Computer Analysis of the ECG

by Jos L. Willems

Computer analysis of electrocardiogram readings can be of value to both general practitioners and small hospitals

As early as 1887, A.D. Waller of London University discovered a measurable amount of current in the human body corresponding to the cardiac contraction. It was not until 1901, however, that an accurate and quantitative recording (electrocardiogram, or ECG) was made possible by the introduction of the string galvanometer by the Dutch physiologist Willem Einthoven. For this invention and the discovery of the mechanism of the ECG, Einthoven was awarded the Nobel Prize for Medicine in 1924. Since then, remarkable progress in the field of electrocardiography has led to the registration of millions of ECGs. In the USA alone close to 100 million ECGs are recorded each year, and a similar figure is true for the European Community.

Computer-aided ECG processing, introduced by H.V. Pipberger 30 years ago, enhances the ability to handle such high volumes of recordings. This benefit is particularly evident in large hospitals or groups of hospitals, and has been one of the major incentives for the involvement of industry in this novel technological market. As a result, small self-contained and relatively inexpensive microcomputer-based ECG systems became available in recent years.

Potentially, computer analysis of the ECG can offer a major service to general practitioners and smaller hospitals as well, and is valuable also in emergency situations where a cardiologist is not available. In addition, computer analysis markedly reduces subjective differences in interpretation and ensures correct classification. These are the major reasons why electrocardiography has been the proving ground for developing many basic concepts in medical decision-making by computer.

The ECG is a graphic record of voltage changes transmitted to the body surface by electrical events in the heart muscle, thus providing direct evidence of certain aspects of myocardial anatomy and function. During its propagation to the surface, extracardiac tissues may intervene and influence the ECG.

The conventional ECG at present contains a minimum of 12 leads. For certain special purposes other leads are recorded and in some research centres, so-called body surface maps are obtained by placing more than 100 closely spaced and evenly distributed electrodes around the torso.

In an ECG data-processing system a
series of sequential processes happen that are interrelated but, to some extent, independent. They are respectively acquisition and transmission of signals; wave recognition and measurement; parameter extraction; rhythm analysis and classification; and, finally, reporting and data base management for programmes performing serial ECG comparison.

Initially, as for many applications, computer-assisted ECG interpretation was performed centrally in larger hospitals on dedicated mini-computers— not time-shared for any other purposes— or on medium- to large-scale computers of regional service bureaus. In recent years, stand-alone microcomputer systems have been introduced which acquire and process data and print results at the bedside.

The computer receives the ECG signals either by means of a MODEM over standard telephone lines, or directly from the ECG recording device, at a sampling rate of 250 to 500 samples per second. The data are stored on disc for further processing, in total between 40,000 and 60,000 samples of a 12-lead conventional ECG recording over 10 seconds. In some ECG processing systems, on-line quality control of the data is performed. The signal quality is checked for noise, baseline wandering, and other artifacts. The technician is informed through a visual or audible signal that the ECG was acceptable so that the patient may be disconnected.

The main task of the ECG measurement programme is the automatic detection of the on- and off-sets of the P, QRS and T waves, that is the main deflections of the ECG in the various leads. The data are first filtered by various techniques. In the next stage QRS complexes are located and the regularity of the heart rate is established. Subsequently, a more refined arrhythmia analysis and wave typing of the various complexes can be carried out to detect whether the beats are all of the same origin.

Because detection methods vary, the results of different programmes are not always concordant even when identical tracings are being analysed. To overcome this problem, a large international standardisation project was undertaken between 1980 and 1985, with support from the European Commission and the Division of Medical Informatics of Leuven University as Coordinating Centre. ECG computer programme developers from Canada, Japan and the USA also participated.

Once on- and off-sets have been determined, the amplitude and duration as well as other measurements of the various waves can be calculated. These measurements are then used in the interpretation phase to arrive at diagnostic classification results.

Classification strategies used by programme developers can be divided into two major groups. In the first and most widely used strategy, the programme sequentially follows a logical decision path, with yes-no branching, to arrive ultimately at a set of non-conflicting statements about the ECG. When certain measurements exceed the limits of normal, the findings are used to arrive at a diagnostic conclusion which may be qualified by a second or third measurement before a final diagnostic statement is made.

The second strategy uses statistics to calculate the probabilities of a particular classification. A large number of ECG variables are used simultaneously, instead of consecutively as in the previous approach, and various statistical techniques make it possible to maximise correct and minimise incorrect classifications of the ECG. A prerequisite for developing such programmes is the availability of a large data base, consisting of records from patients with diagnoses firmly documented by methods independent of the ECG.

Detection of cardiac arrhythmias remains one of the intriguing problems in computer analysis of the ECG. It is widely accepted that complex arrhythmias can hardly be recognised on short strip recordings of surface ECG leads routinely submitted for computer analysis. Most programmes, therefore, only attempt to recognise the most common rhythm abnormalities. Fortunately the incidence of complex arrhythmias is very low.

Comparative analysis of serial electrocardiograms is another feature that is still not fully developed and clinically used. A prerequisite for analysis of serial tracings is a centralised system with efficient storage and retrieval capabilities providing rapid access to old records to which the new incoming records are to be compared. Practicality and economics usually dictate decisions.
concerning such retrieval. Disc space limitations impose severe constraints on the length of records, measurement and classification results to be stored. The volume of ECGs processed in several large hospitals in Europe, for instance at the Leuven University Hospitals, exceeds 45,000 per year. Optical laser-disc storage devices are increasingly suggested as a solution to this problem.

After the computer has processed the ECG, it generates an unconfirmed analysis report, which is either forwarded directly to the physician who requested the ECG, or to a cardiologist centrally or remotely located, for approval or over-reading. Indeed, computer-generated reports in most countries still need to be verified or annotated by a reviewer cardiologist, due to legal and other requirements. The over-reader may return the comments to the central computer site for editing of the computer diagnosis or may communicate the comments directly to the user.

One of the most important consequences of the use of computers in large hospitals has been a decrease in the time required by the cardiologist to interpret ECGs – as much as 30 to 70 per cent. Similarly, clerical time for transcribing interpretations and for other administrative functions, such as billing, has been markedly reduced. The consistency of the computer interpretation in content, format and language is also viewed as an important benefit. To attending physicians such as surgeons, gynaecologists or general practitioners – who generally do not have special expertise in ECG interpretation – the major change is an improvement in the service provided to them by the ECG department.

A key question that has to be answered concerns the evaluation of diagnostic programme accuracy. What is the programme’s ability to identify properly the patient’s condition? Several studies have already provided evidence for an increased, or at least equal, accuracy of computer analysis compared with visual ECG interpretation made by an average cardiologist.

The growing importance of informatics in medicine has been demonstrated by the widespread use of computers in hospitals not only for administrative but also for medical purposes, for laboratory automation, intensive patient care monitoring, nuclear medicine, radiology, medical records and so on. Small self-contained and relatively inexpensive microcomputer systems are now becoming available for the private physician’s office and ambulatory care applications.

The ECG is only one of many pieces of information used by physicians in making diagnostic and/or therapeutic decisions. So, although the computer may have quite an important impact on the use, the availability or the timeliness of the ECG, actual patient care is affected in only certain cases and the overall impact of ECG computer processing on health care delivery is still only very modest. However, considering the extent and ever increasing costs of health care, and the importance of cardiovascular diseases, it is evident that even a modest improvement contributes to the care of many people and may have considerable economic benefit.

The time required by a cardiologist to interpret ECGs has been cut by as much as 70% through the use of computers.

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Dental Passports

WHO’s Oral Health (ORH) Programme has been collaborating with a number of member states and national institutions in developing better ways of monitoring and managing oral health care programmes.

An initial effort towards this end was aimed at developing a simple system for collecting and recording dental patient information. This “dental passport” system, as it was called, provided the health workers with more complete and readily accessible information on a patient coming for treatment.

A prototype microcomputer-based system for storing and processing the data contained in these “passports” was developed jointly by ORH and the International Centre for Oral Health in Chiang Mai, Thailand, together with technical support from WHO’s Information Systems Support Division and its Collaborating Centre for Medical Informatics in Tokyo, Japan.

Field testing of this prototype encouraged the Programme to consider upgrading it to a knowledge base system. One major use of such a system is to support the diagnosis and proposed treatment of oral health conditions, and to produce information which would help health care managers with the planning, monitoring and evaluation of oral health care services.