In this For-Discussion-Section, Thomas M. Deserno and Nikolaus Marx are presenting a farseeing yet somewhat controversial review paper on electrocardiography (ECG) [1]. In the paper, after the concise assertive historical review of the development of ECG technology and its clinical use for a century up to now, they are showing a future vision to be pursued which is symbolically expressed by the word *Computational Electrocardiography* (CECG). This For-Discussion-Section consists of their paper presenting current issues to be explored in terms of CECG followed by comments addressed by seven distinguished researchers in the field of medical informatics, biomedical or health care engineering [2]. Their comments vary from affirmative ones showing even additional supporting evidences to ones including constructive criticism.

In their review paper [1], Deserno and Marx summarized the ECG reading status quo as it remains in the *needle-in-the-hay stack* approach based on the short period recordings with the limited number of manually extracted indices to characterize ECG waveforms. One of the commentators, J. H. van Bemmel complements the history by adding that of quantitative ECG (QECG) introducing an extensive effort of developing and validating the computerized ECG analyses and their clinical use [3, 4]. Caiani introduces the recently published successful guideline of the use of prolonged, yet non-continuous recoding for atrial fibrillation (AF) detection by the European Heart Association [5, 6] as a sprout example toward CECG practice. In his comment, he describes the technology introduced in the guideline is the *magnet to guide the needle in the hay stack without the help of physician*. Deserno and Marx may be envisioning more than the *needle* intending to find a *bright wide angle transmitting light* which enable to capture the whole essence of the hay stack, i.e. big ECG data, continuous both in time and space (potential distribution), possibly with multimodal additional data. This idea is quite attractive although their illustrative example of the long term changes in QRS duration for limited number of subjects is not convincing for this big picture as van Bemmel remarked in his comment.

In the vision of CECG practice, continuously generated multichannel ECG signals are acquired by e.g. wearable sensors and collected by a PDA via wireless link. Then, original or preprocessed data are relayed to the cloud data system for their life-long recording and timely processing. Data are analyzed on the cloud system and individual feedback will be made. ►Figure 1 depicts this CECG vision. C. Baumgartner supports the idea by introducing already existing tele-monitoring system of cardiovascular disease [7, 8]. He also suggests the use of the record from large number of electrode leads for visualizing ventricular electrical activity [9] as an example of valuable big data in the CECG scheme. H. Witte and K. Schiecke supported the CECG concept by introducing their work...
to apply continuous ECG recordings to the prediction of the onset of epileptic seizure.

As C. A. Kulikowski and H. Dickhaus commented, the major challenge is not the development of data recording hardware and cloud data handling systems, i.e. wireless relay of the data via PDA or cloud data handling systems, but the development of the reliable methods for the big data analysis. With continuous accumulation of the data, the CECG system is expected to predict clinically significant events such as sudden cardiac death. Innovative new practical methods to work on big data, e.g. 8GB ECG data accumulated per week should be developed. In addition, data are not as clean as clinical data recorded on the lab bench. Personalized data characterization for tailored abnormality detection and prediction on the life-long continuous data is a real challenge.

Dickhaus refers to the data repositories and data warehouses of the ECG data [10, 11] to share them with the ECG research community. Such data sharing system will be the key to facilitate the development of ECG big data analysis methods. THEW ECG data warehouse [11] utilizes a modified ISHINE format [12] for annotated ECG beat timing records. In 2015, ISO approved the medical waveform format [13] proposed by MFER (Medical waveform Format Encoding Rules) committee [14]. To have consensus on the common data format will provide the firm bases for the expected force coming fruitful worldwide collaboration of the CECG research development.

Although further clarification and deep discussion have to be made, the concept of CECG certainly is an attractive comprehensive up-to-date research framework which need intensive integration of emerging technologies.

References