Innovative Instrumental Analysis of Heartbeat Signals and Its Clinical Application

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A new apparatus has been built that annexes a normal electrocardiograph, ECG, with the aim to enhance its capacity. It adds the normal ECG power to superpose multiple records of ECG altogether and averages them and, further, makes sophisticated analysis, such as normalizing the peak heights, evaluating the half-line widths of the peaks, or that of the standard deviations of measurements like the inter peak distances. The results of the said calculations have not been obtainable using the former instruments, and are expected to be useful for clinicians.

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Introduction

This note reports on the production of an apparatus that annexes the normal electrocardiograph (ECG) and endows it with the capacity to make sophisticated analysis of heartbeat signals. The analysis of the heartbeat signals is currently recorded by an electrocardiograph (ECG). It was first measured by Einthoven in 1887.1 The naming of the peaks in the records is also due to him.2 For convenience, we hereafter call one set of all those peaks as a family of signals.

In practice, clinicians use ECG records by referring to a one-shot record, which actually reflects a one-shot beat of the heart. Although the heartbeat is actually recorded for several cycles, the recordings are examined by a simple visual comparison, and thus the examination is based on a consideration of individual beats, rather than on the average data of multiple measurements. This is due in part to the fact that the period of the beat is only semi-regular. This makes it difficult to superimpose the recordings to obtain average results for multiple measurements. It must be admitted as a fact that in the reality of clinical science, the said visual examination of the records of ECG has worked well so far, and has made an enormous contribution to the whole of medical science.3 However, it is also true that one single-shot record is not good sufficient for applications to the modern technology of instrumental science. We have taken interest in introducing a more instrumental approach to this situation. Multiple measurements in ECG could be averaged by a computer to produce a “normalized” ECG record. With such a normalized record, we may be able to perform more sophisticated analytical procedures, such as an evaluation of the standard deviation of the distances between peaks, an evaluation of the half-line widths of the peaks, and so on.

Also, such a procedure that involves the superposition and averaging of multiple ECG records would eliminate the danger of introducing an aberrant one-shot beat, which may be caused by a transient effect on the patient, such as movement of the patient, or a change in his or her environment.

We have constructed an apparatus that connects to a commercial ECG meter (Fig. 1). It makes it possible for a normal ECG meter to produce a normalized electrocardiogram, after superposition and averaging of the ECG records of multiple families of signals. Furthermore, it can perform not only a normal analysis, such as measuring the relative heights of the peaks and the distances between the peaks, but also more sophisticated examinations, such as calculating the standard deviations of the peak heights, the peak-to-peak distances, and the half-line widths of the peaks etc. None of these features of a normalized signal can be obtained with a one-shot record.

We have coordinated the results of our work on the normalization of observed records with a clinical standard reference, the Minnesota codes.4,6 All of the procedures cited above can be performed automatically, which eliminates the labor required in former procedures that were performed manually and visually. As an example, we performed the averaging and analytical procedures cited above on the records of ca. 200 volunteers, both manually, which required several months of work for professionals, and with the set-up described here, which required only several tens of minutes.

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A Flow-chart of the New Apparatus Which is to be Connected to an Electrocardiograph

The heartbeat data are sampled by the normal method adopted by the commercially available device. Briefly, we introduce normal ECG data to the device. The set then outputs digitized data, and introduces it to our instrument, which we refer to as the “Annex” (Fig. 1).

Function of the Annex

The set-up collects the records of multiple heartbeats in a computer file in the Annex, averages them, and performs a sophisticated analysis of the averaged data. The procedure, as described above, is the same as that which is generally performed by an electrocardiograph. It is based on the handling of a one-shot record, whereas, with the Annex, the analyses are performed using a normalized record of heartbeats.

The scheme of the Annex is shown in Fig. 1. The output of the commercial ECG instrument is introduced to the Annex. The number of beats to be introduced here is chosen arbitrarily, say as 30. Then, the data reflect ca. 30 families of beats. All of the data are kept in files of the computer, and classified into groups according to the “family”, i.e., all data are classified into families, where each family consists of peaks lined up along the time path. We then proceed to “averaging”, which can be done with respect to any of the different families, or on any specific peak of different families. First, however, we have to normalize the peak height. As an example, let us consider the peaks in a single family. We assign one peak, such as R, a relative height of 100, and then divide the heights of all other peaks by it, which gives the heights of all peaks in the family under consideration as normalized percentages. We can also apply this normalization procedure to the distances between peaks.
By the above procedures, ECG signals that show irregular periods can be averaged. All of the above procedures can be performed by the computer in the Annex, in addition to more sophisticated procedures, such as measurement of the half linewidths and a calculation of the standard deviation of any parameter, such as the peak heights or the inter-peak distances.

**Presentation of the Work of the Annex**

The Annex can provide a bird’s-eye view of the results of measurements or those of the analyses on any subjects, or on any items shown in Fig. 2 (cf. Fig. 3) according to the interest of the user. The subjects numbered in Fig. 2 from 3 to 11 refer to those to be measured by the Annex and kept in its file. The operators of the Annex can pull out any data from that file according to their interest. Furthermore, the Annex can supply data of any one of those subjects simultaneously with respect to the standard 12 lead electrocardiograms. Although the function to carry out measurements simultaneously on the 12 leads is not new at present, the Annex is unique in that it can perform more sophisticated analyses and can present the results of the analysis in a way of a figure of a bird’s-eye view of the 12 leads. Moreover, those data are displayed together with two kinds of the standard deviations: one, that of the individual patient (the examinee), and the other, that of the group of examinees. In other words, the former refers to the standard deviation with regard to an individual specific patient, and the latter to the statistics of multiple people. Figure 3 presents one example of a presentation of the work of the Annex of this sort. There, the data of one patient on the peak heights of the leads are presented. Another 6 of the 12 could be put on the display alternatively. In the figure, the two kinds of the standard deviations are shown as well. The clinician could make his/her view with the assistance of those data. Such a kind of work should be taken as that only available after the Annex. In summary, the data in situ measurements are presented in the form of a part of the figure of the bird’s-eye view, where, other data of additional 11 modes can be compared with each other. Moreover, there, it is possible to examine its quality statistically, and chronologically. It is a simple job to extend the work to other subjects, because it is possible by changing the assignment of the item of the subject. Thus, we conclude the usefulness of the presentation of the bird’s-eye view figure of the 12 modes of measurements and that of the analyses of ECG by the Annex.

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**References**