Jubilee Editorial

Electrocardiography then and now: where next?

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When the Cardiac Society of Great Britain and Ireland met for the first time its initial task was to set up a committee to define the best location for a single chest electrocardiograph lead. The recommendations were agreed with the American Heart Association and a joint report was published in both countries and republished in the first issue of the British Heart Journal. At that time the electrocardiograph was the specialised investigation in cardiology; indeed it was the first clinical tool to become an essential component of cardiac practice since the introduction of the stethoscope, ophthalmoscope, and sphygmomanometer. An indication of its importance is its predominance in the first volume of the British Heart Journal, published in 1939. Of the 23 original articles that appeared that year, the electrocardiograph was the topic, or an important feature, in 12. Its importance remains undiminished. As Fisch has reminded us: it is a non-invasive technique that does not harm the patient; it is inexpensive, simple, and reproducible; it permits serial studies to be made; and provides the only practical means of recording the cardiac action potential. It has several other virtues: it provides an independent marker of myocardial infarction, and enables one to undertake complex electrophysiological analysis through deductive reasoning.

Fifty years before the transformation of the Cardiac Club into the British Cardiac Society, Augustus Desiré Waller recorded the first electrocardiogram in man, using a Lippmann capillary electrometer. Though this technique was impracticable for clinical use, this observation led to the introduction by Einthoven of his string galvanometer as a clinical instrument. This aspect is more fully discussed by Howard Burchell on page 190 of this issue. Once Einthoven had established the basis, he selected the Cambridge Scientific Instrument Company of England as the original manufacturer. Much of the early work on the interpretation of electrocardiograms was carried out by Sir Thomas Lewis in London. Though not the first book on the subject, Lewis's was most influential; and the third edition of his The Mechanism and Graphic Registration of the Heart Beat remains a comprehensive testament to the excellence of his work. Lewis's researches on electrocardiography ended by 1923, though W H Craib carried out electrocardiographic research in his laboratory for another couple of years. Sir Thomas took little direct interest in this work, and it came to a halt after Craib had important disagreements with a number of established authorities, notably Lord Adrian.

The end of the Lewis era

Why did Lewis discontinue his research interests at that stage? It is widely thought that he gave them up because he grew tired of tackling the kinds of questions the instrument could answer and longed for the adventures suggested by his own mind. Drury gave two reasons: Lewis felt that a problem should not be taken up unless it could be carried through; otherwise the researcher would only “foul the nest”. He also believed that if one had the capacity “one should try and skim the cream off the milk and leave the skim to others”. Lewis's own earlier comments, however, suggested that, at the age of 43, he had become weary of being tied to an elaborate instrument and that he had come to the natural end of his studies on the disordered action of the heart. Paroxysmal tachycardia eluded him because it could not then be produced experimentally, and he had great intuition in foreseeing what problems a certain method was capable of solving. Certainly intracardiac electrography and programmed stimulation later provided the tools to explain arrhythmias, very

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much in the terms that he had already predicted. Lewis had never explored the importance of the electrocardiograph in the study of ischaemic heart disease, nor did he do so in the next few years, when the early observations of Pardee were extended and further analysed, especially by Levine.

British cardiologists stepped back from greater involvement in research in electrocardiography at the very time when others, notably David Scherf, then of Vienna, and Lewis's own good friend and fellow bird-watcher, Frank N Wilson, of Ann Arbor, Michigan, were enhancing its dimensions. Wilson recognised the dependence of his dipole theory on the basic work of Craib, who had called the same phenomenon "the doublet" a few years earlier. But many papers from British institutions appeared, covering a host of aspects. To take two examples of such groups, both Wood and Selzer took a practical interest in electrocardiography. Both groups strongly favoured the use of specific bipolar (CR) chest leads, but Wilson's unipolar chest leads gradually prevailed—though as late as 1939 he was a co-signatory to the recommendation of a single bipolar chest lead.

When the Cardiac Society was established the electrocardiograph was either hospital based or used in the consulting room. The development of portable apparatus, battery operated in some cases, allowed it to be taken to the patient's home. This was at first somewhat impractical because the photographic recordings had to be developed, though with some machines this could be done on the spot. The first direct-writing units were becoming available (not always with enhancement of the quality of the tracings) but they only became more widely used from 1950 onwards.

**Newer applications**

At this stage the electrocardiograph had achieved considerable practical value in the diagnosis of cardiac ischaemia, notably myocardial infarction, and simple exercise tests aimed at reproducing angina and displaying ST segment changes had been introduced. Arrhythmias could be diagnosed solely on recordings made at the time of an attack—long term ambulatory tracings were yet to come. Conduction defects were better defined—the patterns of right and left bundle branch block were now correctly appreciated and the misunderstandings based on earlier observations in canine studies had long been rectified—but the significance of conspicuous left or right axis deviation as possible markers of impaired conduction in the left bundle branch system was not yet recognised. The principles of vectorcardiography, a technique which never achieved widespread independent application, had an important impact on this aspect of electrocardiography.

Parkinson was among the original authors of the classic paper on pre-excitation though an earlier case, the first ever reported, also exemplified Anglo-American collaboration. British electrocardiographers were well aware of the pattern of the Wolff-Parkinson-White syndrome. Criteria for ventricular hypertrophy were still to be established though the studies of Wood and Selzer had led to tentative answers. The intricate analysis of the electrocardiogram, to which Lewis had paid so much attention, received further consideration elsewhere and concepts such as concealed conduction, aberration, and overdrive suppression that can be identified in Lewis's early writings were amplified by workers in other countries. Many of them were continental cardiologists who had emigrated to the United States to escape persecution. Among those who made their home in Britain were Adolf Schott, who collaborated closely with Scherf, and Cornelio Papp, a former assistant editor of the British Heart Journal. They played a crucial role in the teaching of electrocardiographic advances.

**Intracardiac electrocardiography and electrophysiological testing**

Intracardiac electrocardiography was first carried out in France during the second world war and extended over the next two decades in the Netherlands. The first clinical intracardiac recording of activity of the bundle of His was, however, reported from Dundee in 1967. Once the techniques had become refined and standardised, intracardiac electrography and programmed electric stimulation of the heart proved to be valuable research tools with wide application to the study of arrhythmia and conduction disturbance (linked with the development of cardiac pacemaking). So where do we stand on these and related issues now, more than 15 years after programmed stimulation became generally available?

Originally it seemed likely that intracardiac recording techniques would prove helpful in the diagnosis of those at risk of sinoatrial or advanced atrioventricular block; however, they have served to point the way rather than precisely to define those likely soon to need pacemakers. None the less, knowledge from such studies has added to the general body of information, including that based on sound history taking and identification of lesser degrees of conduction impairment on the electrocardiogram, and this has helped to restore decision-making to the clinician.
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Performance—for example, overdrive pacing of the atrium in order to assess sinus node recovery time or measurement of conduction between stimulated atrium and the sinus node—have enhanced our knowledge of sinus node behaviour and established the relatively benign prognosis of pure sinus node block; however, this technique usually only identifies patients in whom the disorder could otherwise be detected more simply. Epidemiological studies have aided us in focusing on population groups who are more susceptible to sinus node disease and on the prognosis in atrioventricular block. The electrophysiological discrimination between carotid sinus hypersensitivity and sinus node disease has, however, proved elusive. The overlap between these two entities may well be responsible for such difficulties.

Antiarrhythmic agents

Reentrant atrioventricular tachycardias, whether intranodal or associated with an accessory atrioventricular pathway, have provided a rich harvest for electrophysiological investigators. The clinical value of such studies is already demonstrable in those few patients who may need invasive treatment, which now includes antitachycardia pacing devices or surgical or endocavitary ablation of normal conducting tissue or an accessory pathway. Much has been gleaned of pharmacological values. It has been possible, for example, to demonstrate that the atrioventricular node is the site of action when such arrhythmias are terminated by calcium antagonists, and thus to corroborate hypotheses based on knowledge of the cellular properties of such agents and on electrocardiographic findings. Indeed it has been possible to discriminate between electrophysiologically active calcium agents and those that lack such properties at the clinical level, but prediction of prophylactic value has also been elusive. Again, empirical observations have added to the knowledge that enables us to choose agents on a clinical basis—a term that includes the use of the surface electrocardiogram.

Electrophysiological studies have also improved the diagnosis of such arrhythmias. Wellens, in particular, has shown how programmed stimulation has generated important information that has enhanced the level of electrocardiographic analysis of arrhythmias. Thus in most patients with paroxysmal atrioventricular tachycardia, electrophysiological study can be withheld unless standard medical management fails, and precise knowledge of the anatomy of the atrioventricular connection, including its location and the possibility of multiple links, is required before the use of a pacing device, ablative technique, or surgical operation is considered. But this is not to deny the relevance of including questions of research importance when performing such studies. We need to know more about atrioventricular nodal function and whether the dual nodal pathways that are responsible for arrhythmias have an undiscovered anatomical basis or represent derangements of physiological function—perhaps of an interplay between autonomic factors, neuropeptides, and purines.

Such studies are also needed to explain the basis for operations on the surface of the atrioventricular node that appear to prevent such arrhythmias and thus to answer the important anatomical question that has never been resolved to the satisfaction of all workers—are such arrhythmias purely intranodal or is adjacent atrium an essential component of the circuit?

Ventricular arrhythmias

Supraventricular tachycardias are straightforward compared with the questions prompted by ventricular arrhythmias and the resuscitation of those who had apparently dropped dead. There is much contention as to whether groups at risk of sudden death are reliably defined and their prognosis improved by electrophysiological testing. Criteria for standardised testing in ventricular arrhythmias have been defined and agreed. These rules can be followed by others, but the question that remains unanswered, after more than a dozen years of worldwide investigation, is the value of electrophysiological testing in this condition and in choosing appropriate medications to prevent ventricular tachycardia. In other conditions we can rely more on the electrocardiogram and at least test its ability to teach us the essentials. Its potential usefulness in discriminating among patients who have right ventricular abnormalities, that is between those with a benign prognosis and those at risk of arrhythmia and possible sudden death, is intriguing. The additional presence of visible late potentials in the surface electrocardiogram of some of these cases may well link up with related observations after acute myocardial infarction.

Back to the electrocardiogram

The electrocardiogram—one hundred years old—is indeed a classic, though not in the clinical form that we know. The string galvanometer and its successors have been cardiological tools for 80 years and the subject of fundamental contributions to the Cardiac Club, British Cardiac Society, and British Heart Journal, and, more extensively, to other
learned societies and publications throughout the world. Interestingly, however, the basic principles are little different from those used by Sir Thomas Lewis. He might have been surprised that there was more to be learnt, and gratified that serious workers in this field still consult his writings before describing apparently new disorders of rhythm or conduction. 55

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