Willem Einthoven (1860–1927): Father of electrocardiography

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We should first endeavour to better understand the working of the heart in all its details, and the cause of a large variety of abnormalities. This would enable us, in a possibly still-distant future and based upon a clear insight and improved knowledge, to give relief to the suffering of our patients. – Willem Einthoven, Het Tele-cardiogram (The Tele-cardiogram), 1906.

Few diagnostic tools have the enduring value of the electrocardiogram (EKG). More than a century after its invention, physicians across the globe obtain millions of EKGs yearly to diagnose arrhythmias, infarctions, electrolyte abnormalities and drug toxicity. Willem Einthoven's fascination with physiology and his genius as a physicist led to the discovery of this indispensable diagnostic tool, and earned him a Nobel Prize.

A PHYSICIAN LIKE HIS FATHER

Willem Einthoven was born on May 21, 1860 in Semarang on the island of Java, where his father worked as a physician for the Dutch military and later became parish doctor for Semarang. Willem Einthoven was only six when his father died, but the elder Einthoven had already instilled in the boy a strong ambition to become a public service physician. In 1878, Einthoven took the first step in this direction by enrolling in the University of Utrecht on a government grant in exchange for a commitment to practise medicine in the Dutch East Indies (present-day Indonesia).

It was a time of flourishing interest in the burgeoning science of physiology, and the application of the laws of chemistry and physics to the understanding of biological processes. However, in his early university years, Einthoven was attracted instead to sports, founding the University of Utrecht Student Rowing Club and presiding over the Gymnastics and Fencing Club. His first brush with research occurred after he fortuitously broke his wrist while practicing gymnastics. During his convalescence and forced abstinence from physical activity, he pondered the elbow and its mechanisms of pronation and supination. Under the guidance of anatomist Willem Koster, Einthoven published "*Quelques remarques sur le mécanisme de l'articulation du coude*" ("Some remarks on the mechanism of the elbow joint") in 1882. The publication impressed the local scientific community and earned him a reputation as a promising young researcher. Later, Einthoven shifted his interest to ophthalmology, working under the great physiologists Donders and Snellen. He investigated aspects of stereoscopic colour vision and published his results as the thesis for his doctorate in medicine. His experience with optics would later prove invaluable in his development of the string galvanometer and EKG.

UNEXPECTED OPPORTUNITY Einthoven had always hoped to follow in his father's footsteps, to return to his place of birth and fulfill his commitment to the Dutch government by practising medicine in the East Indies. However, in 1885, a professorship in physiology became available at the University of Leiden, and even before Einthoven had passed his state medical licensing exams, Donders began to lobby for his appointment. As a Professor of Physiology, Einthoven could establish his own laboratory and follow his intellectual curiosity, but to do so, he would have to abandon his promise of returning to Java. Furthermore, he was obligated to repay his government scholarship of 6,000 guilders, a handsome sum considering that his meager professor's salary would only be 4,000 guilders per year. Torn between conflicting callings, Einthoven ultimately succumbed to his fascination with science, and joined the faculty at the University of Leiden.

COMPASS OF CURIOSITY In 1791, Galvani first demonstrated the presence of action potentials in nerves and muscles, and through the 1850s, others such as Matteuci, Kolliker and Muller discovered the heart's intrinsic electrical activity. Through a series of related experiments, they found that a nerve-muscle preparation laid on an exposed heart would beat in synchrony with the heart, implying that an electrical impulse was flowing through. Gabriel Lippmann allowed the next advance in cardiac physiology with his invention of the capillary manometer, a device that consisted of a capillary tube filled with mercury that would move ever so slightly when an electrical potential was applied. Augustus Waller used this device on the heart by attaching electrodes to the skin and recording the fluctuations of the capillary manometer on photographic paper. His first subjects

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were frogs, followed by dogs, specifically his English bulldog Jimmy and finally, humans. Although his was the first recorded evidence of cardiac electrical activity, Waller's 'electrogram' with the capillary manometer was too crude to be useful clinically.

EINTHOVEN'S EKG In 1889, four years after his appointment as Professor of Physiology, Einthoven traveled to London for the First International Congress of Physiologists. There, he was astounded by Waller's demonstration of his 'electrogram'. So impressed was Einthoven that he decided to shift his own research to cardiac electrophysiology, beginning by recreating the Lippmann capillary manometer. He found that the inertia of mercury prevented it from accurately recording the miniscule and fleeting electrical currents of the heart. Einthoven tried improving the apparatus, but eventually abandoned the capillary manometer for a more sensitive tool. It was to be the 'string galvanometer', which consisted of a wire suspended between magnets. As current flowed through the wire, it would generate a magnetic force, deflecting the wire. A device sensitive enough to accurately record the electrical activity of the heart in this manner would require an exceedingly thin and light wire. So Einthoven created an impossibly thin quartz filament for his galvanometer by attaching one end of a quartz rod to an arrow and fixing the other end in place. He then heated the rod and shot the arrow across his laboratory to extrude the filament. By coating the resulting three micron quartz string in silver, he had thus invented an instrument capable of registering a measurable movement whenever the current from a patient's heartbeat passed through it. This improved sensitivity of the tiny filament was further magnified using principles of optical physics that he had acquired during his early research career. The entire tracing was then recorded on photographic paper. In 1901, Einthoven published his first recordings of the heart made with his string galvanometer, naming the recordings the 'elektrocardiogramm'.

Still, the early EKG machine was hardly user-friendly. It weighed over 270 kg and required five people to operate while the patient sat with hands and feet submerged in buckets of salt solutions. To increase its clinical utility, Einthoven developed the 'tele-cardiogram' in 1906 by using cables to connect the string galvanometer to the Leiden Hospital 1.5 km away. Patients at the hospital could then be connected to electrodes to record their EKG, allowing the hospital to use Einthoven's invention to diagnose abnormalities of the heart. Two years later, Einthoven patented his invention and allowed commercial production of the EKG by the Cambridge Instrument Company, whose owner was Horace Darwin, son of evolutionist Charles Darwin. Initially, only a few hospitals took to the machine, but it gained widespread use with further research by Einthoven as well as the likes of British cardiologist Thomas Lewis, and James Herrick, an American physician who used the EKG to diagnose myocardial infarction. Einthoven was awarded the Nobel Prize in Physiology or Medicine in 1924 "for his discovery of the mechanism of the electrocardiogram".

Einthoven died just three years later on September 28, 1927. He was a mild-mannered, generous and selfless man, sharing his Nobel winnings with the surviving family of his assistant Van de Woerdt. In the truest sense, Einthoven's particular talent was not in clinical medicine, physiology or even physics, but in recognising and transforming the magnetic wonders of science to benefit humanity.

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