He is an Adjunct Professor of Radiology with the University of Medicine and Dentistry of New Jersey. He has authored over 215 research papers and book chapters. He has also authored or co-authored several books in medical imaging and image analysis. His research interests lie in medical imaging, medical image analysis, point-of-care technologies, pattern recognition, and computer-aided-diagnosis. He was a recipient of numerous awards, including the Martin Epstein Award (1984), the NIH FIRST Award (1988), the Sigma-Xi Young Investigator Award (1992), the IEEE EMBS Early Career Achievement Award (1995), the Doermann Distinguished Lecture Award (1999), and the EMBS Distinguished Lecturer Award (2012–2013). He is a member of the Sigma Xi and Eta Kappa Nu Honor Societies. He is the Co-Editor-in-Chief of the IEEE JOURNAL OF TRANSLATIONAL ENGINEERING IN HEALTH AND MEDICINE. He was the Conference Chair of the 28th International Conference of the IEEE Engineering in Medicine and Biology Society, New York, in 2006. He served as the Conference Chair of the IEEE International Conference on Point-of-Care Healthcare Technologies in 2013. He chaired numerous NIH special emphasis and review panels, including the NIH Chartered Study Section on Biomedical Computing and Health Informatics (2008–11). He is listed in *Who's Who in the World*, *Who's Who in America*, *Who's Who in Engineering*, and *Who's Who Among America's Teachers*.

WILLIAM J. HEETDERKS received the Ph.D. degree in bioengineering from the University of Michigan, and the M.D. degree in internal medicine from the University of Miami. He was with the National Institute of Neurological Disorders and Stroke, where he directed the neural prosthesis program.

He is the Director of Extramural Science Programs with the National Institute of Biomedical Imaging and Bioengineering, NIH. The extramural program supports approximately 800 research and training grants at universities and research centers throughout the United States in fields of bioengineering and biomedical imaging.

MISHA PAVEL (SM'67) received the B.S. degree in electrical engineering from the Polytechnic Institute of Brooklyn, the M.S. degree in electrical engineering from Stanford University, and the Ph.D. degree in experimental psychology from New York University. He developed a number of quantitative and computational models of perceptual and cognitive processes, eye movement control, and a theoretical framework for knowledge representation, and the resulting models have been applied in a variety of areas, ranging from computer-assisted instruction systems to enhanced vision systems for aviation and to augmented cognition systems. His current research is in the intersection of computational modeling of complex behaviors of biological systems, engineering, and cognitive science with a focus on information fusion, pattern recognition, augmented cognition, and the development of multimodal and perceptual human–computer interfaces.

He currently holds a joint faculty appointment in the College of Computer & Information Science and Bouvé College of Health Sciences at Northeastern University. Under the auspices of the Northeasternbased Consortium on Technology for Proactive Care, he and his colleagues are targeting technological innovations to support the development of economically feasible, proactive, distributed, and individualcentered healthcare. Previously, he was the director of the Smart and Connected Health Program at the National Science Foundation, a program cosponsored by the National Institutes of Health. Earlier, he served as the chair of the Department of Biomedical Engineering at Oregon Health & Science University, a Technology Leader at AT&T Laboratories, a member of the technical staff at Bell Laboratories, and faculty member at Stanford University and New York University.

SOUMYADIPTA ACHARYA received the M.B.B.S. degree in medicine and surgery from the University of Calcutta, the M.S.E. degree in biomedical engineering from the University of Akron, and the Ph.D. degree in biomedical engineering from Johns Hopkins University, Baltimore, MD, USA. His residency training in cardiology with SSKM Hospital, Kolkata, India.

He is an Assistant Research Professor with the Department of Biomedical Engineering, Johns Hopkins University. He serves as the Graduate Program Director of the Center for Bioengineering Innovation and Design with the Whiting School of Engineering.

Dr. Acharya was the Chief Architect of a new and innovative graduate program in bioengineering innovation and design that has attracted top engineering students, outside funding, and numerous awards. He runs a program in global medical technology innovation, which focuses on developing appropriate healthcare technologies for resource-restrained customers globally. His research focuses on neural engineering. He has authored over 40 peer-reviewed articles and book chapters. He was a recipient of the NASA Space Act Board Award (2008) and the NASA Tech Briefs Award (2006).

METIN AKAY (F'87) received the B.S. and M.S. degrees in electrical engineering from Bogazici University, Istanbul, Turkey, in 1981 and 1984, respectively and the Ph.D. degree from Rutgers University, in 1990. He is the Founding Chair of the Biomedical Engineering Department and the John S. Dunn Professor of Biomedical Engineering with the University of Houston.

He has played a key role in promoting biomedical education in the world by writing and editing several books, editing several special issues of prestigious journals, including the Proceedings of the IEEE, and giving more than 100 keynote, plenary and invited talks at international conferences, symposiums, and workshops regarding emerging technologies in biomedical engineering.

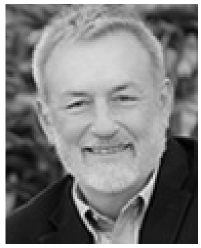
He is the Founding Editor-in-Chief of the book series of *Biomedical Engineering* (Wiley and IEEE Press), and *Wiley Encyclopedia of Biomedical Engineering*. He is an Editor of *Neural Engineering Handbook* (Wiley/IEEE Press) and the first Steering Committee Chair of the IEEE Transactions on Computational Biology and Bioinformatics. He established the Annual International Summer School on Biocomplexity from Gene to System sponsored by NSF and the IEEE EMBS, and is the Founding Chair of the IEEE EMBS Special Topic Conference on Neural Engineering. He is the Chair of the IEEE EMBS Neuroengineering Technical Committee. He was the Program Chair of the International IEEE EMBS 2001, the Co-Chair of the Annual International IEEE EMBS 2006, and the Program Co-Chair of the Annual International IEEE EMBS 2011 conference in Boston. He serves on the Advisory Board of several international journals, and several NIH and NSF review panels.

Dr. Akay was a recipient of the IEEE EMBS Early Career and Service Awards, and the IEEE Third Millenium Medal. He is a fellow of the Institute of Physics, the American Institute of Medical Biological Engineering, and the American Association for the Advancement of Science. His Neural Engineering and Informatics Lab is interested in developing an intelligent wearable system for monitoring motor functions in Post-Stroke Hemiplegic Patients and detecting coronary artery disease. In addition, it is currently investigating the effect of nicotine on the dynamics of ventral tegmental area dopamine neural networks as well as the detection of coronary occlusions.

ANURAG MAIRAL received the B.E. degree from NIT Raipur, the M.Tech. degree from IIT Bombay, the Ph.D. degree from the University of Colorado at Boulder, and the M.B.A. degree from the Haas School of Business, University of California at Berkeley. He was a Product Director with Cordis and a Development Director of Business Development, and Nitinol Devices and Components with Johnson and Johnson Company. He was a Post-Doctoral Fellow with the University of Twente, Twente, The Netherlands, and the University of Michigan, Ann Arbor, MI, USA. He is the Co-Founder of the South Asian MBA Association, a global network of MBAs with interest in South Asia. He has over 22 publications and seven issued patents.

He is the Director of Global Exchange Programs with Stanford University. He has senior leadership roles with India and Singapore Biodesign programs. In these roles, he is responsible for developing an extensive network of partners from the industry, academia, regulatory bodies, and investors in Asia and the U.S. to foster these Asia-focused programs. Furthermore, he directs the NIH-funded Global Exchange Program that offers students, faculty, and fellows the opportunity to work on Global Needs at Stanford.

Dr. Mairal is actively involved in the industry. He is the Co-Founder and an Executive Vice President of Orbees Medical, a consulting firm serving medical device industry in the U.S., Europe, and Asia. He serves on the Boards of several for-profit and non-profit organizations, and is a Charter Member with EPPIC.



BRUCE WHEELER (F'75) received the S.B. degrees in physical science and history from MIT, in 1981, and the M.S. and Ph.D. degrees in electrical engineering from Cornell University, in 1977 and 1981, respectively.

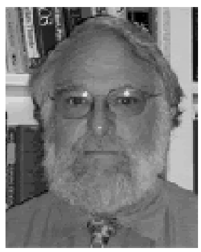
He moved to the University of Florida in 2008 as a Professor, and an Acting Chair of the Department of Biomedical Engineering, after 28 years with the Department of Electrical Communication Engineering, University of Illinois. He founded the Bioengineering Department at Illinois and served as Acting Department Chair at Illinois. Previously he served as Illinois Chair of Neuroscience and Associate Head of Electrical and Computer Engineering, including being Chief Academic Advisor to 1600 undergraduate students. He has had an active teaching career with many B.S., M.S., Ph.D., and post-doctoral students.

His research interests lie in the application of electrical engineering methodologies to neuroscience. His work influenced the development of neural spike sorting technologies, and demonstrated that microelectrode array recording from brain slices was possible and productive, and has been the Leader in the development of lithography to control cells, in particular, neurons, in culture. This work aims at basic science understanding of the behavior of small populations of neurons, in hopes of creating better insight into the functioning of the brain.

He has developed a great interest in biomedical and health informatics as he sees this area is having the greatest growth of all the biomedical engineering fields, both absolutely and in practical health impact, and for job and professional growth of the IEEE EMBS members and students in biomedical engineering at all levels.

He is a fellow of the American Association for the Advancement of Science, the Biomedical Engineering Society, and the American Institute for Medical and Biological Engineering.

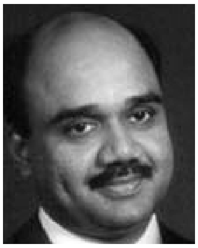
Prof. Wheeler served as the 2014–2015 President of the IEEE Engineering in Medicine and Biology Society, the world's largest, oldest, and most global bioengineering society. He has served as the Editor-in-Chief of the IEEE Transactions on Biomedical Engineering, the oldest and most cited of all general biomedical engineering journals.



CLIFFORD C. DACSO received the B.A. and M.A. degrees from the University of Pennsylvania, in 1972, the M.D. degree from the Baylor College of Medicine, in 1975, the M.P.H. degree from the University of Texas, in 1980, and the M.B.A. degree from Pepperdine University, in 1990. He is a Professor of Molecular and Cellular Biology and Medicine with the Baylor College of Medicine, a Hugh Roy and Lillie Cranz Cullen University Professor with the University of Houston, an Adjunct Professor of Electrical and Computer Engineering with Rice University, and a Consultant to the Biological Diagnostic Institute with Dublin City University.

He has been helping patients and clinicians acquire, structure, and use information to improve healthcare for over 35 years. He is the Founder and an Executive Director of the Abramson Center for the Future of Health, a research center that leverages technology, clinical medical expertise, and theoretical mathematical decision theory to support individuals as the primary managers of their own health. The Abramson Center's multidisciplinary approach integrates social sciences, technology, and community-based care, both in the United States and internationally.

Dr. Dacso's research and development focuses on new technologies that integrate information and support for patients with chronic disease, in particular, in under-resourced communities. His current work includes remote patient monitoring systems for congestive heart failure, asthma, exercise, and diabetes. His partnerships in developing countries include research on Buruli ulcer and breast cancer detection and prevention. He is the Founding Co-Editor of the IEEE Journal of Translational Engineering in Health and Medicine with Dr. A. Dhawan.



T. SUNDER is a Senior Consultant and Cardiothoracic and Transplant Surgeon at the Apollo Group of Hospitals, Chennai, India. He is also a Faculty Member of Minimally Invasive Thoracic Surgery at the Endo-Ethicon Institute, Chennai, Visiting Faculty, Department of Surgery, Annamalai University, Chidambaram, India; and Academic Coordinator, of the Department of Cardiothoracic Surgery, Apollo Hospitals, Chennai.

He is an Adult Cardiothoracic Surgeon with over 20 years of experience. His areas of clinical expertise include heart and lung transplantation, high risk coronary artery and heart valve operations, aortic surgery and pulmonary thromboendarterectomy, operations for lung cancer and esophageal cancer, and minimally invasive thoracic Surgery–Video Assisted Thoracoscopic Surgery.

Dr. Sunder established the Heart Failure Clinic and Minimally Invasive Thoracic Surgery at Apollo Hospitals, Chennai. He is interested in predictive health analysis and pattern recognition and is involved in updating the electronic medical records and hospital information systems at Apollo Hospitals, Chennai.

NIGEL LOVELL received the B.E. (Hons.) and Ph.D. degrees from the University of New South Wales (UNSW), Sydney, NSW, Australia. Through a spinout company from UNSW, TeleMedCare Pty. Ltd., he has commercialized a range of telehealth technologies for managing chronic disease and falls in the older population. He is one of the key researchers leading a research and development program to develop an Australian bionic eye. He is with the Graduate School of Biomedical Engineering, UNSW, where he is a Scientia Professor. He has authored over 450 refereed journals, and conference proceedings and abstracts. He has received over 68 million in research and development and infrastructure funding. His research work has covered areas of expertise ranging from cardiac modeling, telehealth technologies, biological signal processing, and visual prosthesis design.

Prof. Lovell received the IEEE Millennium Medal for services to the IEEE Engineering in Medicine and Biology Society (EMBS) and the profession. He was the EMBS Vice President (VP) of conferences (2004/2005 and 2010/2013) and the VP of member and student activities (2002/2003). He was the Conference Co-Chair of the World Congress in Medical Physics and Biomedical Engineering in Sydney, Australia, in 2003, and the Scientific Co-Chair of the Annual IEEE EMBS Conference in Lyon, France, in 2007.

MARTIN GERBER received the B.S. degree in electrical and electronics engineering from the South Dakota School of Mines and Technology, in 1984, and the M.B.A. degree from the University of Saint Thomas School of Business, in 1990.

He is the Senior Research and Development Director of Medtronic, Mumbai, India. He is the Core Team Leader (Program General Manager) for complex neurostimulation systems and new therapy development. He is responsible for developing and commercializing new therapies and products, developing business cases and managing execution to ensure that therapy/product development meet goals for time-to-market, quality, development expense, and product cost.

Mr. Gerber's specialties include strategy development, program management, therapy and product development, merging science and business, general management, intellectual property, and strategic problem solving.

MILIND SHAH received the degree in chemical engineering from IIT Delhi, and the M.B.A. degree from IIM Calcutta. As an active member of the World Presidents' Organization, he is affiliated with industry associations, such as the Confederation of Indian Industries, the American Chamber of Commerce, and the Federation of Indian Chambers of Commerce and Industry (FICCI). Until recently, he was the Chairman of FICCI's Medical Devices Forum and the Co-Chair of AHWP, an Asian body for harmonization of regulatory policies for medical devices.

He joined Medtronic as the Managing Director of India Medtronic in 2004. He is the Vice President and South Asia and Managing Director of India Medtronic. As the Vice President of South Asia, he is responsible for driving the company's expansion and growth in the region, in addition to running the entire operations for Medtronic South Asia.

Mr. Shah's previous assignments include a leadership role with Henkel India and Thailand from 1997 to 2004, the Business Leader with 3M from 1988 to 1997, and roles in corporate planning and marketing with Shell Petrochemicals. He has over 28 years of experience in leadership, sales and marketing, and corporate planning positions in Healthcare, Specialty Chemicals, Telecommunications and Petrochemicals.

S. G. SENTHILVEL is a Subject Matter Expert and an Industry Solutions Leader of Healthcare and Public Sector with IBM India. He is professionally qualified in the healthcare and life sciences domain with over 17 years of professional experience with MNC Healthcare and IT organizations, as a SME, Principal Industry Consultant, Solution Architect, and Business Analyst.

He specializes in the 360° view of patients and evidence and knowledge-based clinical analytics domains, and change management practices to improve the adoption of healthcare IT within the clinical community. He has significant expertise in areas, such as public health profiling and monitoring, clinical portals, clinical data warehousing, scientific information management, predictive analytics, clinical trial data management and mining, and RFID solutions for biobanks. He has vast experience in integrating applications and services with a strong focus on industry standards viz., HL7 and CDA.

As a Subject Matter Expert, he has worked on health information technology, solutions, health exchanges, hospital information systems, picture archiving and communication systems, radiology information systems, clinical information systems, and clinical data analytics research for lifestyle diseases, like diabetes and coronary heart disease for multiple clients across different geographies.

Dr. Senthilvel handles university relations and shared university research programs for the healthcare and life sciences domain in the country. He serves as a member of the industry expert's panel in defining curriculum and conducting train-the-trainer programs in healthcare and bioinformatics and pharmaceutical biotechnology at various Indian engineering universities.

MAY D. WANG received the B.Eng. degree from Tsinghua University, Beijing, China, the M.S. degrees in electrical engineering, applied mathematics, and computer science from the Georgia Institute of Technology (Georgia Tech), Atlanta, GA, USA, and the Ph.D. degree in electrical engineering. She has several years of industrial research and development experience with AT&T Bell Labs, Intel Architecture Labs, Hughes Research Labs, Lucent Technologies Bell Labs, and Agere Systems.

She is a Tenured Associate Professor with The Wallace H. Coulter Joint Department of Biomedical Engineering, Georgia Tech and Emory University, and a Georgia Cancer Coalition Distinguished Cancer Scholar.

She has published in journals, such as the *Annals of Biomedical Engineering*, *Briefings in Bioinformatics*, *BMC Bioinformatics*, *Trends in Biotechnology*, *Nature Protocols*, *Proceedings of National Academy of Sciences*, *Pathology Informatics*, the IEEE Transactions on Informatics Technology in Biomedicine, the IEEE Reviews on Biomedical Engineering, and the *Annual Review of Medicine*, as the corresponding author. Her research interest is in biomedical and health informatics, such as clinical biomarker identification using omic and next-generation sequencing, molecular imaging informatics, therapeutics modeling for nanomedicine, and data analytics of personal health record for prevention.

Dr. Wang is the Director of Bioinformatics and Biocomputing Core with the Emory-Georgia Tech Cancer Nanotechnology Center. Her bioinformatics software systems, such as caCORRECT and omniBiomarker have been certified by the National Cancer Informatics Program of NCI/NIH (a.k.a caBIG) as silver-level compatible (In addition, she has been active in FDA-led Microarray Data Analysis and Next Generation Sequencing Consortium. She was a recipient of the Outstanding Undergraduate Research Faculty Mentor Award from Georgia Tech in 2005, and the Outstanding Service Award from the IEEE BIBE in 2007. She serves as the Co-Chair of the Information Technology for Health Technical Committee in the IEEE Engineering in Medicine and Biology Society.

BALRAM BHARGAVA is a Professor with the Department of Cardiology, Cardiothoracic Sciences Centre, and an Executive Director of the Stanford India Biodesign Centre and the All India Institute of Medical Sciences, New Delhi, India. He is one of the foremost leaders in biomedical innovation, public health, medical education, and medical research in India. He developed the indigenous Platinum Iridium coronary stent and has been instrumental in clinically evaluating Indian stents. These low cost indigenous stents have benefitted several thousand patients. He set up the Centre for Excellence for Stem Cell Studies, which has initiated treatment of patients with dilated cardiomyopathy for the first time in the world. This has benefitted a number of no-option patients waiting on the cardiac transplant list.

Dr. Bhargava has promoted the India-Stanford Biodesign Program, a unique interdisciplinary program to foster innovative design in low cost implants/devices. The Fellowship on Biomedical Technology Innovation has led to over 20 patents on low cost medical devices. He is currently developing the chest compression device for sudden cardiac death patients, funded by the Wellcome Trust. He is providing leadership for a creative disease prevention, early detection, and transport system for sick cardiac patients. He has received the SN Bose Centenary Award by the Indian National Science Congress, the National Academy of Sciences Platinum Jubilee Award, the Tata Innovation Fellowship, and the Vasvik Award for Biomedical Technology Innovation.