Journal of Electrocardiology 57 (2019) 122–127

Contents lists available at ScienceDirect

Journal of Electrocardiology

journal homepage: www.jecgonline.com

Review

The winner takes it all: Willem Einthoven, Thomas Lewis, and the Nobel prize 1924 for the discovery of the electrocardiogram

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ARTICLE INFO

Keywords:
W Einthoven
T Lewis
GR Mines
J-E Johansson
Electrocardiography
Nobel prize

Abstract

Professor Willem Einthoven of Leiden, the Netherlands, was the first to record the human ECG with high technical quality. He is therefore considered "the father of electrocardiography". Einthoven was awarded the Nobel Prize in Medicine or Physiology in 1924. For that year's prize he was nominated together with Professor Thomas Lewis of London, the United Kingdom, who is considered "the father of clinical electrocardiography" because of his studies of various arrhythmias, notably atrial fibrillation and flutter. Both scientists have been the subjects of many books and articles, but there is no account in the literature of the reasons why the Nobel Assembly in Stockholm awarded Einthoven only. We have therefore researched the archives of the Nobel Assembly and we recount the detailed, written deliberations of the chairman of the Nobel Committee, Johan Erik (Jöns) Johansson that was presented to the Nobel Assembly for their final decision not to award Lewis the prize.

Introduction

The Nobel Prize in Physiology or Medicine is one of the most prestigious prizes in science. It has been awarded annually, almost without interruption, for well over a hundred years. Nobel prizes in Physics, Chemistry, Literature as well as a Nobel Peace Prize are also awarded annually. Each prize comes with a large monetary award (1.000.000 dollars in 2019) and involves lavish ceremonies held annually in Stockholm on December 10, the so-called 'Nobel Day' [1]. The Peace Prize is awarded in Oslo on the same day.

The Nobel prize in Physiology or Medicine 1924 was awarded to Willem Einthoven, "the father of electrocardiography". Einthoven had been nominated for that year's prize along with Sir Thomas Lewis, the "father of clinical electrocardiography", but in the final evaluation the prize was awarded to Einthoven alone.

The names of nominees and the protocols in the Nobel Prize Archives were initially confidential, but today documents older than fifty years are available for research on topics of science history. The nobelprize.org website publishes the names of nominees, as well as the names of those who nominated them, but in 2019 only those from 1969 or earlier. But documents such as the nominating letters and the evaluations are difficult to study. One has to visit the archives in Stockholm, order the specific documents one wants to read, and read them there. And most of the documents are written in Swedish, which makes it difficult for international researchers.

In the present study we have read the nominations of Einthoven and Lewis submitted during the autumn of 1923, and the final evaluation of their scientific achievements written in July 1924 by Professor J.E Johansson, chairman of the Nobel committee at the Karolinska Institutet in Stockholm. The evaluation concluded with the recommendation that only Einthoven should be awarded the Nobel Prize in Physiology or Medicine 1924. Lewis was nominated several times after 1924, but he never received the prize.

Our review of the archives of the Nobel Assembly at the Karolinska Institutet regarding the 1924 Prize in Physiology or Medicine reveals an intriguing story leading to the award.

Back story

When the industrialist Alfred Nobel died in 1896 he had written a will stating that his fortune should be used for five prizes to those individuals who "have conferred the greatest benefit on humankind". One prize was for "the one who had made the most important discovery in the area of Physiology or Medicine". "The prize……. should be awarded by the Karolinska Institutet in Stockholm". To fulfill the will a Nobel Foundation was established in 1900. The newly created foundation then delegated to the faculty at the Karolinska Institutet the task of finding the most worthy laureates in Physiology or Medicine by appointing a Nobel committee, consisting of up to five faculty members. The Nobel committee should invite distinguished researchers around the world to submit names of worthy candidates for the Prize. The nominations should be written in English, German, French, Latin, Swedish, Danish or

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https://doi.org/10.1016/j.jelectrocard.2019.09.012

Norwegian. The invitations to nominate candidates were to be distributed during the autumn. The Nobel committee would then process and evaluate the nominations until the next summer. The evaluation would result in a proposal of the most important discovery, with 1–3 Prize winners. This proposal would then be presented before the faculty of the Karolinska Institutet which was alotted the task of formally selecting the winner or winners (today the prize is awarded by the Nobel Assembly, an independent entity that elects its members from professors at the Karolinska Institutet; see www.nobelprizemedicine.se). The winner should be revealed in October. The procedure is codified in the Statutes of the Nobel Foundation (Nobelstiftelsens grundstadgar) [2].

Nobel had stated that the winner should be found among those who had made the most important discovery during the preceding year. This was interpreted as saying that the most recent discoveries should be rewarded, but also that older discoveries could be rewarded, if their importance had only recently been observed (paragraph #2 in the Statutes). This paragraph, and paragraph #8, which states that the nominations should include a motivation and a list of relevant publications, would become important in the evaluation of the candidates for the 1924 prize, as seen below.

The nominations for the 1924 Nobel Prize in Physiology or Medicine

During the autumn of 1923 invitations to nominate candidates were distributed. At deadline, January 31, 1924, 102 proposals, nominating 43 worthy scientists, had been received. The Nobel Committee then started the evaluation process. In July 1924 the chairman of the Committee, Johan Erik Johansson made the final evaluation. The remaining candidates were now Willem Einthoven and Thomas Lewis (Fig. 1). Einthoven had been a candidate 7 times before. For the 1924 prize he had been nominated by Paul Trendelenburg, Professor of Pharmacology in Freiburg im Breisgau, Germany, the Professor of Medicine, Daniel Danielopolou in Bucarest, Romania, and the Physiology Professor Archibald Vivian Hill, London, U.K. Professor Hill, who had been awarded the Nobel prize in 1923, also nominated sir Thomas Lewis to share the prize with Willem Einthoven.

Danielopolou wrote his nomination letter in French (4 pages), Trendelenburg in German (2 pages), and Hill in English (14 pages). Below are short excerpts of passages in their letters that pinpoint the main motivation for their nomination(s).

Danielopolou:

"Professor Einthoven has conceived the string galvanometer device, through which experimental physiology as well as diagnostics and therapeutics have made very great progress. The method of Einthoven allows to register and to study in a precise way the electrical phenomena which take place in the organism."

Trendelenburg:

"W. Einthoven discovered in 1903 the string galvanometer used to register the finest electric currents….It is only because of his discovery that we possess a great amount of new knowledge about the formation of cardiac activation, its transmission, the nature of ventricular fibrillation and the analysis of arrhythmias..."

Hill:

"The discovery or invention on which their candidature is based is as follows: The invention and design of the string galvanometer, its application to the exact analysis of the heart-beat in animals and man, and recently and especially the discovery by its means of the precise nature of one of the commonest causes of irregularity of the heart, viz. clinical fibrillation and flutter of the auricles."……….."Without Einthoven's work Lewis could never have carried out his very fundamental researches of the last five years: without Lewis, Einthoven's work would have missed its full fruitfulness and its most important application: without both of them the world would still be in profound ignorance of the fundamental nature of some of the commonest causes of irregularity of the heart. The award of the prize jointly to them, therefore, would signify your belief in and your approval of the collaboration, not only of men of different nations, but of the scientist and the clinician in elucidating the problem of disease."

The nominees

Willem Einthoven

The first of six children, Einthoven was born in 1860 in Semarang on Java, then a colony of the Dutch East Indies and now part of Indonesia.

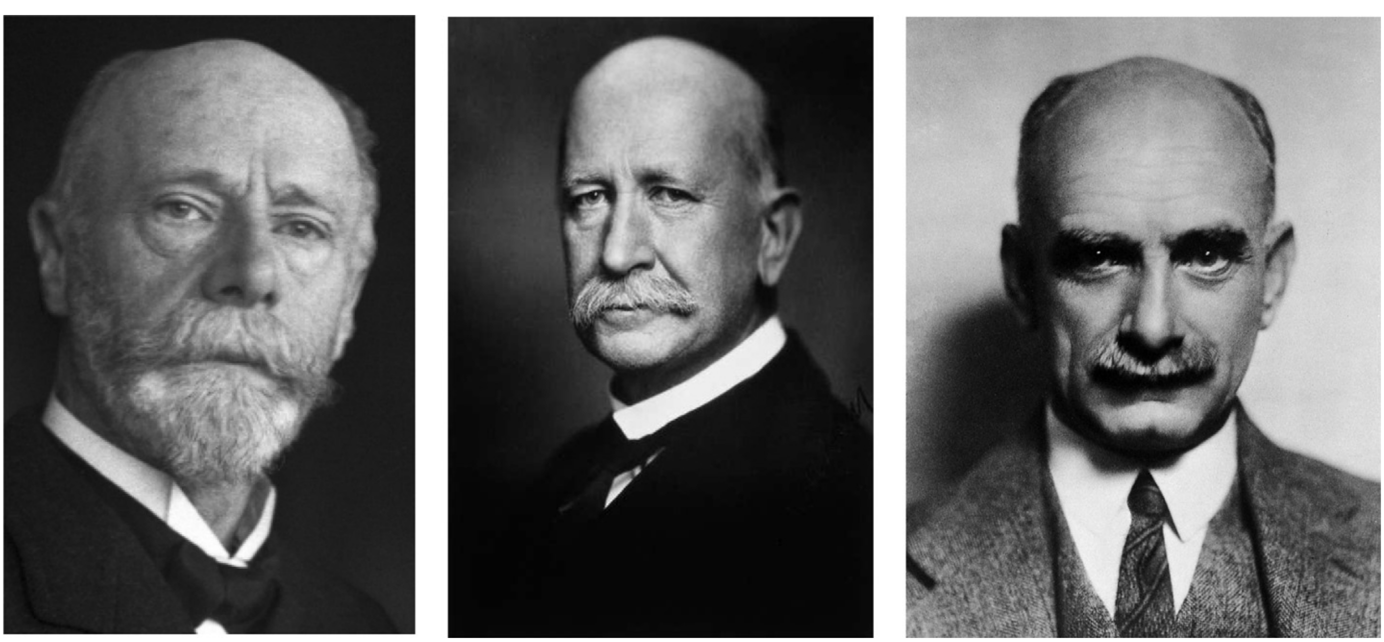

Fig. 1. The persons involved in our story. To the left Willem Einthoven, who was awarded the 1924 Nobel Prize in Physiology or Medicine. In the middle Johan Erik Johansson, who as chairman of the Nobel committee made the final evaluation of Einthoven and Lewis. To the right Sir Thomas Lewis, who did not receive the prize.

His father, who was also a physician, died when Einthoven was 6 years old. When he was 10, his mother moved to The Netherlands with her children.

He began his medical studies in Utrecht in 1878 and rapidly became interested in research. His first publication, written with guidance from anatomist W. Kouder, concerned the function of the elbow joint. He then began work in the laboratory of the physiologist F.C. Donder. In 1885, he published his thesis 'Stereoscopie door kleurverschil' (stereoscopy by means of colour variation). The same year, at age 25, he was appointed Professor of Physiology at Leiden.

The next years saw publication of a series of articles at the border between the physiology of vision and optics. His 1892 publication 'Über die Wirkung der Bronkialmuskeln nach einer neuen Methode untersucht, und über Asthma nervosum' (On the function of the bronchial muscles investigated by a new method, and on nervous asthma) had great impact.

In 1894, he published an article on recording heart sounds. This effort led him into recordings of the electric activity of the heart. British physiologist Augustus Waller had published a now-classic article on this topic in 1887 [3], but his recordings had been distorted by the inertia of the recording system. Einthoven developed a method to transform the recordings from such systems into a true electrocardiogram (ECG) [4]. In his seminal 1895 paper, he denoted the electrical deflections P, Q, R, S, and T, still in use worldwide today.

He became engrossed in attempts to create a recording system with low inertia that would give a true picture of the heart's electrical events. He devised his first version of the 'string galvanometer' in 1903, publishing the results in a physics journal [5]. He then used this device in a series of articles to record the human ECG. Most of Einthoven's publications were in German, some were in English and a few were in French; he mastered all three languages.

Using his continuously-improved string galvanometer, Einthoven had intense research activity not only in electrocardiography but also in recordings of heart sounds and electrical activation in the nerves and eyes. He had the capacity to conduct in-depth studies in all subjects that came within his scope of interest, also being proficient in physics and mathematics. His reputation attracted visiting scientists from all over the world to his laboratory in Leiden. He had already been nominated for a Nobel Prize 27 times between 1911 and 1922, 19 times by Dutch researchers.

In 1924, Einthoven was 64 years.

Thomas Lewis

Lewis was born in 1881 in Cardiff, Wales, the son of a mining engineer. His mother provided most of his initial education. At age 19, he graduated from University College in Cardiff with an undergraduate science degree. By 1905, he had received an MBBS degree from University College Hospital (UCH) in London and had begun work as a house physician at UCH and other local hospitals. He earned an MD degree in 1907 and became a lecturer in cardiac pathology at UCH in 1911. He was promoted to full physician in 1919 and remained at UCH for the remainder of his life.

In 1908, Lewis was able to record an ECG with a string galvanometer from Einthoven's laboratory that had been installed in Waller's nearby facility. He obtained his own device a year later. That same year he founded the journal *Heart: a Journal for the Study of the Circulation*, which he renamed in 1933 to *Clinical Science*. This journal continues publication today. In 1913, he published the ground-breaking book *Clinical Electrocardiography* [6].

During World War I, Lewis worked at the Military Heart Hospital in Hampstead. He directed a study on a condition called 'soldier's heart', and published a monograph showing that the condition was not a true cardiac problem [7]. At the same time, he continued his research at UCH on the spread of excitation (electrical waves) and mechanisms of cardiac arrhythmias.

Lewis also set out to determine the origin of the heartbeat, the so-called 'pacemaker'. In a 1910 paper, he identified the sinoatrial node as the initiator of electrical signals in the heart [8]. He then showed that the parts of the ventricles reached first by the electrical wave correspond to where bundles of specialized cardiac muscle cells branch out. If the branch to a ventricle is cut, its contraction is delayed. He thus confirmed Einthoven's suggestion that the anatomy of the conduction system determines the electrical path for the heartbeat. He also showed that propagation of the electrical signal was orders of magnitude faster in specialized (Purkinje) cells in the conduction system than in ventricular muscle cells (5 *vs* 0·5 m/s).

Lewis then focused his interest on understanding the mechanisms behind cardiac flutter and fibrillation. A young British researcher, George Ralph Mines, had published an article in 1913 suggesting that an uneven spread of electrical activity in the atria could result in a long, circular excitation loop, and 'delirium cordis' (fibrillation) [9]. The suggestion was based on his experiments on fish, frog, and reptile hearts, but he died at age 28, perhaps from self-experimentation [10], before he could test his theory in humans. Lewis published a series of articles in 1920–1921 that confirmed and extended Mines' theory. Based on his thorough experimental data, he developed a 'circus movement' theory that prevailed for decades [11].

Lewis was 43 years old in 1924.

Professor Johan Erik (Jöns) Johansson, chairman of the Karolinska Nobel Committee

Johansson was born in 1862, finished his medical studies at Uppsala University in 1885, and then moved to Stockholm to work with physiologist Robert Tigerstedt. In 1889, he moved to Carl Ludwig's laboratory in Leipzig, Germany, presenting his thesis the next year: 'Die Reizung der Vasomotoren nach Lähmung der cerebrospinalen Herznerven' (Stimulation of the vasomotor nerves after paralysis of the cerebrospinal heart nerves). He then spent 5 months in Alfred Nobel's medical laboratory near Paris, working on a study of blood transfusion. The project was a failure, possibly because the existence of blood groups had not yet emerged.

Johansson returned to Stockholm and succeeded Tigerstedt, who moved to Finland in 1900. Johansson introduced modern health statistics in Sweden, worked against criminalization of women involved in prostitution, and was also engaged in improving conditions in Swedish prisons. In 1919, the Karolinska Institute sent him to Germany to report on the starvation that followed the Allied food embargo during and after World War I [12]. When Nobel's will was read in 1896, Johansson became actively involved in its implementation. As the only faculty member with personal knowledge of Alfred Nobel and his intentions, Johansson played an important role in setting the final Prize rules. He was a member of the Nobel Committee between 1904 and 1926, becoming its chairman in 1918.

By all accounts, Johansson had a strong character: either you liked him, or you did not. In the words of a contemporary faculty member [13]:

> "Einthoven had to wait long for a very well deserved Nobel Prize. The too-dominating chairman of the Nobel Committee, Johansson, although personally fairly inactive since many years, thought that he understood everything that concerned the prize in medicine, both formally and scientifically, better than everybody else. He always emphasized that a 'discovery' should be somewhat of a surprise, and had not wanted Einthoven to receive the prize, although many others considered it obvious. But finally Einthoven received the prize in 1924. It was then maliciously said that the surprise on that occasion was that Jöns suddenly understood the great value of the discovery."

Contrary to this judgment, another faculty member wrote in his memoirs [14]:

'Jöns Johansson was one of the foremost characters on the faculty. He had been a good friend of the donor (Alfred Nobel) and had served as his assistant in the design of the regulations of the will. Therefore he became an authority regarding the interpretation of the will in accordance with Nobel's intentions, around which there were often disputes. Moreover, Johansson was an eminent physiologist, and, which was even better, an original and independent personality.'

Johansson was 62 years old in 1924.

The process

The Nobel Committee processed its nominations for 1924 during that spring. By summer, Einthoven and Lewis were the remaining candidates, and Johansson wrote the final memorandum to be presented to the faculty, detailing whether Einthoven, Lewis, or both should be awarded the Prize. The main part of Johansson's assessment was devoted to Einthoven. Below are excerpts of his 32-page memorandum to the Karolinska faculty, translated from the Swedish original by the authors:

"Einthoven is, along with Lewis, nominated by last year's Nobel laureate Hill. Paul Trendelenburg, Professor of Pharmacology in Freiburg im Breisgau, and the Professor of Medicine in Bucharest D. Danielopolu nominated only Einthoven. Lewis is nominated this year for the first time. Einthoven has since 1911 been nominated no less than 9 times". (Nobelprize.org: he was nominated 7 years and by 28 nominators).

Regarding Einthoven's method of correcting the recordings of the ECG made by Waller into a more realistic electrocardiogram, not distorted by the inertia of the recording system, Johansson writes:

"With this method E. could (1895) construct the real electrocardiogram of a human being. He labeled the details of the electrocardiogram P, Q, R, S, T. These labels remain to this day….. Einthoven realized the importance of an instrument, which directly reflects the time course of the electrical potential changes in the process of an organ, a muscle or a nerve. One such instrument is the string galvanometer (1903) which Einthoven introduced in experimental physiology, and likewise introduced for clinical use". ……………"Einthoven can with full justification be regarded as the discoverer of the electrocardiogram. But what did the electrocardiogram mean at this time? …In an overview which covered literature in the field through the first half of 1912, E. emphasizes explicitly the uncertainty in trying to interpret the cardiogram..……….In the work 'Le telecardiogramme' ……. he also announces something with the greatest clinical significance, namely that different forms of heart disease show themselves in the electrocardiogram in a characteristic way. He cites examples of electrocardiograms in patients with hypertrophy of the right (*sic*) ventricle in mitral insufficiency, hypertrophy of the left ventricle in aortic insufficiency, hypertrophy of the left atrium in mitral stenosis, degeneration of myocardium, and different degrees of heart block, as well as extrasystoles, or rather "atypical ventricular systoles"."

Johansson evaluates Einthoven's accomplishments with the string galvanometer:

"One could not in detail explain the origin of the different waves, P, Q, R, S, T, but right from Einthoven's "Le télecardiogramme" (1906), it was beyond doubt that P is associated with atrial and QRS with ventricular systole, and thus one could reach quite far particularly as regards diagnosing heart block. A full interpretation of the electrocardiogram was, however, necessary, and it was Einthoven who led the way"..…………"According to Einthoven the P wave is an expression of propagation of the wave in the atrial muscle. The wave of negativity which corresponds to the wave of excitation in the His-Tawara system, is considered by E. to be too weak to give any deflection on the galvanometer. QRS complexes are determined by propagation of the excitation waves in the myocardium of the two ventricles, which proceeds asymmetrically in relation to the recording points, at different moments of time, beginning at the tree-like branched Purkinje fibers where they pass over to the different parts of the heart muscle. When the contraction has reached its full magnitude in all parts of the ventricular wall the string returns to its original position. If the contraction ceases in the different parts at different time points, a T wave is obtained…"..……………"E. found it necessary to always state the lead used, and in conjunction with this he proposed (1908) the nowadays commonly accepted standardization: Leads I, II, and III"..…………

Johansson stresses that the string galvanometer is a physical instrument and that its significance in Physiology or Medicine has been realized by other researchers:

"As far as Einthoven's string galvanometer is concerned, it must undoubtedly be considered a truly original contribution. One can, however, discuss whether the design of an instrument should be considered a discovery. The construction of the string galvanometer is by itself a purely physical task, and it is with good reason that one can question if it is appropriate by the prize group in "Physiology or Medicine" to reward a physics instrument, before discoveries have been made, that proved the instrument's real significance for those sciences that the prize represents….. It is of course its use and the development that the string galvanometer has undergone that has made it possible to realize its importance, and I would like in this context to recall Trendelenburg's statement in his nomination: 'Discoveries and findings whose importance could only be appreciated at later times'."

Johansson then introduces Thomas Lewis:

"I have felt it necessary to make a fairly detailed account of Lewis' studies regarding the interpretation of the electrocardiogram, though they are not directly nominated for the award. Through these studies the electrocardiogram has had a completely different importance than before. It is no longer an obscure writing. We now understand the various details, the normal as well as a substantial part of the pathological, and it is clear that the advent of this writing, as well as its prerequisite, the string galvanometer, must be described as one of the most significant discoveries in physiology."

Regarding Lewis' work on atrial fibrillation and flutter, Johansson traces an influence from previous results by Mines:

"Such a conspicuous phenomenon as heart fibrillation must attract attempts at explaining, even more so since it has proved to be part of an important symptom complex from a clinical point of view. However, here I leave aside all publications that are not of interest for the present prize evaluation. A young English scientist Mines (*Fellow of Sidney Sussex College, Cambridge, who died during the war),* produced (1913) in connection with an investigation "On the dynamic equilibrium in the heart" an explanation of delirium cordis".

After having described Mines' experiments in detail, Johansson returns to Lewis' studies and reviews an article where Lewis states: "We have been guided especially by an observation recorded by the late Dr. G.A.Mines".

"Lewis states regarding the idea behind his study: 'The conception was an outgrowth of those of other writers, and especially it was an outgrowth of the simple and dramatic experiments which Mines describes. The pathways of the stimulus wave, that Lewis was able to follow in atrial flutter in mammals, consist of the natural muscle strands around the venous ostia. From the central or 'mother wave' 'centrifugal' waves branch in different directions to both auricles. If the spread of these waves changes from one circus movement to the other, then 'impure flutter' occurs, and if the 'mother wave' from one circus movement to the other propagates along different paths, there will be 'fibrillation'. In a series of carefully performed studies Lewis showed that the stimulus wave velocity and duration as well as the myocardial refractory period are affected by the stimulus frequency are essentially the same in mammals as Mines found in cold-blooded animals. There is no doubt that the depicted 'circle of excitation wave' is the cause of various forms of 'heart delirium' in both humans and animals. Lewis says, however, 'but in that it has so obvious a bearing upon practical medicine we have felt that every endeavor should be made to render it certain by further distinct tests'. This task was undertaken in a way which must be described as brilliant. We remember Einthoven's determination of the electrical axis and his leads I, II, III. In order to observe the stimulus wave in the atrium Lewis moves these three leads to the chest wall and attempts to reduce the resistance of the skin to a minimum. In Einthoven's drawing 'the equilateral triangle' he projected the electrical axis onto the frontal plane. Lewis chooses a sagittal, a frontal and a horizontal plane through the chest, records in each of these planes three electrocardiograms and applies on them Einthoven's calculations. On a patient, suffering from typical atrial flutter, he was able in this way to show that the electrical axis rotates clockwise in a plane corresponding to the muscle strands around the venous ostia in the heart, one lap in 0.245 sec… The circular movement of the excitation wave is described, as we have seen, among other things, by its speed and duration. We could compare it to a snake moving in a circle and does not rest until he bites his own tail. If one would somehow be able to fill the 'gap' between the excitation wave's 'tail' and its 'head', then the circular movement would terminate and the normal form of contraction would be restored. We now know that some toxins, digitalis, etc., affect the conduction conditions of the heart muscle. Lewis' latest studies have been focused on the study of the effects of various toxins in these respects."

Based on his evaluation of the specific scientific accomplishments of Einthoven and Lewis, put forward in the nominations, Johansson now makes his final recommendation to the Karolinska faculty to award the Nobel Prize to Einthoven alone:

"A division of the prize in the present case could be motivated because it is, as we have seen, mainly by Lewis' publications that the importance of Einthoven's discoveries became clear…… The prerequisite for dividing the prize is obviously that the proposed works have the prominence which Nobel's will intended. Hill writes in his nomination that Lewis should be awarded on the basis of his discovery of the mechanism of atrial fibrillation and atrial flutter. In his letter he writes: *'Far the most important, however, of the clinical applications of Einthoven's galvanometer and method have been made in the last five years by Sir Thomas Lewis, who - starting largely from the work of the late G.R. Mines on the wave circulating in the auricle - has applied them with great skill and insight into the elucidation of clinical fibrillation and flutter'*. I have in the foregoing tried to show Sir Thomas' excellent experimental skills and his critical acuity. However, one cannot ignore the fact that the main idea of his works, cited by Hill, stems from Mines. Even those schematic figures, which Lewis uses in his Oliver Sharpey Lecture for explaining the mechanism of the atrial fibrillation, do not differ in any essential way from the figures that Mines used for the same purpose (Fig. 2). As far as Lewis is concerned it is at present difficult to invoke any particular discovery in the meaning of the Will that justifies awarding a prize, and therefore obviously the issue of sharing the prize between him and Einthoven has to be turned down. In reference to § 2 of the Statutes the recommendation remains to award Einthoven the prize undivided. Stockholm in July 1924.J.E. Johansson".

Could the outcome have been different?

The documents raise two main issues. First, Johansson seemed to have very high regard for Lewis' research on the conduction system, and the effects of its pathologies on the ECG. He listed several articles he considered very important, although he felt, referring to paragraph 8 in the Statutes, that he could not take them into account in his evaluation for the prize. He felt bound by Hill's nomination—which considered only Lewis' 'work on fibrillation and flutter of the auricles (atria)'—and the articles Hill had listed. Was Johansson's elimination of Lewis a consequence of poor and narrow motivation on Hill's part? Would the outcome have changed if Hill had phrased his nomination to include Lewis' other achievements and not only the work on fibrillation and flutter, which Johansson thought merely expanded on Mines' work? Second, if Mines had not died in 1914, but had continued his 1913 research, would he also have been a candidate in 1924? We will never know.

What happened later?

On October 23, 1924, Johansson announced that the faculty of the Karolinska Institutet had decided to award Willem Einthoven the 1924 Prize in Physiology or Medicine for 'the discovery of the mechanism of the electrocardiogram', and a telegram was sent the same day to Leiden. Einthoven happened to be on a lecture tour in the U.S. then, and he read about the award in an American newspaper. He did not collect his award until 10 December of the next year.

Johansson's speech at the Nobel award ceremony, where he presented Einthoven's achievements, was held in Swedish (by tradition) with a printed German translation. Einthoven's Nobel lecture was in German, and had the title 'Das Saitengalvanometer und die Messung der Aktionsströme des Herzens' (The string galvanometer and the measurement of the action currents in the heart) [15]. His speech at the Nobel banquet was also in German and concerned the historical links between Swedish and Dutch research projects [15].

A week after Einthoven had won, Lewis wrote to him with congratulations: 'The splendid news of your Nobel Prize came this morning, and gave me very great pleasure. You have given so much to Physiology & Medicine that the prize in itself is but a small return; but I rejoice, and there will be many rejoicing with me, that your great work has received this public recognition'. Einthoven responded to Lewis' letter 3 months later: 'Dear Lewis, Accept my best thanks for your kind letter of Oct 30th. Your kind words have touched me deeply. I owe so much to you. Without your steady and excellent work to which you have devoted a great part of your life there would have been in all probability no question of a Nobel prize for me. You have given to Medicine at least as much as I have.' From Snellen's research [16,17] it seems reasonable to assume that Lewis was aware that Hill had nominated both him and Einthoven. Hill had even asked Lewis to write an appraisal of Einthoven's work. We have not been able to elucidate whether either of them knew that Lewis had been so close to sharing the award with Einthoven.

Einthoven and Lewis continued their mail correspondence, but Einthoven died less than 2 years later, on 29 September 1927. It is interesting to note that Lewis discontinued his ECG research in 1925 and devoted his research time to peripheral vascular circulation [18]. Thomas Lewis was nominated again five more times by renowned researchers from England, Hong Kong, and the U.S., but he was never awarded the prize. He died in 1945 at the age of 64. Johansson retired in 1926 from the position as chairman of the Nobel Committee, and in 1927 from his position as Professor of Physiology at the Karolinska Institutet. He died in 1938.

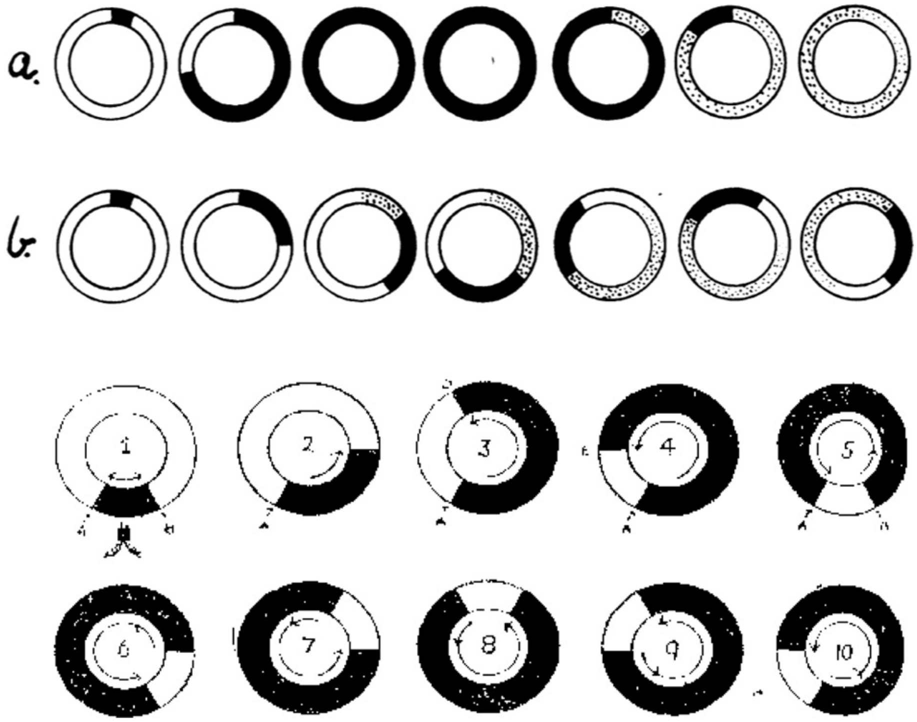

Fig. 2. The upper illustration is from Mines' 1913 article, and the lower from Lewis' Oliver-Sharpey lecture 1921 (see The Lancet 1921, pp. 785–788). Panel b in the illustration by Mines shows that a continuous clockwise circular excitation of the auricular muscle might occur if the excitation wave is slower than normal. In the illustration from Lewis an excitation block in one direction would lead to the same situation (the excitation wave is counterclockwise in Lewis' illustration). In his evaluation Johansson was concerned by the similarities of the two illustrations. He concluded that Lewis' contribution was not original enough to merit a Nobel prize.

Contributors

OP and BU conceived, wrote, and approved the final version of this article.

Declaration of competing interest

The authors declare no competing interests.

Acknowledgments

Initial contacts with the Nobel Assembly were provided by Ms Carola Stenberg and Professor Martin Ugander of the Karolinska Institutet, for which we are very grateful. Ms Stenberg also kindly transcribed the document by J E Johansson into a Word file, so that it could be more easily translated and edited. We thank Professor Giorgio Gabella, UC London, and Patricia A. French of Left Lane Communications for editing assistance in the development of this article. We are grateful to Ms. Ann-Mari Dumanski at the office of the Nobel Assembly at the Karolinska Institutet, for able help in the archives, and the staff of the Library of the Rijksmuseum Boerhaave, Leiden, The Netherlands, for sending us photocopies of the letters exchanged by Einthoven and Lewis in 1924 and 1925.

References

[1] Official website of the Nobel Prize. https://www.nobelprize.org, Accessed date: 10 June 2019.
[2] Nobelstiftelsens grundstadgar (Statutes of the Nobel foundation). Kungl. Boktryckeriet P.A. Stockholm: Norstedt & Söner; 1931.
[3] Waller AD. A demonstration on man of electromotive changes accompanying the heart's beat. J Physiol 1887;8:229–34. https://doi.org/10.1113/jphysiol.1887.sp000257.
[4] Einthoven W. Ueber die Form des menschlichen Electrocardiogramms. Arch gesamte Physiol Mensch Tiere 1895;60:101–23. https://doi.org/10.1007/BF01662582.
[5] Einthoven W. Ein neues Galvanometer. Ann Phys 1903;317:1059–71. https://doi.org/10.1002/andp.19033171308.
[6] Lewis T. Clinical electrocardiography. London: Shaw & Sons; 1913. https://archive.org/details/clinicalelectroc00lewiuoft/page/n4, Accessed date: 10 June 2019.
[7] Lewis T. The Soldier's heart and the effort syndrome. London: Shaw & Sons; 1918. https://archive.org/details/soldiershearteff00lewiuoft/page/n4, Accessed date: 10 June 2019.
[8] Lewis T. On the electro-cardiographic curves yielded by ectopic beats arising in the walls of the auricles and ventricles. Br Med J 1910;1:750.
[9] Mines GR. On dynamic equilibrium in the heart. J Physiol 1913;46:349–83.
[10] Aciernom LJ, Worrell LT. George Ralph Mines: victim of self-experimentation? Clin Cardiol 2001;24:571–2.
[11] Lewis T. The Oliver-Sharpey lectures on the nature of flutter and fibulation of the auricular. Br Med J 1921; 1: 551–5, 590–3.
[12] Johansson JE. Om Tysklands folknäring under kriget och för närvarande (on the nourishment of the German population during the war, and at present). Hygiea 1919;81:257–96.
[13] Henschen F. Min långa väg till Salamanca (My long road to Salamanca). Stockholm: Bonniers; 1957; 199.
[14] Holmgren I. Mitt liv (My life). , vol. 1Stockholm: Natur och Kultur; 1959; 222.
[15] Les Prix Nobel en 1924. Stockholm: Norstedt & Söner; 1925.
[16] H.A. Snellen two pioneers of electrocardiography. The correspondence between Einthoven and Lewis from. Rotterdam: Donker Academic Publications; 1983.
[17] H.A. Snellen. Willem Einthoven (1860–1927). Father of electrocardiography. Issued by Kluwer Academic Publishers, Dordrecht, the Netherlands in 1995.
[18] A. Hollman. Sir Thomas Lewis. Pioneer cardiologist and clinical scientist. Issued by Springer-Verlag London Limited in 1995.