The Beginnings and Development of the Electrocardiograph

EMM Besterman

In 1791, Galvani, in Italy, first showed electromotor activity in the leg muscle of the frog (1). Action potentials of skeletal muscle were later found by several physiologists in the 19th century and in the 1870s, electromotor phenomena were found in heart muscle using exposed animal hearts. Lippman in Paris, in 1872, invented the capillary electrometer which could demonstrate cardiac electrical activity without having to expose the heart (2). This sensitive but sluggish apparatus consisted of sulphuric acid and mercury in a capillary tube with wires at each end (Fig. 1). Movements of the meniscus

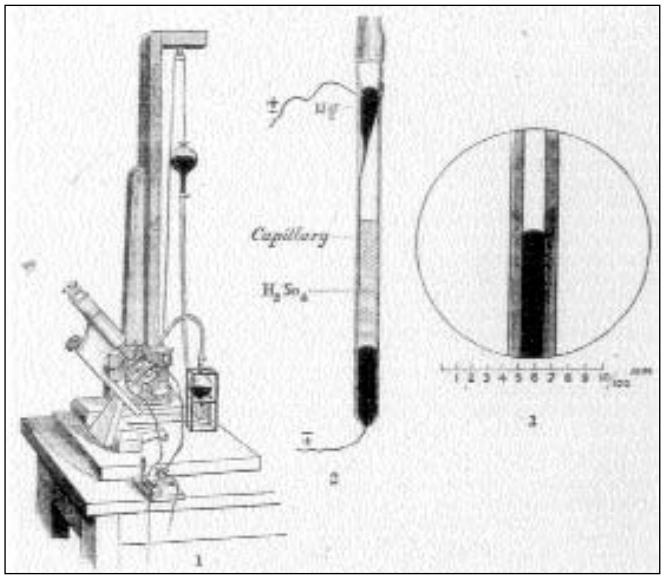

Fig. 1: Lippman Capillary Electrometer

were recorded photographically. This device was used to make the first records of human cardiac activity from wires at the person's extremities, with both hands in tubs of saline.

Augustus Desire Waller, who dipped his hands and saw the mercury column pulsate in time with his heart beat, was the pioneer of this (3). Waller was professor of physiology at St Mary's Hospital Medical School in London and used his full name to distinguish himself from his eminent father Augustus Volnay who had described nerve degeneration. The electrogram, as he called it, was recorded from a light beam on the mercury meniscus aimed at a slowly moving toy train carrying photographic plates (Fig. 2). Waller's dog Jimmy, (Fig. 3), standing in saline jars was his collaborator

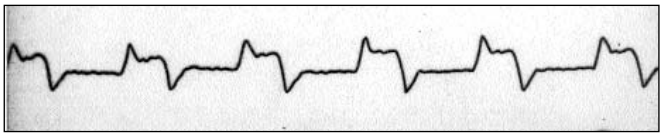

Fig. 2: An electrogram recorded by Waller using the Lippmann electrometer.

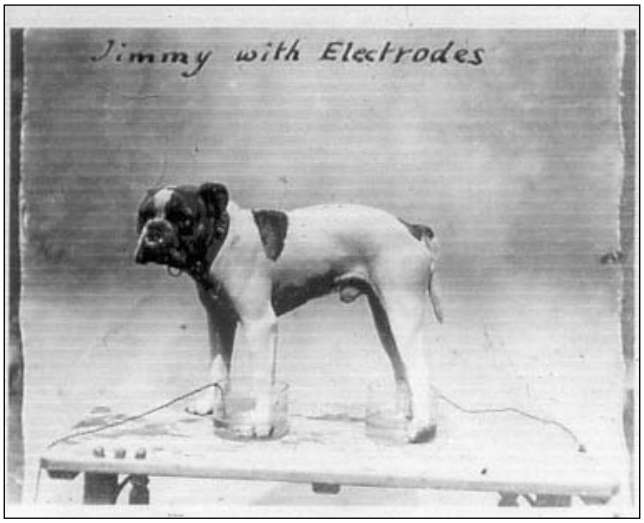

Fig. 3: Waller's dog, Jimmy, connected for electrogram with feet in saline.

and provoked a question in the House of Commons: "At the Royal Society, a bull dog was cruelly treated when a leather strap with sharp nails was wound round his neck and his feet immersed in glass jars containing salts. Surely, such procedure should be dealt with under the Cruelty to Animals Act?" The Minister's reply was "the dog wore a collar ornamented with brass studs. If my honourable friend had ever paddled in the sea, he would appreciated the pleasant sensation of this experience" (4, 5). We found Waller's apparatus in the physiology Department of St Mary's and moved it to the newly created Waller Cardiac Department. It was later divided

From: Department of Medicine, Faculty of Medical Sciences, The University of the West Indies, Kingston 7, Jamaica, West Indies.

Correspondence: Professor EMM Besterman, Department of Medicine, Faculty of Medical Sciences, The University of the West Indies, Kingston 7, Jamaica, West Indies. Fax: (876) 977-0691.

between the Science Museum and British Cardiac Society in London. Waller was author of a physiology textbook and in 1917 (6) he presented a paper on 2000 electrocardiograms (ECG). Ironically, he had previously stated that he had no idea that the electrical signs of the heart's action could ever be utilized for clinical investigations. He was nominated for the Nobel Prize along with Einthoven but died before it could be presented, so Einthoven alone received it. Waller's daughter, Mary, physics professor at the Royal Free Hospital, told me that Sir Thomas Lewis credited Waller with the invention of the term electrocardiogram (7). She felt that her father had never received adequate recognition from posterity.

The Dutch physiologist Einthoven was in Waller's audience in 1887 and reproduced his findings with a Lippman electrometer. He labelled the deflections PQRST. The origins of this nomenclature are still debated. A and C were pulse waves which may explain failure to use ABCDE. Another theory is that PQRST are five consecutive consonants, so what is wrong with a vowel? Descartes is even dragged in for his geometric convention of straight lines beginning with A and curved lines with P (8).

Einthoven developed the string galvanometer as a more sensitive and less sluggish device than the electrometer and it has been in use subsequently. A silver coated quartz thread was suspended between the poles of an electromagnet. The patient's electric current moved the thread according to the strength of the current. A light focussed on this thread and then on to a slowly falling photographic plate producing the ECG tracing. The thread was made as fine as possible; then by attaching one end to an arrow, then fired in the laboratory. Einthoven's original machine weighed 500 pounds and needed five operators (9). Conflicts then arose between commercial firms about production of a smaller marketable machine. Finally, it devolved upon the English Cambridge Instrument Company, owned and run by Horace Darwin, son of the great Charles Darwin. The Company still remained in this family decades later when I worked with them. Their first three machines were presented to British cardiologists of whom Thomas Lewis is best known. For many years, these machines were virtually unchanged (Fig. 4). In an early House physician post, I restored one of these. The patient had to come to the large machine; the photographic plates had to be developed to ensure a satisfactory trace and three quarters of an hour later the patient could leave. Next day, with a dry negative, I could make contact prints for the patient's notes: a one-hour procedure at best. Contact electrodes had appeared in the 1920s when three standard leads only were recorded. Suction electrodes allowed chest leads in the 1930s.

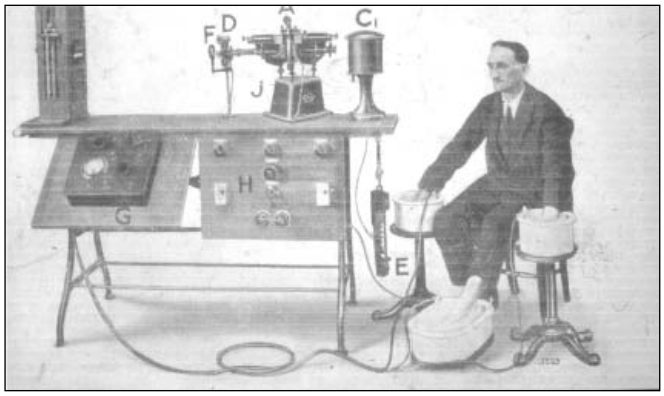

Fig. 4: A 1920 Cambridge electrocardiogram, before the invention of contact electrodes.

Compact, portable direct writing ECG machines were designed by Duchosal in Switzerland in 1932 (10). In the United States of America, Wilson (11) showed the value of multiple chest leads, but he is best known for introducing unipolar limb and chest leads. Formerly limb leads reflected potential difference between the extremities (lead 1, 2, 3). Wilson obtained direct measurement of potentials by connecting all three limb leads as the indifferent, then an exploratory electrode reflected the true potential at its site of application. Later, 1n 1942, Golberger augmented unipolar leads by removing resistors from the circuits giving aVr, aV1, aVf. These technical modifications to the ECG machine led to the modern recording from 12 leads; three bipolar and three unipolar limb leads and six unipolar chest leads.

The application of electrocardiography started with the study of arrythmias. Auricular, now atrial, fibrillation had been studied by physiologists using indirect arterial pulse tracings. Lewis described ECG findings in both fibrillation and flutter, postulating the circus movement theory of causation (12). Lewis also recorded paroxysmal tachycardia. The ECG of complete heart block both in man and experimental animals was published by Einthoven in 1906 (8) and Lewis in 1910 (13). In the 1920s, there were many studies of bundle branch block, culminating with a paper by Wilson (14).

The ECG changes of myocardial infarction were described by Pardee in 1920 (15). In 1931, Wood first used exercise to provoke ECG changes in suspected angina (16). The ECG changes of left and right ventricular hypertrophy, p mitrale, and extrasystoles were all described by Einthoven (9).

For details on the history of electrocardiography see "A History of Electrocardiography," Burch and DePasquale, Year Book Publishers 1964, Chicago.

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