NIKOLA TESLA AND MEDICINE

NIKOLA TESLA IN MEDICINE, TOO

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Descriptors: Famous people - history; Electricity - history; Electrotherapy - history; Croatia

Summary. In this paper, using primary and secondary sources, we have presented that segment of Nikola Tesla's activities that was also applied in the field of medicine. Special attention is paid to the performance of Tesla's experiments in high school classes, which points to the popularization of Tesla's work and the prompt acceptance of his discoveries in the territory of Croatia. Tesla's research aroused great interest in the local academic community, and his experiments were repeated and introduced into classes. It was pointed out that Tesla's interest was primarily focused on physics and electrical engineering, without personal pretensions of encroaching on biomedical research. Nevertheless, his researches contributed to bringing these two fields closer together, paving the way for medical physics, especially radiology and high-frequency electrotherapy.

Descriptors: Famous persons – history; Electricity - history; Electric stimulation therapy – history, Croatia

Summary. Using primary and secondary sources we have shown in this paper the influence of Nikola Tesla's work on the field of medicine. The description of his experiments conducted within secondary-school education programs aimed to present the popularization of his work in Croatia. Although Tesla was dedicated primarily to physics and was not directly involved in biomedical research, his work significantly contributed to paving the way of medical physics, particularly radiology and high-frequency electrotherapy.

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Nikola Tesla was born at midnight on July 10, 1856, in the Lika village of Smiljana near Gospi}, to his mother \uka (Georgina). Mandi} and father Milutin Tesla, an Orthodox priest. He attended the new school from 1862 to 1866. He started school in Smiljan and finished in Gospi}, where the Teslas moved after the tragic death of Nikola's older brother Dana. From 1866 to 1870, Nikola Tesla attended the lower real gymnasium in Go spi}, and from 1870 to 1873 he attended the real school in Rakovac near Karlovac, where he graduated in 1873. After recovering from cholera and receiving a scholarship from the administration of the Military Territory, Tesla enrolled at the Polytechnic College in Graz in 1875. This school has had a tradition since 1811. After completing two school years (1875/76 and 1876/77) and although he was an excellent student, Tesla left Graz in 1878, without completing the third year of studies, due to the loss scholarships. Tesla intended to continue his studies in Prague in 1880, but since his father had died in the meantime, he did not enroll at the University of Prague, but only attended lectures in physics and other subjects. and studies literature from libraries. He got his first job in Budapest in 1881. He got a job as a draftsman (engineer) in the telecommunications-engineering department of the ministry. From 1882 to 1884, he worked in Paris to maintain Edison's electronics. In 1884 he went to America and in 1891 he became a citizen of the USA, where after many years of fruitful work he died on January 7, 1943 in a room on the 33rd floor of the New Yorker Hotel in New York. He visited Europe and his homeland at least twice (in 1889 and 1891/92). The urn with his ashes was transferred from America to Belgrade in 1956, where it is still

kept in the Nikola Tesla Museum.1 The ideas that led Tesla to the important inventions of the system of multi-phase alternating currents already possessed him. at the Technical High School in Graz in the period 1875-1878. He achieved their realization only in his laboratory in the USA years later. In the period from 1881 to 1884, working as an engineer in Pest, Paris and Strasbourg, Tesla discovered the wider possibilities of alternating currents in multiphase systems, where he obtained effect of rotating magnetic field. The discovery of this field resulted in the practical application of alternating current in the production of various types of electric motors and generators. Until the appearance of Tesla's iron-core transformer, the area of high-frequency currents was unknown. Tesla transformers were used in wireless radio transmission, and they also provided very high voltages. His research in the field of high-frequency currents had a significant impact on the development of telecommunications (first radio, then television). Many of Tesla's devices were intended to improve lighting. Tesla's fluorescent tubes in oscillating circuits of high frequencies gave a very strong light, and some are still used for lighting today (neon lighting). From a technical point of view, Tesla's invention of the turbine is also important, where the rotor, which consists of plane-parallel plates with a very small distance between them, is driven by a spiral jet of fluid. The turbine works on the basis of the adhesion of the fluid and the plates and the viscosity of the

fluid.1 For his discoveries and patents, Tesla received numerous awards and was an invited lecturer before distinguished professional and scientific societies in Europe and America. He wrote 73 articles in various magazines. In the literature, Tesla is cited as a forerunner of certain discoveries, for example the

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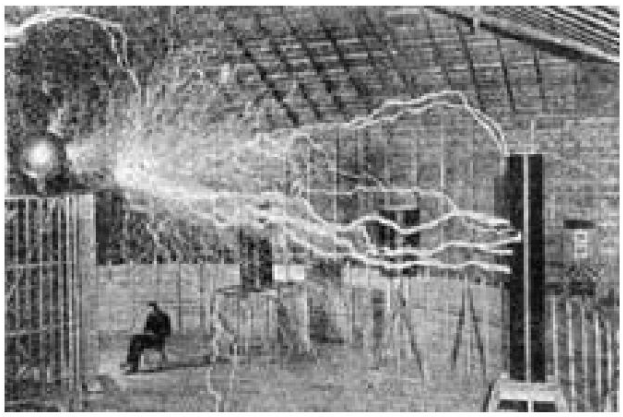

Figure 1. *Tesla's high frequency and high voltage currents in an experiment made in Colorado (1899), taken from Pejnovi} D, 192710* Figure 1. *Tesla's high frequency and high voltage in experiment made in Colorado, from Pejnovi} D, 192710*

Figure 2. *Copy of the diploma of the University of Zagreb – gradus doctoris honoris causa in the field of technical sciences of Nikola Tesla (source: Nikola Tesla Museum in Belgrade), taken from Han`ek B, Franz-[tern, 20061* Figure 2. *Photocopy of diploma of the University of Zagreb gradus doc toris honoris causa in area of technical science to Nikola Tesla (original: Museum of Nikola Tesla in Belgrade), copyright Han`ek B, Franz-[tern, 20061*

Figure 3. *Translation of the Latin text of the honorary doctorate diploma with an explanation of the abbreviation marked *, image taken from Han`ek B, Franz-[tern, 20061 Figure 3. Translation of Latin text of honor Ph. D. diploma with explanation of symbol *, picture taken from Han`ek B, Franz-[tern, 20061*

connection, X-rays, radar, electron microscope, particle accelerator, cosmic radiation, induced radioactivity and lasers.2 In addition to the University of Zagreb, Tesla was awarded honorary doctorates by the University Columbia (1894), Vienna University of Technology (1908), University of Belgrade (1926), Prague University of Technology (1936), University of Poitiers (1937), Technical College in Graz (1937), University of Paris (1937), Polytechnic School in Bucharest (1937), University of Grenoble (1938), Sofia University (1939 – doctorate in physics), University of Brno. He was declared an honorary member of HAZ (then JAZ) in 1896, a full member of the Serbian Academy of Sciences in Belgrade (1937), an honorary member of the American Philosophical Society in Philadelphia (1896), New York Academy of Sciences (1907), winner of the Edison Gold Medal (1916), winner of the John Scott Medal (1934), and also received an honorary master's degree (M.Sc.) at Yale University (1894).3

The unit for magnetic flux density (sometimes called magnetic induction; symbol B) was named in his honor . The unit of tesla (symbol T) is defined by the ratio of the unit of magnetic flux *weber* (Wb) and the unit of area square *meter* (m2), i.e. T= Wb/m2. 4

One crater on the Moon on the invisible side was named the Tesla crater in 1966, along with "our" craters dedicated to A. Mohorovici}, RJ Bo{kovi} and L. Brenner ([. Gop- ~evi }in). The asteroid that now bears the name (2244) Tesla was also named after *Tesla,* and was discovered in 1952 by the Serbian astronomer Mi lorad Proti}.1

Echo and recognition of Tesla's work in Croatia: honorary doctorate from the University of Zagreb

At the second regular session of the Council of the Technical Faculty, which was held on May 26, 1926, it was unanimously decided: *that Nikola Tesla, as a deserving person, should be given the title of Associate Doctor of Technical Sciences.* After the decision was confirmed on May 28, 1926 by document no. 843/1926. a notification was sent to the Rectorate, which expressed itself on June 21, 1926 with document no. 2115–1926. In the document signed by the then rector of the University of Zagreb, prof. Dr. Drago Perovi} (1888-1968) it was noted that the University Council was at its meeting on June 2. In 1926, unanimously accepted the conclusion of the Assembly of the Technical Faculty that Nikola Tesla be promoted to the honor of Doctor of Technical Sciences *honoris causa,* unanimously for information.1

The public only knew that the ceremonial promotion of the awarding of the diploma of honorary doctor of technical sciences was held in Zagreb on June 29, 1926. Tesla did not attend it personally, but this diploma was presented to him later. Thus, in the book of doctors of the University, which has been kept in the Rectorate since the first doctorate in 1877, the name and title of honorary doctor Nikola Tesla is mentioned without his signature.1 As an illustration, in this paper we show copies of the diploma itself . *honoris causa* and documents related to the process of awarding the honorary title (picture 2). A translation of the original Latin text into Croatian is attached (Figure 3). The pictures are taken from the article Nikola Tesla - Honorary Doctor of the University

in Zagreb published in the University Gazette and mentioned in the literature under serial number 1.

Milan ^alogovi} (1878–1945), professor of the Civil Engineering Department of the Technical Faculty of the University of Zagreb, informed the Technical Faculty of the same University in a letter from New York on August 10, 1926 that on August 6, 1926, presented Nikola Tesla with a diploma and letters from the rector and dean. At the end of the notice, prof. ^alogovi} asks that the letter about the graduation be forwarded to the rector of the University of Zagreb. This document was reconciled with the original on August 31, 1926.

On the same day, by letter number 1256/1926, the Faculty of Engineering instructed the Rectorate of the University of Zagreb to deliver a letter from Professor Milan ^alogovi} stating that he had personally presented Nikola Tesla with an honorary doctorate in technical sciences. and a private letter sent by the rector. From the reception seal of the Rectorate, it was established that the Rectorate received the mentioned letter on 21. IX. 1926 under number 4019, with one attachment.

Nikola Tesla's biography and his influence in the field of physics and electrical engineering have been researched many times, especially recently, when the 150th anniversary of his birth was celebrated. However, less attention has been paid to the influence of Te saliva on the field of medicine. Therefore, we will use primary and secondary sources, as well as unpublished sources, in this paper to present this segment of his influence and work. For the first time, the descriptions of experiments in middle school classes, which were made in Croatia, very shortly after, from my Tesla, are being made public. They are connected with Tesla's important discoveries that later found application in medicine as well.

Tesla's contributions to medicine

Few authors in Croatia have dealt with the segment of Tesla's work that has its application in medicine.5,6,13 In the recent article by Igor Salopek and Gordana @au har *Tesla's contributions to medicine5 ,* a picture of Tesla's transformer was also published for creating high-frequency and high-voltage so-called *Tesla* currents, so that article was one of the starting points for this review. The application of *Tesla* currents has found its place in medical diathermy. Tesla's transformer from 1908, manufactured by the Max Kohl company from Chemnitz, is today kept in the Department of Physics of the Faculty of Medicine of the University of Rijeka. Allegedly, this device (apparatus) was acquired for teaching physics at the Naval Academy in Rijeka, where physics was taught by Peter Salcher (1848–1928). Salcher is known to the medical readership as a pioneer in performing and demonstrating his experiments based on Röntgen's discoveries (Stella Fatovi}-Feren~i}: The discovery of X-rays as a model for the adoption of scientific knowledge in Croatia. Medicina 1995; 31 /32: 81–84). It is known that Tesla corresponded with doctors WJ Dugan and SH Monella, finding a common language with them in connection with electrotherapy. It is equally well known that Tesla's device for treatment with high-frequency currents, from the beginning of the 20th century, is kept in the Nikola Tesla Museum in Belgrade. A photograph of the skull made by Tesla in 1896, made with the help of X-ray radiation, was also shown. It is equally well known that Tesla also corresponded with Röntgen.5 Tesla's observation of the occurrence of electrography (the outline of the image of an object placed on a photoplate placed in a high-frequency electric field) was also highlighted. Today, this phenomenon is called Kirilian photography. Tesla's ozonator patent was produced by his company *(Tesla Ozone Company),* and the devices were sold to doctors. Tesla also constructed a vibrator that he used to reduce the feeling of fatigue in the leg muscles.5

As a supplement to the aforementioned article, we point out that Professor Mile Cindri} (1869–1939) produced *Tesla* currents with his transformer as early as 1902, at the gymnasium in Su{ak, as the first in high school teaching in Croatia. An article about these experiments appeared in Nastavni vjesnik under the title: Several experiments with Tesla's currents.8 Mile Cindri} was from October 19, 1895 until the end of {sk. in 1905/06. professor of physics at the Rijeka Grammar School, which was moved to Su{ak in 1896. Here he was the custodian of the physics collection, and as such he ordered a Röntgen tube, Tesla's instruments, an apparatus for electric waves for the cabinet collection.7 Cindriÿ first saw experiments with electric waves in Rijeka, which he Professor Peter Salcher of the Rijeka Naval Academy performed the experiments with the purchased apparatus. 7 During the experiments with Tesla currents, which could be performed with small and cheap apparatus that the physics collection of the Šaša Gymnasium had, in addition to the transformer, it is necessary to have Ruh mkorff's inductor and the Leyden bottle that is slowly emptying. Cindri} pointed out that already in 1894, 1897, 1898, 1899, and 1900, some authors from the German-speaking area had performed experiments with Tesla currents with small and cheap devices that can also be found in physical collections of Croatian secondary schools.8 Apparently, Cin dri} performed the experiments in his own way, different from the way these experiments are performed in the published literature. He used a Ruhmkor ff inductor, Leyden bottles and a Tesla transformer. So, after the inductor charged the Leyden bottles, they discharged oscillatory, which resulted in a high frequency, while a high voltage was obtained with the help of a large number of coils of the conductors of the Tesla transformer. Suddenly, at the ends of the threads, electricity erupted into the air in the form of bright strips, like flames. Cindri} also describes an experiment in which a brass ball is connected to one end of a transformer coil, while the other end of the coil is connected to the ground. Opposite the sphere stood a spike connected to an electroscope on an insulated stand. In the second experiment, a brass plate was placed instead of the ball. An experiment with a spherical sphere near which there is a metal plate is also described, and the sphere is struck as previously mentioned. Cindri} also describes an experiment in which two electroscopes are simultaneously charged with opposite electricity, and finally an experiment in which a round Hertzian resonator is connected to one end of the coil, and the other end of the coil is connected to earth. Everything is connected so that a gap can be made between the large brass balls for a spark. At a suitable distance, sparks up to 5 mm long can be obtained.8 These experiments performed in this way have a physically didactic role, and in the medical sense they can act as a demonstration of harmlessness as long as the person performing the experiments is nearby of all connected devices.

Ladislav Stjepanek (1874–1951), the first full-time professor of theoretical physics at the Faculty of Arts in Zagreb, in 1905 conducted experiments with alternating currents of rapid change and high tension according to Tesla in the physics lecture hall of the Royal High School in Zagreb. Stjepanek pointed out that the experiments with Tesla's currents are rarely mentioned in schools. 9 Before the experiment, he explained the concept of electric induction, the concept of transformation of current from a battery with the help of an inductor, and the concept of the oscillatory discharge of a Leyden bottle. Stjepanek got a quick change by transforming the battery current with an inductor and then charging the Leyden bottle. One pole of the inductor coil was connected to the inside of the Leyden bottle, and the other pole was connected to the outside of the bottle. The bottle was thrown over the spark. Stjepanek emphasized that with alternating current, impedance appears, unlike ordinary resistance that occurs with direct currents. High voltage

he got it by running the alternating current from the bottle to the Te saliva of the transformer. There, in the coil, he received a current of high change (frequency) and high voltage. In an experiment, Stjepanek showed the large sparks that he got by striking the ground with electricity, but over the surface of a glass plate covered with magnesium powder. He also showed an experiment with Geisslero vim and Crookes tubes that glowed intensely when he brought them close to a metal ball connected to one pole of the transformer, while the other pole was connected to the ground. At the end of that lecture with experiments, Stjepanek was sent off with shouts of "@ivio!" and the fifty physics professors present promised that they would perform these experiments in schools that have these devices, and it was also suggested that these experiments were also

included in school textbooks.9 According to Du{an Pejnovi},10 a physicist who (taking the place of the first university professor Vinko Dvorhák) as the first expert started working in the Physical in the cabinet of the Faculty of Arts of the University of Zagreb, Tesla also interpreted the physiological effects of high-frequency currents, allowing for two effects: the concentration of current on the surface of the body (skin effect) and the action *of* tissues as a capacitor system. In a lecture from 1891. Tesla stated that high frequency currents heat the isolated human body. He performed an experiment on himself with a frequency of 700,000 Hz (data that Pejnovi} transferred from a publication by S. Bok{an), passed current of that frequency through his body and interpreted that the human body is like a series of capacitors . Pejnovi} points out that Nernst's previous research from 1897 was decisive for the physiological effects of high-frequency currents.10 Insensitivity to currents is not because the high-frequency current only passes through the surface, but } from the cellular structure of the organism it follows that physiological effects necessarily depend on frequency. These effects disappear as soon as the concentration changes on the cell membranes, stimulated by the current, become insignificant. The changes are more insignificant the faster the current changes its direction at the same alternating current strength.

In the university lectures on experimental physics at the then Faculty of Philosophy (magnetism and electricity) that were published in 1936, Stanko Hondl (1873–1971) conjured up, among other things, magnetism and electricity with experiments related to Tesla. In these lectures, Hondl talks about the Ruhmkorff inductor and shows the qualities of an excellent experimenter. This can be seen from the sentence that the given current in the first winding *ad oculos* can be shown with a log graph. As an experimenter, Hondl interprets that the resulting curve is not a true picture of current fluctuations because the mirror is large and the oscilloscope loop is slow. If a lens with a smaller refraction is taken, a more faithful image will be obtained, but the image will be unsharp. Therefore, this kind of curve is photographed. He also lectured on Tesla currents of high voltage and high frequency, using a similar transformer. Tesla's currents were used by Hondl in Tesla's impedance experiment. The experiment shows that the current flows more easily through the bulb than through the arc of the copper wire, even though the Ohm resistance is greater in the bulb, but that's why the pedantry of the arc is great. With Tesla's transformer, experiments were carried out where a high voltage of 100,000 V was caught by the hand on the way out of the transformer without any consequences, while another experiment showed that touching that end with a light pipe caused it to die. He also lectured on the application of Tesla currents (d´ar sonvalization), stressing that this method of treatment was not highly valued at that time (1936). Hondl also performed Tesla's experiments, where hot sparks are obtained that can ignite wood, paper, etc. It is important that there be a large number of sparks, i.e. that the sparks are as frequent as possible, and it doesn't matter if the voltage is high. Therefore, Wagner's spark served Tesla his experiment. 11

Mario Filipi also wrote about Tesla's contributions to medicine, who states in his book that it is possible to achieve electrical anesthesia.6 According to this author, Tesla installed a device with high-frequency currents in the dressing room of a theater in New York. removed the stage fright of actors before the performance, and he even proposed stimulating children with electricity in schools. During the development of the apparatus for the application of high-frequency currents, he came across the vibration effect of some flat plates placed over the apparatus that produce high-frequency currents. This invention of his was voluntarily tested by the famous writer Mark Twain, who after a few minutes spent on the shaking platform hurriedly got off the platform, because the device allegedly had the effect of stimulating bowel movement.

Tesla's contribution to electrotherapy

Electrotherapy with alternating currents began in the middle of the 19th century, using the electromechanical Ruhmkorff inductor (1851 - picture 4). As the inductor was based on Faraday's electromagnetic induction, the sequence of impulses was called *Faraday currents,* and the therapeutic procedure *Faraday*

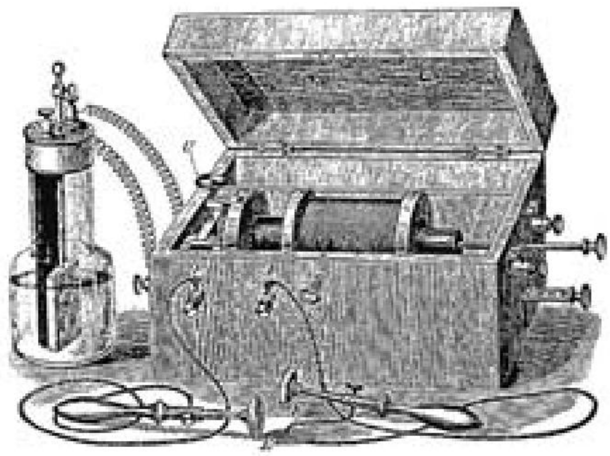

Figure 4. *Ruhmkorff inductor for medical use (80s of the 19th century)*

Figure 4. *Ruhmkorrf inductor for medical usage (eighteen-eighties)*

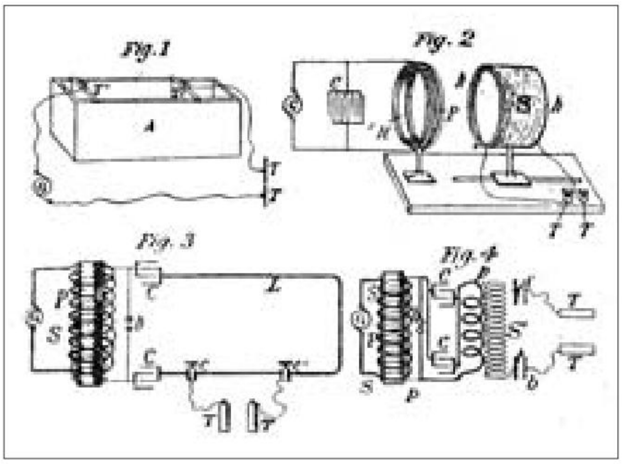

Figure 5. *Tesla's original spark oscillator designs for electrophysiological experiments; TT are electrodes for contact with the patient12* Figure 5. *Tesla's original drawings of oscillator with sparkles for Electrophysiological experiments; TT are electrodes for contact with patient12*

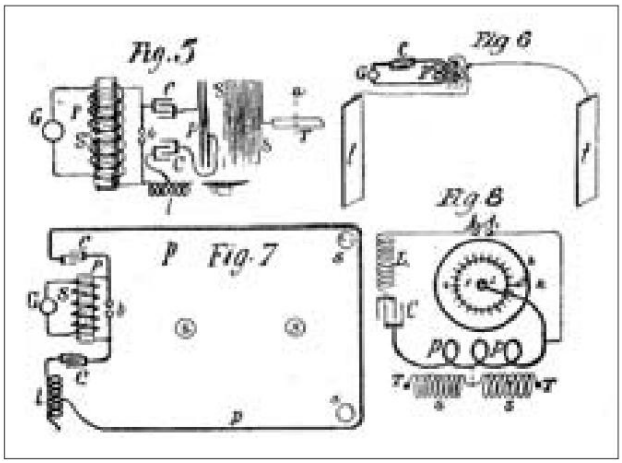

Figure 6. *Tesla's original spark oscillator designs for electrophysiological experiments; tt are capacitor plates for creating an electric field12*
Figure 6. *Tesla's original drawings of oscillator with sparkles for Elektrotherapy experiments. tt are capacitor plates for making electrical field12*

by zation. Faraday currents stimulate nerves, so it was a form of *electrostimulation.*

A comprehensive account of his experiments with HF currents was given by Nikola Tesla himself in numerous public lectures, and especially extensively and comprehensively in a lecture for the *American Electroelectric Association* (Buffalo, September 13-15, 1898), under the heading *High-frequency oscillators for electrotherapeutic and other applications.*[12]

In it, Tesla clearly limits himself to researching phenomena on living tissues, and leaves the application for treatment to doctors. In that lecture, he clearly states: "While the doctor is left with the research of the effects on organisms and the research of suitable treatment procedures, the electrical technician is forced to research the different ways of applying these currents." in the published work on that lecture12, there are Tesla's original designs of oscillators with a spark for electrophysiological experiments (figure 5 and figure 6).

Furthermore, it describes the devices, experiments and their work in detail.12 Figures 4, 5 and 6 are taken from the article by Z. Jakobovi} "Tesla's HF currents in electrotherapy" published in the Annual 2006 of the Croatian Academy of Engineering, and mentioned under order. no. 13 in the literature.

Conclusion and discussion

The starting point for this article were the few works devoted to Tesla and medicine published in our area, from the earliest ones by Cindri}, Stjepanek and Pejnovi} published in the first decades of the 20th century8– 10 to newer ones published mainly on the occasion of Tesla's anniversary.5,6,13

In this work, we supplemented the existing data of previous authors with those segments of his research that had an echo in medicine and therapy. It was a time when the echo of positivism and science was very important for the development of medicine and certain therapeutic methods. In this sense, physics, starting with the sensational discovery of X-rays, encouraged further intertwining of these two areas and gave impetus to further research. In the atmosphere of progress and contemporary scientific echoes that spread throughout the world, the area of our homeland was, without a doubt, a part of Europe where recent scientific achievements were readily applied (Fato vi}-Feren~i} S Medical journal in the atmosphere of the beginnings of radiology in Croatia. Lije~ Vjesn 1996; 118:84–85). It came to light that Tesla's research aroused great interest in the local academic community, that his experiments were repeated and even more often introduced into classes, and that they aroused the interest of fewer doctors. The progress of this work is reflected in the fact, on the one hand, that Tesla was presented more comprehensively to the scientific public, and on the other hand, that, although he was associated with medicine, Tesla left the research of the effects of his works to doctors. inventions, so all later therapies based on his inventions were carried out without his personal involvement.#

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LITERATURE

1. *Han`ek B, Franz-[tern R.* Nikola Tesla – honorary doctor of the University of Zagreb. Sveu~ Vjesn 2006;52:74–80.
2. *Paar V.* Nikola Tesla in physics. Collection of papers dedicated to the 60th anniversary of the death of Nikola Tesla. Zagreb: 2004; p. 35–48.
3. *Anonymous.* Tribute to Nikola Tesla. Nikola Tesla Museum. Belgrade: in 1961
4. *Jakobovi} Z.* Measurement unit *tesla.* Radio HRS 2006;6:22–4.
5. *Salopek I, @auhar G.* Tesla's contributions to medicine. Acta Med-hist Adriatic 2006;4(2):189–98.
6. *Filipi M.* Nikola Tesla under the cobwebs. Samobor: Own edition; in 2006
7. *Pejnovi} D.* In memory of Mila Cindri}. Nast Vjesn 1940–1941;49:225–7.
8. *Cindri} M.* Several experiments with Tesla currents. Continued Spring 1902; 11: 23–32.
9. *Anonymous.* From III. of the social meeting on November 8, 1905. Nast Vjesnik 1905–1906; 14:320–2.
10. *Pejnovi} D.* From the life and work of Nikola Tesla. Nast Vjesnik 1927;25:347.
11. Experimental physics (according to the lecture of Prof. Dr. Stanko Hondl, the script was created by student Franjo O`egovi}). Zagreb 1936; 127–9.
12. *Tesla N.* High frequency oscillator for electro-therapeutic and other purposes (read at the eighth annual meeting of the American Elec tro-Therapeutic Association, Buffalo, NY Sept 13 to 15 , 1898) – Re printed in: Nikola Tesla-Lectures Patent Articles. Nikola Tesla Museum, Belgrade 1956.
13. *Jakobovi} Z.* Tesla's high frequency currents in electrotherapy. Ann Croat Acad Eng. Zagreb: Croatian Academy of Engineering; 2007, p. 289–302.

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