Standards for electrocardiographs

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The electrocardiogram is perhaps the one diagnostic aid in common use which is more beloved by N.H.S. and university medical physics and electrical engineering departments than any other. Home-made electrocardiograph amplifiers abound by the score and there must be few known mathematical procedures from Fourier analysis to factor analysis which have escaped application in electrocardiography. Despite being the subject of intensive research, there is surprisingly little agreement among cardiologists about, for example, the frequency content of clinical value in the electrocardiogram or the significance of minor ST changes and so on. With the advent of computers into the field of electrocardiograph interpretation, it may be appropriate to borrow the computer adage 'garbage in - garbage out'. In other words, there is little point in arguing about the importance of minor electrocardiographic changes if there is a possibility that they may result from deficiencies in the recording equipment. It is, therefore, worth considering the design of electrocardiographs in detail.

The original electrocardiographs that were developed in the early years of this century (Einthoven, 1908) were bulky, inconvenient to use, and prone to failure, especially when, as so often happened, the string galvanometer broke (Barron, 1950). However, the tracings, which were produced photographically, accurately reflected the signal that reached the electrocardiograph from the patient. With further developments, portable models of such photographic units became available by 1928 (Barron, 1950), but the disadvantage persisted that an immediate reading could not be obtained. The advent of direct-writing electrocardiographs (Duchosal and Luthi, 1932), which only became widely available after the Second World War, seemed to

herald an age of convenience as well as of accuracy, but many lamented the passing of the photographic units, holding that their tracings were better. Nevertheless, direct-writing units have so many advantages that they have become an integral part of medical life.

High standards, however, should not be sacrificed on account of portability and in an attempt to maintain these twin virtues, it became desirable to set out suggested standards that electrocardiographs should meet in order to record electrocardiograms accurately. It is not always that the commercial dictates of the manufacturer coincide with the needs of the purchaser. So far, the most comprehensive, and indeed demanding, set of standards is that proposed by the American Heart Association Committee on Electrocardiography (1967), and other attempts to formulate acceptable standards have been based on this.

Some difficulties in meeting specifications arise because of different requirements in various countries. Factors such as variation in mains frequency mean that filters for the suppression of AC interference behave differently in Europe compared with North Africa. There, too, it has always been customary to use mains-operated direct-writing machines, whereas, in Great Britain as well as in many continental and, importantly, the developing countries, local circumstances have made battery-powered units more popular. It is partly because compact batteries are too weak a source of power to meet some of the demands laid down by the American specifications that it is necessary to appraise these standards to determine whether they are more stringent than sound clinical practice necessarily demands.

Electrocardiographs should be reliable, and easy to operate; well set-out controls not only shorten the recording time but reduce the chance of errors. It would also be useful if machines from different manufacturers were to use the same symbols, colour

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codings, and similar controls, so that an operator could switch from one to another without confusion. The recording paper should be easy to change, and sufficiently wide so that, with the normal standardization, diagnostic tracings can be obtained from the majority of patients. When complexes are too large, there must be provision for halving or even quartering the sensitivity. It is often possible to see more detail if electrocardiograms are recorded at twice the normal paper speed: such a facility is currently available on many machines and could be more widely used. It has also been suggested that this speed be used in conjunction with increased sensitivity, with circuitry to limit the excursion of the stylus during QRS inscription (Butterworth and Glassman, 1973), so that, ideally, a wide range of sensitivities should be provided.

The question of frequency response is of cardinal importance. Much attention is paid to adequate high frequency response, and it has been suggested that the present American specification whereby signals in the range 0 to 50 Hz should be recorded accurately (i.e. within $\pm 6\%$), with a decrease in recording accuracy to approximately 70 per cent of true amplitude at 100 Hz, is inadequate for important fine details (Butterworth and Glassman, 1973). The precise upper limit of accurate frequency response needs determination, in the light of the clinician's needs. While some have suggested that signals of diagnostic value lie in the range 0 to 80 Hz (Stark *et al.*, 1965), others have indicated that high frequency QRS notching of clinical value can be observed using equipment with an accurate frequency response in the range 0 to 1000 Hz (Langner, Geselowitz, and Mansure, 1961). The research worker, should he require to record accurately the high frequency content of an electrocardiograph, will select a unit with this in mind. On the other hand, less attention has been paid to the importance of adequate low frequency response. This is most conveniently measured as the time constant and can easily be checked by the physician or technician making the recording. If the standardization control is depressed so as to produce an initial 1 cm deflection in response to a 1 mV signal, the amplitude of the deflection should wane to 36.8 per cent of the original 1 cm in 3.2 seconds or longer (American Heart Association, 1967). Under these conditions, greater reliance can be placed on the interpretation of slight degrees of ST segment depression or elevation or flattening of the T waves. This is of particular importance after exercise tests, when early junctional ST depression is often seen. With machines that have a poor low frequency response, such depression can be exaggerated and give an erroneous idea of the true magnitude of the

change. There is unfortunately every reason to believe that the majority of machines currently in use in this country fail on this count. Whereas greater high frequency response demands more power than most battery units are capable of providing, the same does not apply to low frequency response, so that there is no reason why this standard should not be achieved.

The choice of paper width is another contentious point, as the chart should ideally be wide enough to enable most recordings to be made at normal sensitivity on a single channel machine. On multi-channel machines that use ink jet or photographic recording, overlap into adjacent areas is possible and this criterion is therefore less important. However, as the paper width is increased, so is the amount of power needed to drive the motor. It is also important to use properly designed and coated recording paper so as to avoid increased 'stiction', i.e. retardation of the stylus movements over the paper due to friction between the stylus and paper.

In this country at present there is no official standard of performance for electrocardiographs (Krikler, 1971); this is also the case in many other European countries. A meaningful international standard is thus desirable and, to this end, a committee formed by the International Electro-Technical Commission, with representatives from most countries where electrocardiographs are made, other than the U.S.A., is preparing recommendations which are awaited with considerable interest. It is clearly important that the expert members of this committee be made aware of the views of cardiologists and their scientific staffs. Designs that are economically and technically desirable for manufacturers may well clash with the interests of those responsible for the use of electrocardiograph machines in clinical situations. It is for this reason that the British Cardiac Society has representatives on committees organized by the British Standards Institute, and they are supported by a small working party which plans at a later stage to look at standards for other equipment used in cardiology. It seems essential to ensure that the voice of the clinician is heard before final recommendations are published.

References

- American Heart Association (1967). Committee on Electrocardiography. Recommendations for standardization of leads and of specifications for instruments in electrocardiography and vectorcardiography. *Circulation*, **35**, 583.
- Barron, S. L. (1950). The development of the electrocardiograph in Great Britain. *British Medical Journal*, **1**, 720.
- Butterworth, J. S., and Glassman, E. (1973). Whither electrocardiography? *American Heart Journal*, **86**, 709.

- Duchosal, P., and Luthi, R. (1932). Portable electrocardiograph giving direct ink tracings. *American Heart Journal*, 7, 798.
- Einthoven, W. (1908). Weiteres über das Elektrokardiogramm. *Pflügers Archiv für die Gesamte Physiologie*, 122, 577.
- Krikler, D. M. (1971). Electrocardiography: standards, techniques, and training. *Lancet*, 2, 310.
- Langner, P. H., Geselowitz, D. B., and Mansure, F. T. (1961). High-frequency components in the electrocardiograms of normal subjects and of patients with coronary heart disease. *American Heart Journal*, 62, 746.
- Stark, L., Dickson, J. F., Whipple, G. H., and Horibe, H. (1965). Remote real-time diagnosis of clinical electrocardiograms by a digital computer system. *Annals of the New York Academy of Sciences*, 126, 851.

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