Future of computerised electrocardiography

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SUMMARY The advent of computerised electrocardiography has been of prime importance for the storage and retrieval of data, but none of the available systems is of universal application for analysis of patterns. Future needs require hierarchical systems of increasing degrees of complexity, depending on the source of requests, and there should be appropriate provision for review by cardiologists before the final report is issued.

Despite the fact that electrocardiography is one of the most important diagnostic tools at present available to clinical cardiologists, computerised electrocardiography still lacks recognition and has not achieved an essential place in clinical practice.

Computer sciences and the application of computer techniques have been helpful in providing more insight into many electrocardiographic problems. But in computerised electrocardiography emphasis has been placed on the computer rather than on electrocardiography: “Electrocardiography has been the proving ground for many of the basic concepts of medical decision making by computer”.1 Medical decision making by computer and clinical electrocardiography do not, however, necessarily have identical goals and should be carefully distinguished. At present computerised electrocardiography is still more an engineering project than a useful and applied diagnostic tool in clinical cardiology. Moreover, computerised electrocardiography has turned out to be not only the proving ground for medical decision making by computer, but also—and perhaps mainly—the playing field for the medical electronics industry. Our patients have served as testing objects for modern electrophysiographic equipment, often very sophisticated, but not very reliable in day-to-day use. This has all been at the expense of our patients and of our hospital budgets.2 Clinical cardiologists shrug their shoulders over computer electrocardiography; let us briefly consider why this is so.

State of art of electrocardiographic reading by computer

For the clinical evaluation of automated processing of electrocardiograms ambulatory patients are used rather than the critically ill.3 Computer analysis of the electrocardiogram does not offer any help when the complexity of a particular electrocardiogram extends the intellectual skills of an experienced cardiologist.

For those patients with complex arrhythmias and/or complicated QRS patterns, computer diagnosis is not very helpful, a state of affairs which may not change within the next decade.4 Up till now automated processing of electrocardiography has neither contributed to expertise in reading of clinical electrocardiograms nor to better understanding of the fundamental electrophysiological properties of the heart. In addition, computer analysis of the electrocardiogram is, in general, no more accurate than a trained electrocardiographer for routine reading of electrocardiograms of a hospital population.5 In our experience it could not compete with respect to the cost or speed of reading of electrocardiograms, provided the human reader is provided with proper organisational tools, including support facilities.6

These unfavourable judgments, however, are only valid for those hospitals that have experienced and sophisticated facilities for reading electrocardiograms. There are undoubtedly many electrocardiographic services in smaller hospitals and
remote places without highly skilled electrocardiographers to perform their routine readings of electrocardiograms. In those places computer electrocardiography may and probably does provide better and cheaper reading of electrocardiograms.  

Current clinical electrocardiography

All are aware of the contribution of electrocardiography to the diagnosis and treatment of all sorts of patients in clinical as well as in epidemiological studies, for men in outer space, for sports medicine, and other fields. Modern medicine would certainly suffer if electrocardiography were to be removed from it.

INADEQUATE STORAGE AND RETRIEVAL FACILITIES

Of all the electrocardiograms ever made probably more than 90 per cent are neatly folded and kept in an envelope in the private file of a doctor somewhere, somehow, or in the patients’ data files of hospitals. In the same envelope or file the results of physical examinations as well as the outcome of laboratory tests, often illegible, can be found. The name of the patient, his initials, his date of birth, and the date the electrocardiogram was recorded may not have been noted on the electrocardiogram; in addition, the 1 mV calibration and the notation of the leads on the strip may be absent. Seldom is such an electrocardiogram of good technical quality, without artefacts, alternating current interference, or baseline drift caused by loosely fitted electrodes. Moreover, it is very difficult, if not impossible, to retrieve such electrocardiograms, for instance when needed for training purposes. An immeasurable amount of electrocardiographic data which could be useful for clinical or epidemiological cardiology is thus quite inaccessible and, to all intents, lost forever.

LACK OF STANDARDISATION

The worldwide application of electrocardiography is paradoxically applied by a total lack of uniformity in electrocardiography equipment and by a Babylonian confusion in electrocardiographic terminology, classification, and criteria. This causes a complete lack of any worldwide, national, or even local system for storage, retrieval, and analysis of electrocardiograms, and interferes with exchange of electrocardiographic data between doctors, hospitals, cities, and countries which is so vital for diagnosis and treatment of cardiac patients and important for epidemiological purposes.

Advantages of computer-assisted electrocardiography

Computerised electrocardiography, if it becomes a reliable and standardised method, can and will modify all these shortcomings, because computers require organisation and well-defined circumstances. Computerised electrocardiography will take care of storage, retrieval, and routine analysis of electrocardiograms. It will eliminate the recording and thus the storage of electrocardiograms of poor technical quality and of electrocardiograms without the necessary identification data of the patient. It will, one hopes, make electrocardiography technically as reliable in operation as a well-functioning telephone system. Computerised electrocardiography will force the user to organise himself to the great advantage of the patient whose electrocardiographic data will be of good technical quality and can be retrieved at will. This aspect of organisation seems to be the most important and most promising aspect of computer-assisted electrocardiography.

Why do we always emphasise the weakest aspect of computer electrocardiography—reading of electrocardiograms—while storage and retrieval barely receive any attention? Reading of electrocardiograms by computer will be helpful in handling large numbers of normal and well defined, easily recognisable abnormal electrocardiograms. If reading of electrocardiograms by computer is not available or not desirable, an adequate electrocardiographic coding system can provide consistent terminology and classification which is a prerequisite for fast data retrieval. So, even without computer analysis of the electrocardiogram, the computer can help to organise recording, storage, and retrieval of electrocardiograms. By using a coding system embedded in simple administrative computer processing, we were able inexpensively to reduce the electrocardiographer’s time to avoid numerical errors and to improve standardisation of nomenclature.

For computer interpretation of clinical electrocardiograms we have employed Pipberger’s program. On the basis of our experience it seems that if one considers different levels of complexity of electrocardiograms and present day limited program reliability reading of electrocardiograms by computer can and should be improved.

Future of computerised electrocardiography

STANDARDISATION OF TERMINOLOGY AND CRITERIA

At the tenth Bethesda conference on optimal electrocardiography a special task force was assigned...
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to consider the quality of electrocardiographic recording. Definite requirements have been outlined for technician training, record format, lead nomenclature, electrocardiographic instrumenta-
tion, functional performance, standards for trans-
mission of electrocardiograms, and computer
acquisition and technical training criteria. Thus
the requirements for the hardware aspects of
(computer-assisted) electrocardiography are well
established for the future. However, only the first
tentative steps have been taken by the World Health
Organisation and the American College of Cardi-
ology to reach an agreement on standardisation of
terminology and interpretation. What has been
possible for aviation should be possible for electro-
cardiography as well. Standardisation of terminology
is one of the cornerstones of present day worldwide
air traffic facilities. Why not try to reach the same
agreements for electrocardiography? A task force
of the World Health Organisation has just published
a report on definitions of terms related to cardiac
rhythm and a classification of cardiac arrhythmias
which also may facilitate coding and analysis of
electrocardiograms. The QRS complex and ST-T
segment, however, still remain terra incognita as
far as any standardisation and/or definition of terms,
let alone criteria, are concerned. Computerised
 electrocardiography certainly will force clinicians
to reach agreement on criteria and nomenclature,
but we still face a long road.

So, one major aspect of future development will
be a worldwide accepted terminology for interpre-
tation and coding of electrocardiograms.

Organisation

In hospitals computer-assisted electrocardiography
can be integrated into a total information system.
This makes it possible to combine and correlate
 electrocardiographic data with other clinical
information such as biochemical tests, x-ray reports,
and the like. In addition, accounting facilities that
can be linked with computerised electrocardio-
graphy may prove of importance for hospital
administration.

The need for larger systems may be counter-
balanced by the development and application of
microprocessors which can be used in the electro-
cardiographic trolleys themselves. Besides signal
control and signal improvement, unconfirmed
reports will then be produced at the bedside,
while overreading and storage of the electro-
cardiograms will take place in a large data base
eventually connected with or integrated into a larger
hospital information system. Non-routine electro-
cardiography like ambulatory and exercise electro-
cardiography will profit from specialised computer
applications derived from standard processing of
electrocardiograms such as data reduction capacity,
 indefatigability, reproducibility, and computational
power.

Hierarchical Analysis Program

There will always be electrocardiograms so
difficult and complex that computer analysis is
impossible. The same holds true for human reading.
Every experienced electrocardiographer will admit
that sometimes, if not often, electrocardiograms
defy his skills.

So, if the future is to bring us fully integrated
computer systems for handling the daily load of
electrocardiograms we must face the fact that the
development of one sophisticated program that is
able to analyse all electrocardiograms without too
many mistakes within a limited time period can be
compared with the pursuit of a mirage. If we
 accept this axiom we should stop trying to develop
programs which can handle every kind of electro-
cardiogram including the very complex and rare—
the human brain is more suited for this. If computer
reading of electrocardiograms should develop into
a respected and useful clinical technique, one that
can also help patients with complicated electro-
cardiographic abnormalities, we need a realistic
approach based on clinical pragmatism rather
than on wishful thinking. Such an approach could
be the development of hierarchical programs. This
would allow for more time and money for other
important aspects of computer-assisted electro-
cardiography, such as storage and retrieval of the
tracings and numerical data.

The first program should be used for electro-
cardiograms drawn from epidemiological studies,
general practice, and small peripheral hospitals.
From these sources we may expect a large number
of normal electrocardiograms. Most available
computer programs will handle these well. The
program itself should be able to identify the
electrocardiograms of a level of complexity un-
suitable for that program. The most important
feature missing in present-day programs is a
decision by the computer that its diagnostic state-
ment about a particular electrocardiogram is
unreliable or uncertain.

A second program should automatically be
called into operation for more complex electro-
cardiograms or, for instance, for electrocardiograms
coming from sources where as a rule abnormal
electrocardiograms are being produced. This
program should at least be able to diagnose the
most common arrhythmias like normal sinus
rhythm with premature complexes or atrial
fibrillation or otherwise state: "undefined rhythm,
for subsequent reading by a cardiologist”. The program should further provide a reliable QRS-ST-T analysis, and again a warning statement should make it possible for the cardiologist to handle the electrocardiogram. It should further provide facilities for comparison with previous electrocardiograms.

The third and most sophisticated program should handle the difficult electrocardiograms from patients in coronary and postsurgical intensive care units. These electrocardiograms usually defy conventional computer analysis. Thus a special program is needed which should also perform a sophisticated rhythm analysis. For those electrocardiograms with the highest level of complexity which the third program cannot handle, a cardiologist is essential.

The future should therefore bring us three different programs each standing on top of the other, or a three-in-one package which, together with human assistance and reading, will provide expert reading of all electrocardiograms.

This approach will save computer time, computer memory, and last but not least, will employ the human mind for those problems it is most suited for, namely the unique ones. The present approach using one program for all electrocardiograms can be termed a failure, at least as far as its contribution to clinical cardiology is concerned.

References

5 Bourdillon PJ, Kilpatrick D. Clinicians, the Mount Sinai Program and the Veterans' Administration Program evaluated against clinico-pathological data derived independently of the electrocardiogram. Eur J Cardiol 1978; 8: 395–412.

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