Scanning Our Past From the Netherlands

THE ELECTROCARDIOGRAM CENTENNIAL: WILLEM EINTHOVEN (1860–1927)

I. INTRODUCTION

The partnership between medicine and electrical technology has been a long and productive relationship.

One of the first links between the medical arts and the electrical world was created by Mr. L. Galvani, who stimulated frog legs to move when a voltage was applied to their muscles. That effect was not fully pursued at the time and the stethoscope remained for a long time the most important and most impressive instrument a physician had to rely upon to determine the medical condition of his patients.

However, in the period after the discovery of radio waves by Heinrich Hertz and before the invention of the thermionic vacuum tube (now the electron tube) by John Ambrose Fleming, Willem Einthoven (Fig. 1) invented the *cardiograph*. This took place after he thoroughly investigated the physiology of the human body, using the basic understanding of physics as available at that time. This fundamental new medical instrument was a major achievement that gave a new dimension to the understanding of potential heart problems. It tremendously improved the quality of human life.

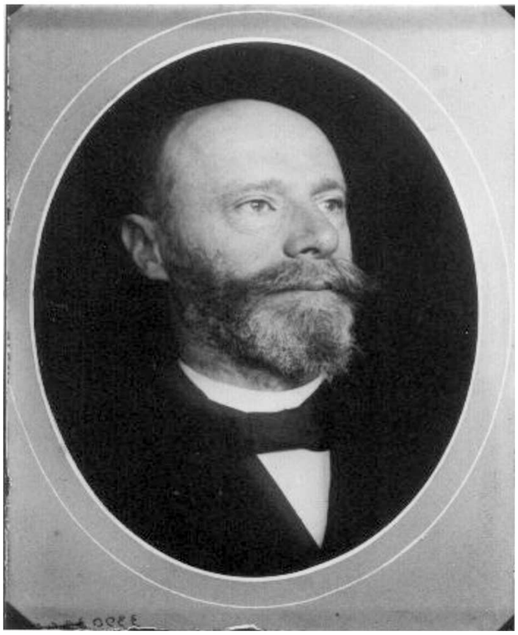

Fig. 1. *Prof. Dr. W. Einthoven. Courtesy of the University of Leiden, The Netherlands.*

In 1924 Willen Einthoven was awarded the Nobel Prize for his important contributions to society, including the development of the first cardiograph.

The modern version of the cardiograph with all its new electronic advancements is still a basic diagnostic instrument for the medical profession. After finishing his education as a medical doctor, Einthoven would soon follow his ambition to investigate the effects of the newly gained knowledge on electricity and applying the physics of the human physiology, as well as the use of their tools and instruments. Einthoven was appointed professor at the University of Leiden in the Netherlands at the age of 25.

Most of his studies were directed towards electrophysiology on human behavior, in particular how to make this science beneficial to the patients; studies on the bronchia and, in particular, on the eye were included. New experiments he undertook were directed toward investigations on electricity within corporal bodies.

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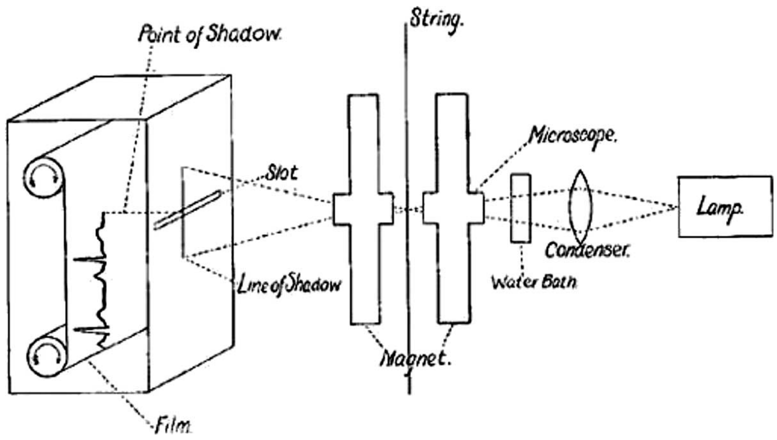

Fig. 2. *Schematic diagram of string galvanometer of Einthoven for ECG. Courtesy of the University of Leiden, The Netherlands.*

Initially, he experimented with turtles and made holes in their shield to see if any electrical current could be detected below that shield, continuing the experiments Etienne-Jules Marey started in 1876.

II. STRING GALVANOMETER USED AS AN ELECTROCARDIOGRAPH

The most sensitive instruments of that time were the galvanometer and the capillary galvanoscope of Gabriel Lippmann, in which a drop of mercury in a horizontal tube moved under the influence of an applied electric field. Einthoven introduced the so-called String Galvanometer (Figs. 2 and 3), whereby the commonly used coil in a magnetic field is replaced by a single thin wire. Actually, the string consisted of a silver-coated quartz wire.

The movements of that string, caused by any current in that wire, were observed with a microscope or projected on a photographic film. The shadow of the string passed a slot in the cover of a moving photographic film and resulted in the *electrocardiogram*, known today as an ECG (1902). During his investigations, Einthoven also recognized the classic types of heart rhythms that constitute the ECG.

III. EARLY ECG RECORDING IN 1902

The sensors attached to a patient consisted often of two or three separate buckets with a salt solution, in which the patient had to put his hands and feet (Figs. 4 and 5) for good electrical contact. These new ECG arrangements allowed telemetry in the early days of telecommunications because telephone wires could be used to interconnect the patient and the heavy ECG recorder over a distance of 1.5 km between the university hospital and his laboratory. In those days, electromagnetic compatibility was apparently not yet a hot item in the healthcare field!

By 1895, Einthoven developed the labelling of heart beat in time zones, indicated as **P**, **Q**, **R**, **S**, and **T** time

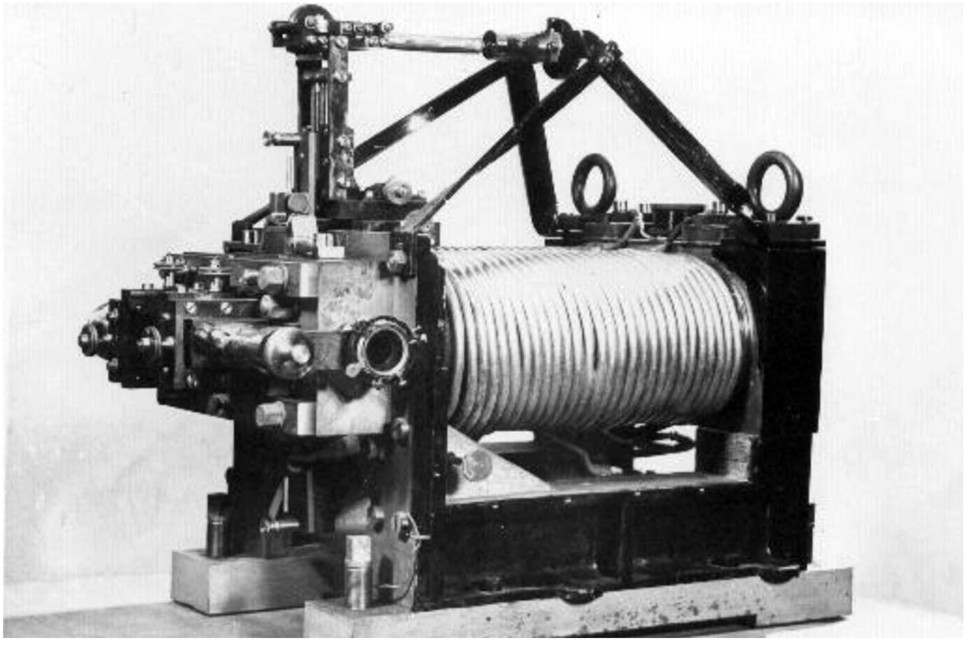

Fig. 3. *String galvanometer of Einthoven, including cooled magnet, vertically mounted string, and an optical viewer. Courtesy of the University of Leiden, The Netherlands.*

Fig. 4. *Patient with electrical contacts made in salt solution. Courtesy of the University of Leiden, The Netherlands.*

zones, a convention which is still in use [Fig. 6]. Einthoven initially reported his invention in 1901 and published his first electrocardiogram in 1902. By 1906, he was able to publish a seminar paper with recordings of several human arrhythmias, but even much earlier, in 1893, he had seen that electrocardiography would be a new method of clinical investigation. His string galvanometer, together with Roentgen's discovery of X-rays, revolutionized clinical diagnosis.

IV. STRING GALVANOMETER USED FOR RECEPTION OF RADIO TELEGRAPHY

In the early days of radio, the same string galvanometer instrument was also used to improve the reception of radio telegraphy. For that purpose, Willem Einthoven, Sr., assisted by Frederic Willem Einthoven, Jr. (1893–1944), an electrotechnical engineer, mechanically tuned the string ($l = 8$ mm) in its vacuum container for resonance to the frequency of the radio telegraph transmitter carrier

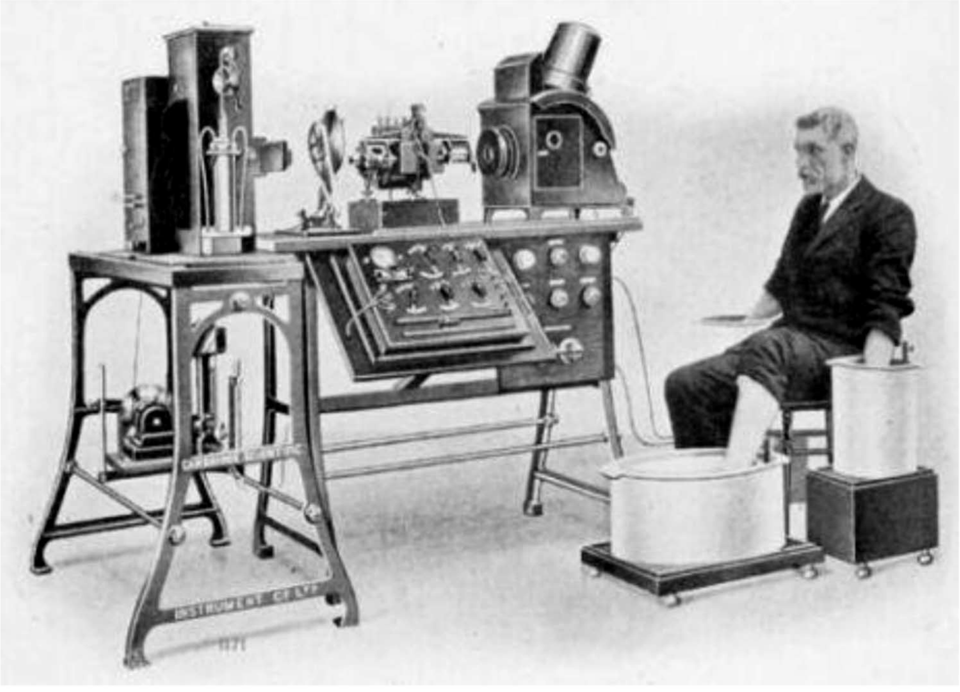

Fig. 5. *Complete instrumentation for ECG. Courtesy of the University of Leiden, The Netherlands.*

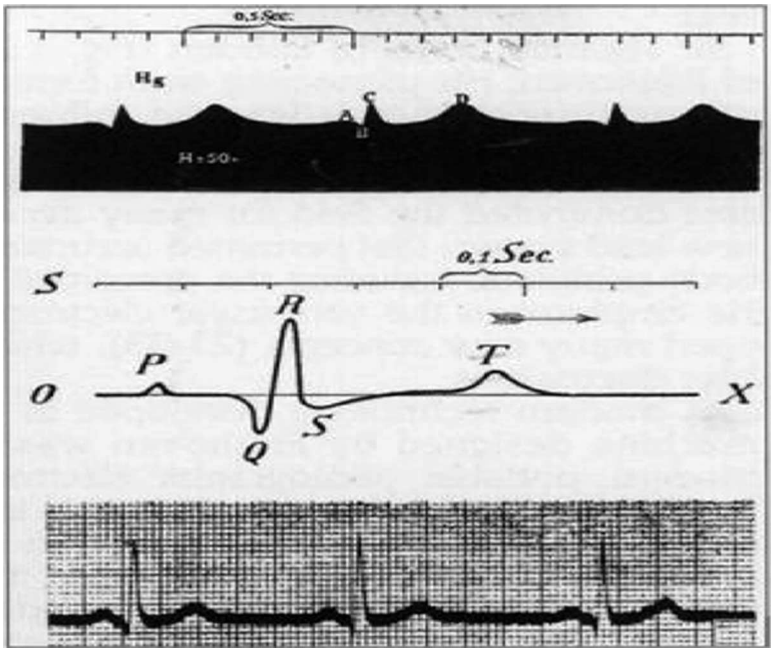

Fig. 6. *Electrocardiogram with P, Q, R, S, and T zones. Courtesy of the University of Leiden, The Netherlands.*

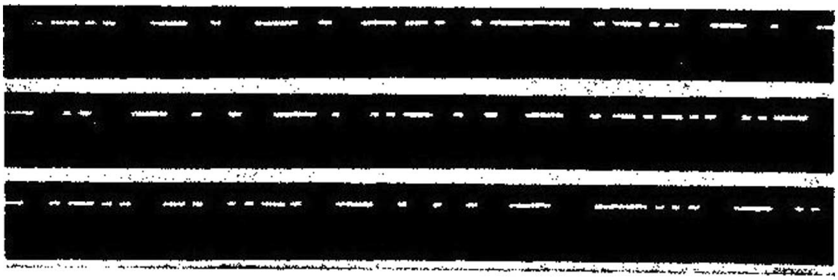

Fig. 7. *Recording of station call received from Bandoeng station. Courtesy of the University of Leiden, The Netherlands.*

(40 kHz) to improve the sensitivity and the selectivity of the receiver. By 1923, this instrument was used as a receiver for on/off keying telegraph radio transmissions between the Netherlands and the former Dutch East-Indies (Bandoeng, Indonesia), over a distance of 12 000 km, using a rotating machine transmitter and long-wire antenna for a wavelength of 7.5 km (40 kHz) (Fig. 7).

V. NOBEL PRIZE

In 1924, Willem Einthoven was awarded the Nobel Prize for his important contributions to society. His final remarks, made at his Nobel Lecture, Dec. 11, 1925, were as follows:

> . . .but in addition, innumerable other workers in the field of electrocardiography have gained great merit. We cannot now name them all but we conclude with a reference to the happy circumstance that investigators of the whole world have worked together. A new chapter has been opened in the study of heart diseases, not by the work of a single investigator, but by that of many talented men, who have not been influenced in their work by political boundaries and, distributed over the whole surface of the earth, have devoted their powers to an ideal purpose, the advance of knowledge by which, finally, suffering mankind is helped.

In 1956 the University of Leiden established the Einthoven Lecture and the Einthoven Award. In 2002 Michael R. Rosen commemorated Einthoven in the ECG Centennial Lecture: The ECG 100 years later; electrical insights into molecular messages.

Those interested in the developments of electrocardiography should refer to the international Einthoven Foundation, which can be found on the Internet. ■

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