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Review Article

Brief History of the Creation of a Diagnostic Method of Electrocardiography

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Received: November 04, 2022; **Published:** December 16, 2022

Abstract

In medical biophysics, we are dealing with the physical and biophysical principles of biomedical methods and devices and their interactions with the human body which makes them useful in health care, including patient and user safety aspects and healthcare quality issues. Electrography combines such important diagnostic methods of recording the electrical activity of organs and tissues as follows: electrocardiography (ECG) which is used to study the electrical activity of human hearts; electroencephalography (EEG) which is used to study the electrical activity of human brain; electromyography (EMG) which is used to study the electrical activity of human muscles, etc. Here, our main focus will be on (a) a brief history of the emergence of the ECG method first studied by Waller in 1887 and then intensively continued by Einthoven during 1896 - 1903 (Nobel Prize in Physiology or Medicine in 1924), as well as on (b) the medical and biophysical foundations of the ECG method based on recording of electrical potential changes in the heart due to passage of an electrical impulse during the cardiocycle [1-3].

Keywords: *Electrocardiography; Current Dipole; Electric Heart Generator; Electric Potential*

Introduction

Prehistory

The field of electrophysiology dates back to an Italian physician Luigi Galvani (1737-1798). He was the first who discovered a so-called "animal electricity" in 1771. In 1791, he wrote his main scientific work about electrical forces at muscular movement. Therefore, Luigi Galvani is rightfully considered to be a "father" of electrophysiology. It is worthy to mention that another famous Italian scientist, a physicist Alessandro Volta (in honor to whom we have a well-known unit of voltage and electric potential - "volt"), has introduced such a title "Galvanization" for one of Galvani's discovery.

Waller's results and findings

The first scientist who received an electrocardiogram in 1887 was a British physiologist Augustus Desiré Waller (1856-1922) of St Mary's Medical School, London. Waller used a capillary electrometer, a device that featured a tube of mercury, being a liquid that conducts electricity. When an electrical current generated from a patient's heart was applied to the tube, it changed the surface tension of the column of mercury, causing the meniscus to shift. This change could then be observed through a microscope and photographed.

Such measurement technique, though slow and imprecise, made a big impression on a very important witness at the demonstration - Willem Einthoven - who would soon invent the electrocardiograph (see figure 1).

Figure 1: *The first electrocardiograph to measure the electric activity of the human heart invented by Willem Einthoven in 1903.*

It is interesting to note that Augustus D. Waller has used his pet bulldog Jimmy as the first signal source and the capillary electrometer as the recording device.

Figure 2: *A.D. Waller with his doggy.*

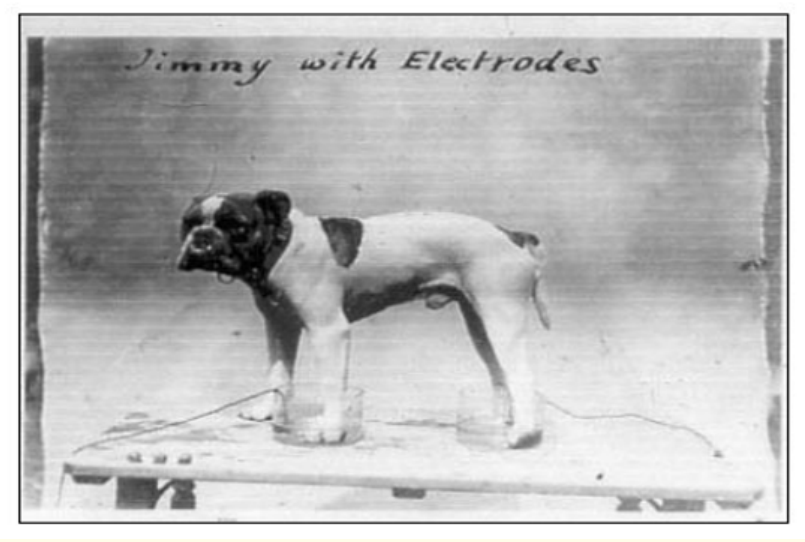

Figure 3: *Waller's dog, Jimmy, connected for electrogram with feet in saline.*

Einthoven's results and findings

In 1903, Dutch physiologist Willem Einthoven has invented the first electrocardiograph to measure the electric activity of the human heart. It is interesting to know that its mass was 270 kg and it was served by 5 persons. Einthoven actually used the Waller's technology by employing the string galvanometer as the recording device and using human subjects with a variety of cardiac abnormalities.

Einthoven is chiefly responsible for introducing some concepts still in use today, including the labeling of the various waves, defining some of the standard recording sites using the arms and legs, and developing the first theoretical construct whereby the heart is modeled as a single time varying dipole. W. Einthoven proposed to consider the electric activity of the human heart as being similar to the electric activity of the current dipole (See below).

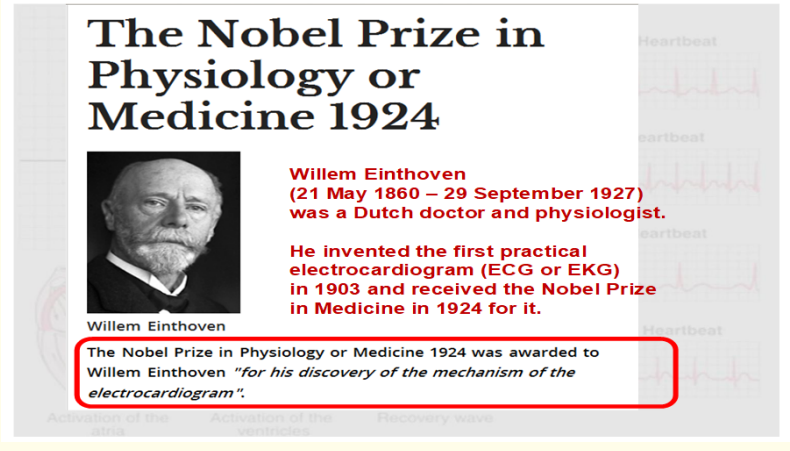

Figure 4

Augustus Waller did not become the Nobel Prize laureate of which he was absolutely worthy along with Willem Einthoven, since he unfortunately died two years before the 1924 Nobel Prize in Physiology or Medicine was awarded to Willem Einthoven.

The medical and biophysical foundations of the ECG method

Consider the main provisions of the Einthoven's concept which underlies the method of electrocardiography.

- **Current dipole:** Current dipole is a system consisting of two currents + I and – I which are equal in magnitude and opposite in direction. Current dipole moment D is a product $D = I \times L$, where *I* is the current strength, and *L* is the vector joined the dipole negative and positive poles. The unit of measurement for the current dipole moment D is the product of an ampere (A) per meter (m), i.e. $[D] = A \cdot m.$ According to the Hodgkin-Huxley model of action potential (AP) generation and propagation (The Nobel Prize in Physiology or Medicine for discoveries concerning ionic mechanisms of excitation and inhibition in the peripheral and central regions of the nerve cell membrane was awarded to John Eccles, Alan Hodgkin, Andrew Fielding Huxley in 1963) [4], the real basis for the two currents in a current dipole are the sodium current during depolarization process and potassium current during repolarization process in the AP formation.

- **Electric heart generator:** A total potential of the heart electric field consists of electric potentials created by separate elementary current dipoles and has a name "electric heart generator" or "integral electric heart vector". The electrical potential φ of the electric heart generator may be presented by the following formula (see details in [1]):

$$\varphi = \frac{\rho D_c \cos\alpha}{4\pi r^2}.$$

Here ρ is a specific resistance of myocardium; D_c is the equivalent electric heart generator, being the vector sum of a general number n of elementary current dipoles D_i of the heart; r is the distance from the centre of the equivalent electric heart generator D_c to a point on the arm or leg where the electric potential of the heart is measured in a specific lead; α is the angle between the vector $\vec{D}_c$ and the direction $\vec{r}$ to the electric potential measurement point in the fixed lead.

- **Einthoven's system of leads:** W. Einthoven introduced the following system of leads which gives a possibility to measure the potential differences: (a) in the 1st lead between the right hand and left hand; (b) in the 2nd lead between the right hand and left leg; (c) in the 3rd lead between the left hand and left leg.

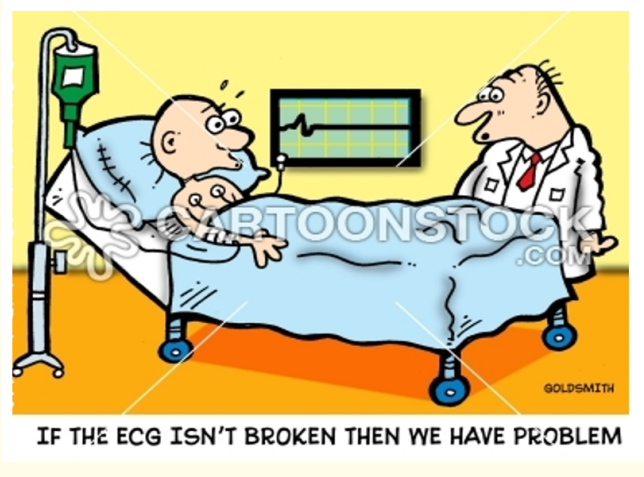

Figure 5

Conclusion

The heart is an organ of the human body, which works like an electrical generator, creating a different in electrical potentials. Such an electrical-potential difference (heart voltage) can be measured non-invasively and be used to precise diagnosis of cardiac function. In this article, we told a brief history of the discovery of the electrocardiography method, being one of the most important achievements of the human mind, in the works of its first creators Augustus Waller and Willem Einthoven, winner of the 1924 Nobel Prize in Physiology or Medicine.

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Volume 6 Issue 1 January 2023