Guest Editorial Cardiovascular Health Informatics: Risk Screening and Intervention

***Abstract*—Despite enormous efforts to prevent cardiovascular disease (CVD) in the past, it remains the leading cause of death in most countries worldwide. Around two-thirds of these deaths are due to acute events, which frequently occur suddenly and are often fatal before medical care can be given. New strategies for screening and early intervening CVD, in addition to the conventional methods, are therefore needed in order to provide personalized and pervasive healthcare. In this special issue, selected emerging technologies in health informatics for screening and intervening CVDs are reported. These papers include reviews or original contributions on 1) new potential genetic biomarkers for screening CVD outcomes and high-throughput techniques for mining genomic data; 2) new imaging techniques for obtaining faster and higher resolution images of cardiovascular imaging biomarkers such as the cardiac chambers and atherosclerotic plaques in coronary arteries, as well as possible automatic segmentation, identification, or fusion algorithms; 3) new physiological biomarkers and novel wearable and home healthcare technologies for monitoring them in daily lives; 4) new personalized prediction models of plaque formation and progression or CVD outcomes; and 5) quantifiable indices and wearable systems to measure them for early intervention of CVD through lifestyle changes. It is hoped that the proposed technologies and systems covered in this special issue can result in improved CVD management and treatment at the point of need, offering a better quality of life to the patient.**

***Index Terms*—Acute cardiac events, information security, personalized risk prediction, sudden cardiac deaths, wearable health system.**

I. Introduction

HEALTH informatics, which has been listed by the U.S. National Academy of Engineering as one of the 14 grand engineering challenges of the 21st century, deals with the acquisition, transmission, processing, storage, and retrieval of health information for the early detection, early diagnosis, and early treatment of diseases [1]. Issues to be addressed in health informatics include some general ones, e.g., security, privacy, and interoperability of health information systems and electronic health records, and also those specific to a kind of disease, e.g., cardiovascular disease (CVD).

CVD, which is the main theme of this special issue, has remained the leading cause of death in most countries worldwide. Around two-thirds of these deaths are due to acute events, which frequently occur suddenly and are often fatal before medical care can be given. It is therefore clear that, in addition to traditional approaches, new strategies for screening and early intervening CVD are demanded. These new approaches are preferred to be personalized, preventive, and pervasive.

In this special issue, selected emerging technologies in health informatics for screening and intervening CVDs are reported. These papers include reviews or technical contributions on 1) new potential genetic biomarkers for screening outcomes of CVD and high-throughput techniques for mining genomic data; 2) new imaging techniques for obtaining faster and higher resolution images of cardiovascular imaging biomarkers such as the cardiac chambers and atherosclerotic plaques in coronary arteries, as well as possible automatic segmentation, identification, or fusion algorithms; 3) new physiological biomarkers and novel wearable and home healthcare technologies for monitoring them in daily lives; 4) new personalized prediction models of plaque formation, plaque progression, and ultimately CVD outcomes; and 5) quantifiable indices and wearable systems that measure them for early intervention of CVD, for example, through lifestyle changes.

The guest editors of this special issue have received 34 submissions and amongst them 11 papers were selected for inclusion in this special issue. Another 10 papers on related topics were selected from the regular paper submissions to cover a more thorough perspective on cardiovascular health informatics.

II. Multiscale and Multimodal Cardiovascular Health Information and Corresponding Informatics

Traditional biomarkers for predicting CVD outcomes include age, sex, systolic blood pressure, smoking habits, etc. It is now becoming apparent that new and personalized biomarkers are needed in order to predict acute CVD outcomes more accurately. Recent studies have been focusing on looking for new genetic, molecular, imaging, or physiological biomarkers with better clinical prediction outcomes and for each of these areas, advancements in different computing and information technologies are needed.

A. Genomics

In this special issue, Pu *et al*. [2] summarized recent studies on genetic variants that are associated with CVD outcomes/traits and perspectives of using genetic information for developing a personalized risk prediction model for CVD. To assist the understanding of the underlying molecular basis for CVDs, Wang *et al*. [3] proposed a biomarker identification pipeline, which takes into consideration the essential steps in analyzing

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genomic datasets: from a high-throughput genomic data acquisition method to the interpretation and validation of candidate biomarkers. The pipeline can also be generalized for other diseases.

B. Imaging Informatics

Imaging the cardiovascular system by ultrasound, computed tomography (CT), intravascular ultrasound (IVUS), and magnetic resonance imaging have been largely studied in the past, with each imaging modality bearing its own pros and cons. The cardiovascular system is a dynamic system. Therefore, obtaining high-resolution images of it *in vivo* are challenging, particularly when fine structures that assist early diagnosis of diseases are of concern. In addition, although a large number of studies on automatic segmentation algorithms for medical images have been proposed for faster extraction of features that are thought to be associated with CVD outcomes, direct comparison of the performance of these algorithms is often difficult due to the lack of a common database with diversified cases as well as the ground-truth definition.

In this special issue, two papers discussing automatic segmentation algorithms are included: Katouzian *et al*. [4] reviewed the state-of-the-art and challenges in developing segmentation algorithms for IVUS images, which is a particularly promising imaging modality for the vulnerable plaques, and Silva *et al*. [5] reported a study on comparing segmentation algorithms of echocardiographic images with those manually sketched by four physicians. Another selected paper by Chen *et al*. [6] reported the potential of using low dose CT for the measurement of myocardial whole heart extracellular volume fraction by a three-step algorithm: first, segment the myocardium and blood pool on postcontrast image; then, a symmetric deformable registration method was applied to register precontrast to postcontrast images; and finally, the correspondences between the voxels from precontrast to postcontrast images were established.

Measuring the motion vectors of the artery wall as indicators of arterial elasticity and contractility can provide new indices to CVD outcomes and Golemati *et al*. [7] proposed and compared a number of techniques to quantify the arterial wall properties in their study. On the other hand, Xavier *et al*. [8] quantified the cardiac wall motion from standard cine-MR examinations by an adapted optical flow algorithm, while Wick *et al*. [9] attempted to synchronize mechanical movements and electrical activities of the heart to allow direct visualization of quiescent phases of the cardiac cycle with respect to heart rate in this issue. Further evaluation of the motion of the cardiovascular system required the advancement of faster and higher resolution imaging technologies.

Since each imaging modality has its own characteristics, fusion of different imaging modality becomes an interesting area of research that draws a significant amount of attention in the recent years, for example, Zhang *et al*. [10] proposed to synchronize 4-D cardiac magnetic resonance and ultrasound images.

The last imaging informatics paper included in this special issue deals with a general security issue in the transmission of medical images via the network. Bouslimi *et al*. [11] presented a joint encryption/watermarking (E/W) system to give access to the outcomes of the image integrity and of its origin even though the image is stored encrypted.

C. Informatics for Physiological Signals

Compared to imaging markers, physiological markers can often be obtained at a relatively low cost and in a noninvasive way. In particular, recent emerging developments in wearable technologies open up a new direction for ambulatory or even ultimately long-term continuous measurement of physiological biomarkers for near-term estimation of CVD outcomes. The continuous measurement of physiological signals also allows the estimation of variability of some of the conventional physiological biomarkers and arrives at new biomarkers, e.g., variability of heart rate and blood pressure. In this special issue, Khandoker *et al*. [12] carried out an initial study on QT variability index to indicate cardiovascular autonomic neuropathy.

To design wearable health systems, novel technologies are needed for designing both the hardware, such as the design of a low-power and low-noise analog application-specified integrated circuit reported by Tsai *et al*. [13] and software, such as artifact removal techniques developed by Sweeney *et al*. [14].

Assistive living technologies for integrating sensors into a home or office environments is another study topic in health informatics. New approaches are needed to monitor health indices pervasively by a noncontact approach during work such as the millimeterwave system studied by Mikhelson *et al*. [15], or during sleep, as if the bed sheet integrated with textile electrodes as developed by Peltokangas *et al*. [16]. The technologies can be useful for tracking potential CV outcomes without affecting the daily activities of the subjects.

III. Personalized Risk Prediction and Early Intervention Technologies

A. Personalized Prediction Models

Personalized risk prediction modeling, in addition to the traditional population-based modeling, is an emerging field of studies in health informatics. To assist the development in this area, Bia *et al*. [17] led a National Public University Center (CUiiDARTE) in Uruguay with the aim of developing and applying strategies to improve cardiovascular risk stratification and subclinical vascular disease detection. The data can be valuable for the development of patient-specific evaluation metrics for CVD outcomes.

Two other proposals for personalized prediction models on plaque formation and progression were selected for publication in this special issue. Parodi *et al*. [18] described the process by a 3-D model that was developed based on well-known mathematical models of the blood flow dynamics, mass transfer within the vessel lumen and across the arterial wall, as well as the inflammatory process. The work [18] presents a new initiative to link up systemic and local hemodynamic features of the vascular tree for potential prediction of the vulnerability of CV patients. On the other hand, Kyriacou *et al*. [19] evaluated the combination of imaging biomarkers of atherosclerotic plaques

with clinical features for better prediction of stroke on over 1000 patients. These models present interesting ideas on combining images with physiological or clinical information for CV risk prediction.

B. Early Intervention Technologies

Lifestyle changes have been found to be an effective approach to prevent CVD. Nevertheless, few objective and quantifiable indices are currently available in clinical practice to assist the assessment of lifestyle changes, for example, via exercise. In this respect, recent developments on posture and activity recognition by wearable sensors can help us to provide valuable data for clinical assessment. Three papers [20]–[22] on this related topic were selected for publication in this special issue. Brulin *et al*. [20] described a set of fuzzy logic for classifying postures in a home environment. Strohrmann *et al*. [21] described a technique based on wearable sensors to quantify kinematic changes in running. Lin *et al*. [22] described a wearable system that estimates daily energy expenditure using a neural-network-based classifier. These technologies are not only useful for CVD but also useful for other home healthcare applications, e.g., in detection of falls of elderly in a home environment.

IV. Concluding Remarks

CVD is one of the most common causes of death worldwide and represents a major financial burden for national economies. Effective prediction and prevention of CV disease, particularly which resulted from high-risk asymptomatic atherosclerosis, has now become a top priority. Traditional methods of risk assessment for premature heart attacks and strokes use risk factors such as smoking, high blood pressure, and blood cholesterol to express the risk of CV deaths as a risk score, for example, the 10-year Framingham risk score. These assessment methods provide good results but also demonstrate clear limitations.

With the advancement of technologies, screening and improved selection of individuals for more effective prevention is now possible because of the following: 1) preclinical (silent) atherosclerotic plaques develop slowly over several decades before they rupture or obstruct an artery becoming clinically manifest; 2) screening methods are now available for detecting the presence and severity of such plaques; and 3) current prophylaxis with aggressive risk factor modification can largely reduce morbidity and mortality from heart attacks and strokes by 50%.

The goal of this special issue is to present a snapshot of original and relevant contributions covering the areas of emerging genetic biomarkers, new imaging techniques and algorithms, physiological monitoring systems, personalized prediction modeling, and wearable systems enabling early intervention. It is hoped that the proposed technologies and systems can result in improved CVD management and treatment at the point of need, reduced hospitalization, and the associated economic burden, offering a better quality of life to the patient.

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