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The Electrocardiogram-ECG: An Application of Physics

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Abstract

The ECG, also known as an electrocardiogram, is sometimes referred to as the "poor man's angiogram" because to its price, availability, sensitivity, and specificity. The Dutch physician Einthovan created the electrocardiogram (ECG) in 1902, and it was thanks to his enormous contributions to clinical research over a ten-year period that the technique's full therapeutic potential came to light. An EKG is a crucial component of the first assessment of a patient who may have cardiac-related issues. The basic heart anatomy and electrical conduction system are reviewed, the ECG signs are illustrated, and the ECG preparation, technique, and clinical importance are described. One of the physics applications created for the diagnosis of various cardiac disorders is the electrocardiogram.In fact, it is referred to as the "poor man's cardiogram.". The EKG has been shown to be helpful among healthcare professionals in a hospital setting, particularly in intensive and cardiac care units where 24-hour monitoring of critically ill patients is necessary. Their understanding of the proper placement of EKG leads, EKG analysis, and thrombolytic therapy in patients with acute coronary syndrome has major implications for lowering morbidity and death.In general, it has been demonstrated that this use of physics benefits the entire medical community.This research paper focuses on the ECG's brief history, the heart's physiology, its principles, and its indications.

Introduction

Electrocardiogram or the ECG is considered as the poor man's angiogram in true sense because of its affordability, availability, sensitivity and specificity. The Dutch physician Einthovan created the electrocardiogram (ECG) in 1902, and it was thanks to his enormous contributions to clinical research over a ten-year period that the technique's full therapeutic potential came to light. An EKG is a crucial component of the first assessment of a patient who may have cardiac-related issues. The basic heart anatomy and electrical conduction system are reviewed, the ECG signs are illustrated, and the ECG preparation, technique, and clinical importance are described.(1) A non-invasive diagnostic technique that has a significant clinical impact on determining the severity of cardiovascular disorders is the electrocardiogram (ECG).[(2)]It has saved lives of many from a severe ventricular tachycardia or an Intra Ventricular rhythm or a dangerous Cardiac arrest. Even in the moden age of diagnosis and treatment ECG stands as the fundamental pillar of modern cardiology. At its core, the ECG is not only a medical tool but also a testament to the deep interconnection between medicine and physics. Considering the Indian healthcare system and the strata of our population and increasing cases of non-communicable diseases in the society, ECG has been a standalone in the screening and diagnosis of various cardic diseases which go silent for years. Given that cardiovascular illness is the leading cause of mortality, it is crucial for medical professionals to get expertise in reading ECGs in order to give the best care possible as soon as possible. Being an application of physics, I would like to review the ECG and its application in this research article.

Physiology of Heart and the Principle of ECG

Two atria and two ventricles make up the four chambers that make up the heart. The atria are low-pressure, thin-walled pumps that take blood from the veins. The majority of the heart's pacemakers are a collection of cells that are found in the top right atrium. The Sino Atrial Node is what this is known as. An extracellular potential field is created by a complicated change in ionic concentration across cell membranes (the current source), which subsequently excites nearby cells and causes a cell-to-cell propagation of electrical events. These potential fields extend to the body surface because the body functions as a fully resistive medium.(11) The amount of tissue that is activating at once, as well as the relative speed and direction of the activation wavefront, all affect how the body surface waves behave. As a result, the ECG does not show the pacemaker potentials produced by a tiny tissue mass. The beginning of electrical activity is detected on the skin and the first ECG wave of the cardiac cycle is noticed as the activation wavefront meets the larger mass of atrial muscle. (11) The P wave shows that the atria are activated. The His-Purkinje system and the A-V node are two specialized cardiac cells that conduct the cardiac impulse from the atria, but they are both too small in mass to produce a signal that is large enough to be visible on a typical ECG. The P wave is followed by a brief, mostly isoelectric period. A rapid and significant deflection is observed on the body surface once the enormous muscular mass of the ventricles is activated. The main force for pumping blood to the body's organs comes from the contraction of the ventricles, which is triggered by their excitement.This large wave appears to have several components . The Q wave represents the beginning downward deflection, the R wave represents the starting upward deflection, and the S wave represents the final downward deflection. The location of the leads on the body, as well as a wide range of potential disorders, affect the polarity and actual presence of these three components. Regardless of its structure, the big ventricular waveform is typically referred to as the QRS complex. The QRS complex is followed by another brief, substantially isoelectric phase. After this brief period, the ventricles resume their electrical resting state, and a wave of repolarization known as the T wave is observed as a low-frequency signal. In some individuals, a small peak occurs at the end or after the T wave and is the U wave. Its origin has never been fully established, but it is believed to be a repolarization potential.(12)

History of ECG

The invention of the string galvanometer was made by Einthoven, the Father of the electrocardiogram, to capture the electrical potentials produced by the electrical activity of the heart as they traveled through the body's tissues.In Leiden, The Netherlands, he was employed by his lab.The string galvanometer was more sensitive, less subject to damping, and easier to use. The original Leiden device was gigantic, taking up two rooms, weighing 600 pounds, having a large electromagnet within, and requiring five people to operate. The electromagnet overheated and needed a sizable continuous-flow water jacket to cool it.The individual submerged his hands and feet in large buckets of saltwater that served as electrodes. His report on the "t'el'ecardiogramme" described how the clinical use of the immobile equipment required a telephone connection from the physiology laboratory in Leiden to the clinic at the Academic Hospital, which was roughly a mile away.(13)

Thus, a few years after his landmark paper, Einthoven described the clinical application of the ECG transmitted through telephone lines ("Le T´el´ecardiogramme")(13) In this context, it is amazing that Einthoven established transtelephonic transmission of the ECG almost 100 years ago. There were numerous ECG patterns and arrhythmias in the 1906 report. Einthoven recognized the patterns of full heart block, ventricular extrasystoles and bigeminy, P mitrale, right and left ventricular hypertrophy, and other arrhythmias. The 1906 publication did not acknowledge the atrial fibrillation and atrial flutter tracings as such. By displaying ECGs from patients with a range of heart diseases, the classic publication "Weiteres uber das Elektrokardiogramme" published in 1908 helped to firmly establish the electrocardiograph's diagnostic capabilities. (14) The electrocardiographic standardization system that Einthoven created is still in use today. Einthoven also established standardization in the recording process by introducing the triaxial bipolar system with 3 leads (standard leads I, II, and III) or "derivations" for recording the ECG.Early electrocardiographers who supported this strategy exclusively used lead I. Leads I, II, and III were not the best choice by Einthoven, but they are still in use and will continue to be so. In 1912 he formulated that **lead II − lead I=lead III**, a relationship which is now self-evident. Einthoven's views and understanding of biophysics were remarkably advanced as evidenced by his statement that "the curve must represent under all circumstances and in every moment, the algebraic sum of all the potential differences which at that moment are developed in the heart. Einthoven conceived the famous equilateral triangle with leads I, II, and III at its sides and the calculation of the electrical axis (in the frontal plane) depicted as a single vector with an arrow at the center of the triangle (Figure 1). The arrow representing a vector with magnitude and direction, was not called as such at the time, but described as "the manifest potential difference in the heart.[15]

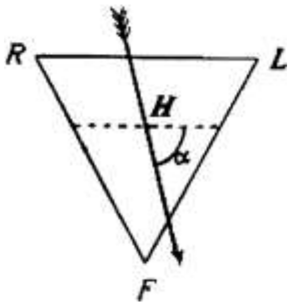

Figure 1: Method of Einthoven et al. [12] using the equilateral triangle to determine the electrical axis from the conventional limb leads. L stands for the left hand, F for the foot, and R for the right hand. H is the center, the heart. The direction of the axis is indicated by the arrow, which also shows the angle formed by the mean electrical axis and the horizontal plane.

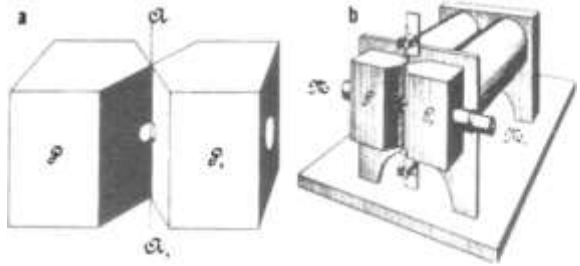

Figure 2: Drawings from Einthoven's 1906 publication show the string galvanometer's basic operating principle. The electromagnet's poles P and P1 only offer a small amount of room for the string A-A1's (thin quartz wire with silver coating) movement. The microscopes M and M1 are attached to the holes in the electromagnet for illumination and observation.

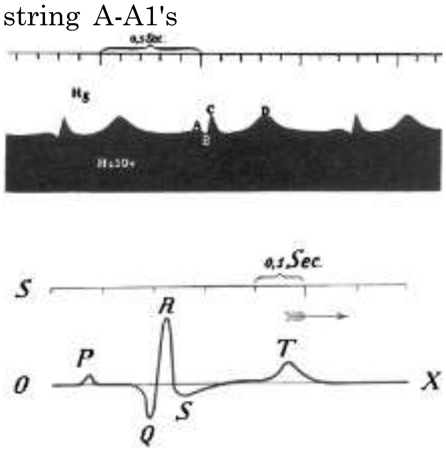

Figure 3: Einthoven's enhanced ECG recording using a modified capillary electrometer. The lower trace, which represents the mathematically corrected reconstructed ECG, closely resembles later traces produced with a string galvanometer.

Indications of ECG

The ECG has developed from a string galvanometer to the sophisticated computerized device we use today, making it the gold standard for diagnosing a variety of cardiac disorders.

Due to the ECG's extensive use in medicine, there are a number of indications listed below.:

1. Symptoms, such as palpitations, vertigo, cyanosis, chest discomfort, syncope, seizures, and poisoning, are the primary indicator of the ECG. (3)
2. Tachycardia, bradycardia, and clinical situations like hypothermia, murmur, shock, hypotension, and hypertension are all indicators or symptoms of heart disease (3).
3. To determine the presence of previous infarction, ischemia, and myocardial damage.
4. Arthritis of the heart(4)
5. ECG alterations are extremely helpful in evaluating the need for intervention in situations like drowning and electrocution(5).
6. Monitoring for the delivery of the proper electrical pacing in patients with defibrillators and pacemakers, detecting pacemaker or defibrillator device malfunction, reviewing their programming and function(6)
7. Analysis of metabolic conditions
8. Beneficial for evaluating blunt cardiac trauma (DM)Heart and lung resuscitation
9. Helpful in the research and differential diagnosis of congenital cardiac conditions(8)
10. Rhythmic irregularities and electrolyte imbalance(9)

1. To monitor the positive and negative effects of pharmaceutical therapy.• Perioperative anesthetic monitoring, including preoperative assessment, intraoperative and postoperative monitoring, and the pharmacotherapeutic effects and adverse effects of drug therapy
2. Cardiomyopathy screening procedure during a sports physical examination(10)

Conclusions

One of the physics applications created for the diagnosis of various cardiac disorders is the electro cardiogram. In fact, it is referred to as the "poor man's cardiogram." The EKG has been shown to be helpful among healthcare professionals in a hospital setting, particularly in intensive and cardiac care units where 24-hour monitoring of critically ill patients is necessary. Their understanding of the proper placement of EKG leads, EKG analysis, and thrombolytic therapy in patients with acute coronary syndrome has major implications for lowering morbidity and death. In general, it has been demonstrated that this use of physics benefits the entire medical community.

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