

Did Einthoven invent a string galvanometer?

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Clinical electrocardiography belongs wholly to this century and stems from a paper of Willem Einthoven "Un nouveau galvanomètre" in 1901.¹ The epochal work of Waller in 1887,² which showed that in man cardiac potentials could be recorded, had aroused Einthoven's interest and he devoted a large part of the next three decades to perfecting high fidelity methods of studying these potentials with instruments of his design.

In a recent review paper Cooper³ opined that Einthoven did not invent the string galvanometer and invited the inference that Einthoven did not give proper priority and credit to Ader. This raises semantic problems regarding the word "invent" and casts doubts on the veracity of Einthoven's account of his own work. It is not a new controversy and undoubtedly some writers, historically minded but not necessarily historical scholars, have used the word "invent" loosely. The hearsay opinion has been repeated in the literature: that Einthoven had his instrument built just by adapting already known equipment to his purpose. For instance, Barker (1910) in a long paper extolling the great clinical possibilities of electrocardiography, states "Einthoven of Leyden devised his string galvanometer based upon the suggestions of Ader."⁴

My argument endorsing the propriety of the use of the word "invent" for Einthoven's instrument is based on the following points. The meaning of any word is defined by its common use. When a person does something in a new and effective way he is said to be inventive or ingenious. In the legal world, the word has implications for patent rights. There is no evidence that Einthoven had strong aspirations for a controlling patent. Snellen⁵ mentioned that any such claims would be abrogated by the publication in 1909 of the detailed specifications of his string galvanometer. I believe that within observed patent practices Einthoven's string galvanometer could have been patented because it was designed for a purpose and was a success in obtaining objectives not previously achieved. It was not a discovery and

much more than a gadget, and I submit would meet one encyclopaedic definition of an invention.⁶ Einthoven (1903) condensed his views of his accomplishments in these words. "I have constructed an apparatus . . . specifically designed to give direct registration of the human electrocardiogram which will give true readings."⁷ Einthoven was generous in giving credit to other investigators. When he read a paper before the Chelsea Medical Society (1912) he praised Waller and Lewis, and credited Waller with coining the term electrocardiogram: "It gives me especial pleasure to bring to remembrance here that the human EKG was first recorded by a London physiologist, Augustus D Waller, who also introduced the term 'electrocardiogram' into science."⁸ Einthoven was unhappy with the editing of this paper, as judged by his correspondence with Lewis.

Many scientists have apparently felt comfortable with the use of the word "invention" for the Einthoven instrument. Below is a list of short quotations from papers in which the word "invent" was used.

Waller (1909): "Professor Einthoven's results with . . . the extraordinarily sensitive galvanometer he has *invented* . . ."⁹

Lewis (1911): "The string galvanometer in its present form, the *invention* of Einthoven . . ."¹⁰ In an obituary (1927) Lewis stated ". . . he moved to the principle of Ader's instrument . . . constructed a galvanometer greatly surpassing all previous instruments . . . created a piece of apparatus of unparalleled delicacy and accuracy."¹¹

A V Hill (1927) (in obituary): "The problem of recording these small and fleeting changes . . . was solved in 1903 by the *invention* of the string galvanometer."¹²

H B Williams (1947): "Accordingly, I agree with you (A E Cohn) that the record should leave no doubts on the score that Einthoven was the *inventor* of the electrocardiograph."¹³

White (1949): "Finally in 1903 came the announcement of the *invention* of the accurate and practicable galvanometer (Einthoven)."¹⁴ (Curiously in the first and second editions of *Heart Disease* the word used was "discovery"; this was changed to "invention" in the third edition.)

De Waart (1961): "Persevering in *inventing* and constructing his string galvanometer."¹⁵

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Burch and DePasquale (1964): "(Einthoven) will always be remembered as the *inventor* of the string galvanometer."¹⁶

Zachary Cope (1973): "The great development of this subject was largely due to the *invention* of the string galvanometer by Einthoven."¹⁷

Snellen (1983): "The mathematical correction (of the capillary electrometer tracings) although satisfactory was cumbersome and Einthoven therefore *invented* a new instrument."¹⁸

The following are excerpts from work by other knowledgeable scientists. They are quoted because they use phrases or words that are equivalent to the word "invent":

Wenckebach (1927) (obituary): "Seine Grosstat, der er einen grossen Teil seines Lebens gewidmet, war das Saitengalvanometer."¹⁹

Samojloff (1930): "First of all, he is the creator of electrocardiography."²⁰

Wilson (1940): (After work with capillary electrometer) "He was then able to determine the characteristics which an instrument suitable for his purpose (should have) and in 1903 he completed the first model of what has since been known as the

string galvanometer."²¹

Barron (1950): "Realising the limitation of this method (capillary electrometer), he devised a more simple sensitive and accurate means of recording these fluctuating potentials."²²

Wiggers (1961): "Einthoven, therefore, undertook careful mathematical studies of the characteristics of moving coil galvanometers which eventually led him to employ the principle that a wire placed between two magnets bows when traversed by an electric current."²³

Adrian *et al* (1976): "Einthoven introduced the string galvanometer in 1901."²⁴

The Nobel Committee, as is reflected by the presentation speech of Professor Johanssen,²⁵ avoided any controversy: the justification of the award was for Einthoven's "discovery of the mechanism of the electrocardiogram" (a somewhat ambiguous phrase), and Einthoven's name was "linked to the design of a physical instrument" (the string galvanometer). Einthoven's Nobel lecture was given in German, but there is an English translation in the published Nobel lectures. The title of Einthoven's address was "The string galvanometer and

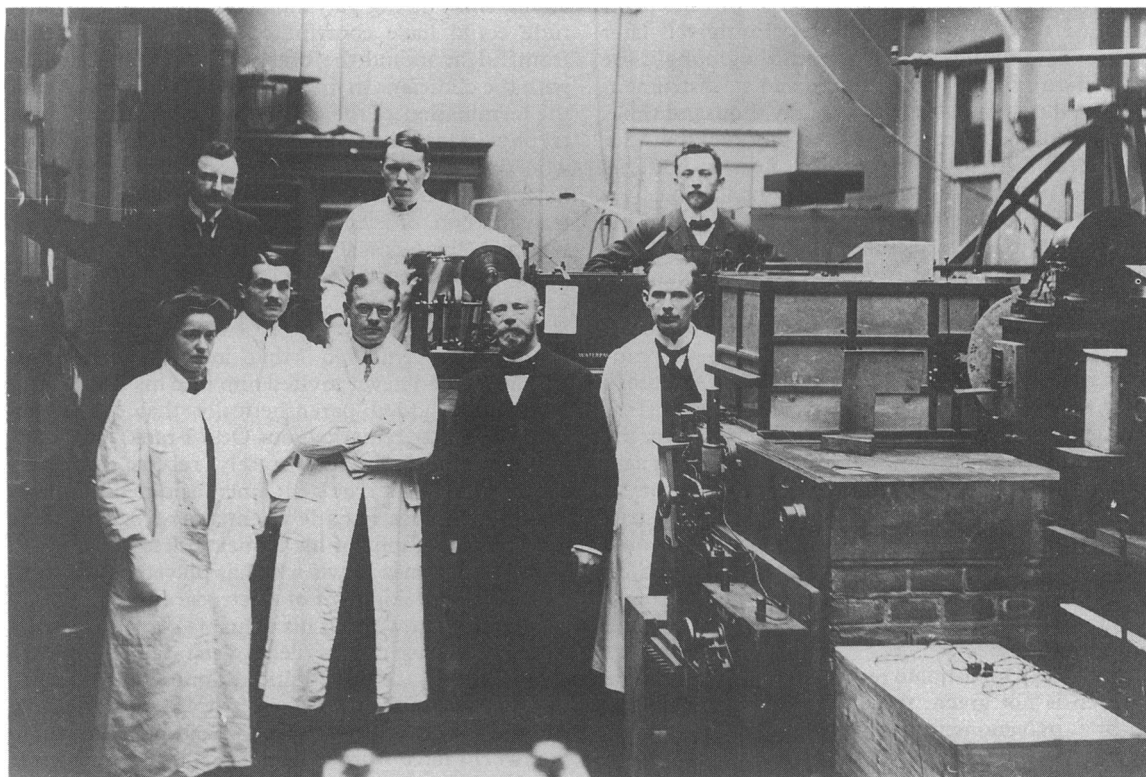


Figure A photograph taken in Einthoven's laboratory in about 1908 given to the author by Dr George Fahr. The string galvanometer in the background is obscured. Dr Fahr is the young man on the left and Dr Einthoven is appropriately in the centre and at the front.

the measurement of the action currents of the heart." This oration, as Snellen has pointed out, "constitutes an important review of a lifetime's work." All the 26 figures also reflect the high technical quality which he demanded in his records.

Those of us who have worked with a string galvanometer may be at a disadvantage when it comes to objectively assessing this instrument; love and admiration for the instrument may have engendered a bias. As well as saying that Einthoven "did not invent the string galvanometer" Cooper also states that "he was not the first to describe the electrocardiogram."³ The claim that the PQRST wave form that was calculated by Einthoven from records taken on the capillary electrometer is the first true description of the electrocardiogram is not without support, as Professor Johanssen said in the Nobel presentation speech: "Einthoven can thus be named the discoverer of the real electrocardiogram." Einthoven added the U wave later in 1903. This was a contribution of the string galvanometer. Waller expressed his admiration for Einthoven's records, and mentioned specifically that with his own 1887 apparatus, "the P wave was not discernible."⁹ Is it really correct to claim that Ader's galvanometer "was the type of instrument that Einthoven later used to introduce clinical electrocardiography": the implication being that Einthoven's instrument resembled that of Ader. It was many thousand times more sensitive, not merely an adaptation of the Ader instrument. Einthoven's credits to Ader in both his 1901 and 1909 papers^{1 26} seem adequate to me. It is not reasonable to equate Einthoven's considerable improvements of the capillary electrometer with the profound changes that were needed to create his string galvanometer electrocardiograph from existing galvanometers. George Fahr, talking with me in his later years of his period with Einthoven, was candid in mentioning that Einthoven had rather clumsy hands and was somewhat secretive about his instrument when visitors came (this is contrary to the statements of others) (fig). Fahr, however, never said anything to impugn Einthoven's integrity or to imply that Einthoven had adapted Ader's instrument. In the late years (1920) there was some secrecy; access to the laboratory was forbidden on Fridays because of experimental wireless transmissions from Einthoven's son who was in the Dutch East Indies.

Burch and DePasquale recount a story, the source of which is not given, that Edelman manufactured the first galvanometers of the Einthoven design under an arrangement whereby Einthoven was to receive a \$25 royalty for each instrument that was sold.¹⁶ After adapting the instrument and using his knowledge of an existing Ader galvanometer Edel-

man reneged on payment of the royalty. Whatever the details of the falling out with Edelman, the event did initiate the development of companies in England²³ and the United States¹³ to manufacture the string galvanometer with Einthoven's "blessing." Here then is *prima facie* evidence of a corporate acknowledgement of Einthoven's rights to a patent.

Einthoven would probably have approved Cooper's assertion that Bosscha "provided both a theoretical and practical support for Einthoven's work"; however, it still seems an exaggeration of Bosscha's role. He was not a teacher of Einthoven.

The labelling of the wave forms according to the PQRST convention was never explained in writing by Einthoven. Waller tried to maintain his original rubric "V₁ and "V₂" but he was unsuccessful in gaining disciples of his cause. I believe that Henson gives the best description of the origins of the PQRST nomenclature, which was based on the geometrical convention of Descartes (by coincidence in a book published in Leiden in 1637).²⁷

My admiration of Willem Einthoven does not preclude a suspicion that he might have been possessive about "his" string galvanometer and that this attitude could have contributed to his estrangement from Edelman and the break up of his relationship with the clinicians in his hospital. Fahr relates²⁸ that the termination of the collaboration with the hospital physicians was engendered by an argument about who was to pay for the telephone line linking the hospital with the physiology laboratory for the transmission of electrocardiograms; another story was that "his occasional electrocardiographic arguments displeased the clinicians so much that in due course, the latter severed the connection." Wiggers²³ mentions in his encomium that Otto Frank once remarked "that in visit to Leiden, Einthoven had never invited him into his laboratory. It may be added parenthetically that Einthoven made a similar remark about Otto Frank."

Successful individuals rarely receive universal acclaim for being true gentlemen as did Einthoven. It is worth repeating a few sentences from the concluding paragraphs of his Nobel address:

"... Thomas Lewis who has played a great part in the development of electrocardiography ... I doubt that without his valuable contributions, I should have the privilege of standing before you today", ... "in addition, innumerable other workers in the field of electrocardiography have gained great merit ... 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 ..."

Einthoven's "invention", the instrument that he bequeathed to us, endures. If one needed a high fidelity, high sensitivity galvanometer with nearly perfect square wave response over a remarkable frequency range (perhaps to celebrate a diamond jubilee of the beginnings of electrocardiography in American hospitals), one could confidently take an ancient string apparatus off the shelf and expect it to work superbly.

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