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THE "NEAPOLITAN SCHOOL OF ELECTROTHERAPY" BETWEENTHE LATE NINETEENTH AND THE FIRST DECADES OF THE TWENTIETH CENTURY

„NAPULJSKA ŠKOLA ELEKTROTERAPIJE" IZMEĐU KRAJA DEVETNAESTOG I PRVIH DESETLJEĆA DVADESETOG STOLJEĆA

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SUMMARY

Electrotherapy is the use of electrical energy as a medical treatment. In the nineteenth century, the "golden age" of electrotherapy, the development of this discipline was part of a historical-scientific context characterized by the affirmation of neurology as an autonomous branch and, finally, detached from psychiatry. After a period of limited scientific interest and development, in the second half of the 20th century, electrotherapy underwent a revival. Nowadays, the use of electrotherapy has been researched and accepted in various fields of medicine, including but not limited to rehabilitation, neurology, pain management, and oncology.

From its first applications, electrotherapy joined neurology which used it for both diagnostic and therapeutic purposes. In Italy, several scientists carried out experiments on the subject, and an important contribution to the development of the discipline was provided by the "Neapolitan school of electrotherapy". This improvement was made above all by Francesco Vizioli (1834- 1899) and his pupil Francesco Paolo Sgobbo (1860-1936). Despite these premises, however, the decline of electrotherapy as an autonomous science soon came. Meanwhile, radiology, associated initially with electrotherapy, developed rapidly. When Mario Bertolotti (1876- 1957), former professor of Radiology at the University of Turin and one of the founders

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of Italian radiology, succeeded Sgobbo in 1935, the name (and the discipline) "electrotherapy" was deleted from the diction of the new chair, and from that of the department, which was indicated only as "Radiology". Radiodiagnostic devices, supplies, and roentgen therapy equipment replaced the numerous devices used for electrotherapy.

This manuscript is focused on the Neapolitan school of electrotherapy from the late nineteenth century to the beginning of the twentieth. The work of the leading figures who have given the greatest impetus to the study and application of electrotherapy is described. Finally, the electrotherapy devices used are briefly illustrated.

Keywords: *Electrotherapy, Electrical medicine, Neurology, Psychiatry, Oncology, Quack medicine*

Introduction

Electrotherapy. Since pioneering attempts to modern applications

The term electrotherapy indicates the use of electrical energy — direct current such as galvanization and iontophoresis, or alternating current at low (e.g., Transcutaneous Electrical Nerve Stimulator, TENS), medium (e.g., Trabert current, and pulse trains), and high frequency(e.g., Kotz current) — as a medical treatment (Radatz, 1997). The use of electricity for therapeutic purposes dates to antiquity (Kellaway, 1946)[1]. Nonetheless, the incredible discoveries and inventions on the topic that have rapidly followed since the mid-eighteenth century have laid the foundation for its most diverse applications[2]. Consequently, rudimental electrical machines were used for multiple purposes, including medicine. For instance, the American scientist and politician Benjamin Franklin (1706-1790) developed a device consisting of a charged glass plate to give shocks to patients to treat "melancholia"[3] (Bol-

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1 For example, as reported by Claudio Galeno (II century A.D.) in his *Methodus medendi - libri XIV*, torpedoes (from the Latin *torpedo-dinis*, from *torpere*, to numb), fish that can generate electric shocks, were used to induce analgesia (electro-analgesia). Other fish with electrical properties are the *Silurus electricus*, and the *Gymnotus electricus*.

2 Although the attraction of luminous bodies to electrified objects has been known since ancient times, the real revolution in the field of electricity came thanks to the work of Luigi Galvani (1737-1798). The Italian anatomistanalyzed the muscles of the frog's legs and, in 1791, discovered that these muscles exhibited curious electrical properties as soon as they came into contact with two metals of a different nature. A few years later, Alessandro Volta (1745-1827) used Galvani's discoveries and developed the first electric battery. It consisted of a series of copper and zinc discs, between which acid-soaked tissues were interconnected. The Volta's battery produced a sort of continuous electric discharge that the French physicist André-Marie Ampère (1775-1836) baptized as "electric current".

3 Melancholia or lipemania refers to an affective syndrome. It is characterized by a morbid and obstinate sadness,independent of external events, an invincible pessimism, as well as a deep sense of mistrust and dejection, which paralyzes the action. The term melancholia derives from the Greek word μελαγχολία composed of μέλας (black) and χολή (bile). Thus, until the 19th century, it indicated a serious sadness of mind that resulted from an excess of"black bile" in the

wing & Fink, 2009; Finger, 2006) and the Italian physicist Giovanni Aldini (1762-1834) treated subjects with mental disorders, reporting their complete rehabilitation following transcranial administration of electric current (Parent, 2004).

Although the German doctor, physicist, and engineer Christian Gottlieb Kratzenstein (1723- 1795) was probably the first to write a text on electrotherapy (*Abhandlung von dem Nutzen der Elektrizität in der Arzneiwissenschaft)* in 1745 (Kratzenstein, 1745), the first medical documented electricity-based treatment conducted using a specific device was described in1767 at the Middlesex Hospital of London (Bentley & Dunstan, 2006). Three years later, in 1770, aseries of experiments collected by Jean Jallabert (1712-1768) were published in the *Experimenta electrica usibus medicis applicata* (Jallabert, 1770), while many other scientists reported their, more or less reliable, experiences in a time span reaching the end of the1700s (Schivardi, 1864). Interestingly, the French physician, scientist, and revolutionary Jean-Paul Marat (1743-1793) also dealt with the subject, reporting beneficial effects in the treatmentof edema, sciatica, and gout (Gaudenzi & Satolli, 1989). Additionally, the Croatian theologianand philosopher Joseph Franz Domin (1754-1819) worked on the electrotherapy of numerous conditions and diseases, such as arthralgias, cephalea, and epilepsy (Habek et al., 2020).

Later, in 1852, Napoleon III instituted an award for the author of a discovery that would bring the greatest innovations in the field of electricity applied in industry and medical practice. The prize was unanimously awarded to Heinrich Ruhmkorff (1803-1877), inventor of the transformer used to produce high voltage pulses from a low voltage direct current source (Ruhmkorff Coil). In particular, Ruhmkorff perfected the "Faraday coil" [4] system — consisting of two wooden cylinders, on which a thin and long thread and a thicker and shorter one were wound — and developed a coil consisting of two concentric spools in whose common center was placed a magnetic bar that enhanced the effect.

In the nineteenth century, thanks to this and other innovations, numerous attempts were made to investigate the possibility of using electrical energy in several fields of medicine. Electricity was used for anesthesia (Cas-

body. According to the Hippocratic theory of the four humors (5th century B.C.), the "black mood" causes alterations of the "spirit" that becomes gloomy, sad, and irascible.

4 In 1831, Michael Faraday (1791-1867) defined the regulating principles of the relationship between electriccurrent and magnetism (Faraday-NeumannLenz law).

cella, 2015a) and for treating disorders such as those of the digestive tract, cachectic diseases, skin disease, gout, and rheumatism, as well as psychiatric conditions, gynecological diseases (La Beaume, 1826), and for the care of the "apparently dead" individuals (Cascella, 2016a). Moreover, between 1865 and 1866, several experiments with electricity were carried out at the Maggiore Hospital of Milan for the treatment of rabid patients (Marinozzi et al., 2016). In brief, during this period, electricity was used to treat tetanus, septic fevers, and, more generally, all the pathologies with neurological symptoms, even if the etiology was not a neurological disease (including infections and infective pathologies). Thus, the nineteenth century is also indicated as the "golden age" of electrotherapy (Heidland et al., 2013).

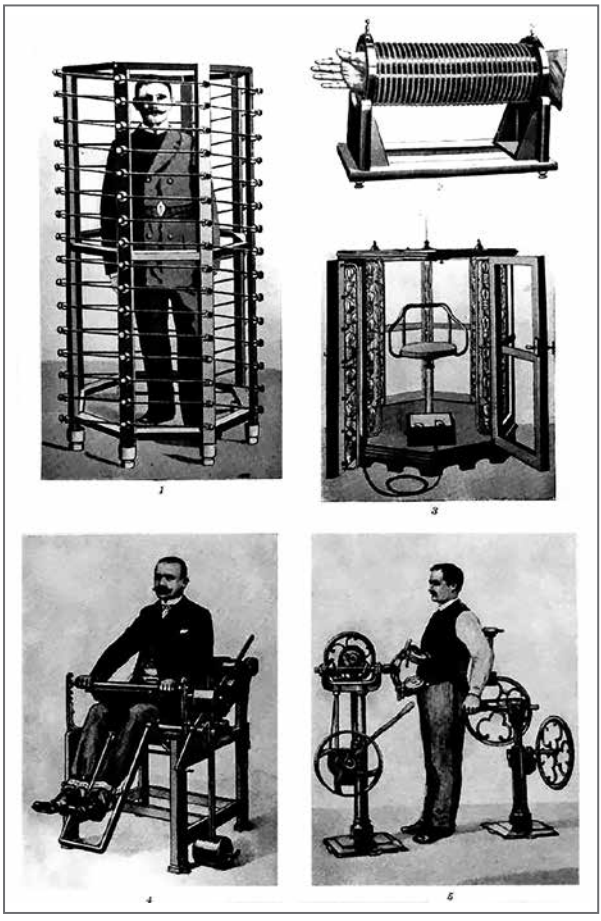


Figure 1. Catalog of electrotherapy instruments. "Modern medical treatment" (by the author).

At the beginning of the 20th century, even in the absence of a solid scientific basis, innumerable devices were developed and proposed for the treatment of the most disparate pathologies and disorders. Nevertheless, these rudimental devices were used especially by charlatans for unserious aims. Consequently, the history of medicine includes electrotherapy devices and their use in this period among the so-called "Quack medicine", a term that referred to every unproven or fraudulent medical practice (Figure 1).

In the early 1900s, not all electrotherapy is identifiable as "Quack medicine". Many applications of electricity in medicine followed a more rigorous path of scientific experimentation. In this period, the use of electricity in medicine was aimed above all at diagnostics. Notably, the notions of electricity were mainly applied to the development of a new discipline: radiology. The nascent branch of medicine itself, however, also included radiotherapy that, in turn, represented the main "scientific" therapeutic application field of electrotherapy in the early twentieth century.

In the span of a few decades, the scenario has changed again. In the second half of the twentieth century, electrotherapy underwent a revival because, its neurophysiological mechanisms were elucidated in more detail based on animal experiments and clinical investigations,. Nowadays, the use of electrotherapy has been researched and accepted in various fields of medicine, including but not limited to rehabilitation, neurology, psychiatry, cardiology, pain management (Helmstädter, 2003), and oncology. The application methods and pathologies or disorders treated are manifold: from cranial electrotherapy stimulation (CES) for the treatment of anxiety, insomnia, depression, and many other disorders, to TENS and pulsed electromagnetic field therapy (PEMF) for muscular rehabilitation, to peripheral nerve stimulation (PNS) and electroacupuncture for the treatment of chronic pain (Qu et al., 2017). Other uses include functional electrical stimulation (FES) for improving neural functioning after stroke and for managing foot drop in people with multiple sclerosis, deep electrical stimulation of brain areas (DBS) for Parkinson's disease, neurostimulation techniques for addressing fecal/urinary incontinence, the use of implantable devices in cardiology for pacemaker, defibrillation, and resynchronization applications, noninvasive brain stimulation methodologies for improving cognitive control of emotion in some psychiatric diseases, vagus nerve stimulation for refractory depression, and brain-responsive stimulation in patients with medically intractable seizures. The list is incredibly vast, and exhaustive coverage of the topic is beyond the scope of this manuscript.

Electrotherapy applications in neurology

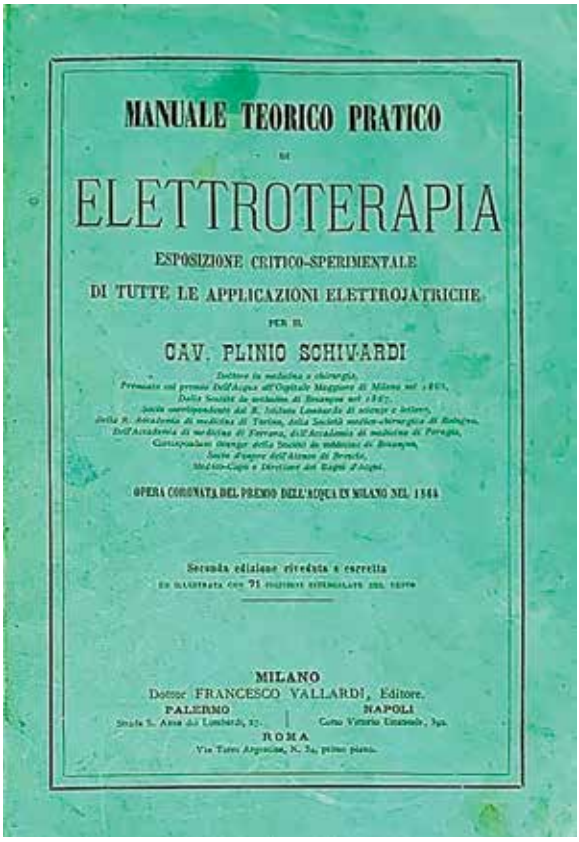
When neurology began to assert itself as an autonomous science, electrotherapy joined it. Indeed, electric devices became paramount tools in many neurological investigations. However, even before the birth of neurology, electrical energy was used to treat neurological symptoms, such as paralysis, tremor and other abnormal movements, gait disorders, and seizures. A widely used device was the Leyden jar. This oldest form of the electric capacitor was independently developed by Ewald Jürgen Georg von Kleist (1700-1748) in Germany and by Pieter van Musschenbroek of Leiden (1692-1761) in the Netherlands in the mid-seventeenth century. Theapparatus was used to conduct many of the earliest experiments on electricity in medicine during the second half of the eighteenth century, and several reports indicate its use for the treatment of weakness and contractures (Baigrie, 2007).

During the nineteenth century, the use of electrotherapy becomes more widespread, contributing significantly to the development of neurology (Piccolino & Bresadola, 2013). For instance, the German Wilhelm Heinrich Erb (1840–1921), maybe the most brilliant clinical neurologist of the latter part of the nineteenth century, was one of the first clinicians who used electricity in the diagnosis and treatment of nervous disorders (Sarikcioglu & Arican, 2007). His manual entitled Handbuch der Elektrotherapie was a standard neurological work of its time (Erb, 1882). Furthermore, the French neurologist Guillaume-Benjamin-Amand Duchenne (1806-1875) used electricity to explore the facial expression of emotions (the famous Duchenne Smile) but especially as a treatment for several neurological disorders (Duchenne, 1868). In particular, the founding father of French neurology developed a non-invasive muscle stimulation technique called "electrisation localisee" and explained the theories on electrotherapy in his book De l'electrisation Localisée et de son Application à la Physiologie, à la Pathologie et à la Thérapeutique, published in 1855 (Duchenne, 1855). Very interesting is the use of Galvani's electricity in the nineteenth century in the United States. Studies on several neurological diseases and based on the battery for electrolysis experiments of Humphrey Davy (1778-1829) and Michael Faraday (1791-1867) were well known in Italy (Schivardi, 1864). The application of electricity in neurology for therapeutic purposes will continue during the first part of the twentieth century. In particular, in 1938, the Italian psychiatrist and neurologist Ugo Cerletti (1877-1963) observed the effects of electric shocks on pigs before being killed, and Lucio Bini (1908-1964) devised and patented an apparatus for

electroconvulsive therapy (electroshock apparatus), driven by Cerletti's insights (Passione, 2004).[5]

Electrotherapy at the University of Naples

In the second half of the 1800s, in Italy, several authors became interested in electrotherapy. Among them, Plinio Schivardi (1833-1908), a pupil of Duchenne who represented the leading exponent of a cultural current that spread rapidly in various universities of the peninsula, is worth mentioning. He collected his experiences in a very interesting manual where the construction methods of the devices and the finding of materials were also illustrated (Figure 2).


MANUALE TEORICO PRATICO

DI

ELETTROTERAPIA

ESPOSIZIONE CRITICO-SPERIMENTALE

DI TUTTE LE APPLICAZIONI ELETTROJATRICHE

PER IL

CAV. PLINIO SCHIVARDI

OPERA CORONATA DEL PREMIO DELL'ACQUA IN MILANO NEL 1864

Seconda edizione riveduta e corretta

MILANO

Dottor FRANCESCO VALLARDI, Editore.

PALERMO — NAPOLI

ROMA

Figure 2. Manuale di Elettroterapia (Handbook of Electrotherapy) of Plinio Schivardi, 1868 (second edition of the text of 1864).

5 The link between Cerletti and electricity tradition is debated. Cerletti aimed to follow the shock therapy tradition (electricity was conceived as a mere means to induce seizures).

Because of this cultural growth, scientists were increasingly convinced that the discipline should have been recognized as an autonomous branch. This issue was widely debated during the Congress of the Italian Medical Association, held in Rome in 1871 (Schivardi, 1864, p. 54). The University of Naples can be considered a point of reference in the discipline (Polichetti, 1974). Here, Francesco Vizioli (1834-1899) and his successor Francesco Paolo Sgobbo (1860- 1936) were pioneers of electrotherapy, and both scientists were awarded professorships in this subject.

Francesco Vizioli was one of the protagonists of the complex process of separating neurology from psychiatry[6]. Vizioli was born in Colledimezzo (Chieti), in 1834. He was an exponent of an aristocratic family and studied letters in Chieti and then moved to Naples to study medicine[7]. After graduating, he was attracted by scientific research and became an assistant of Antonio De Martini (1815-1905) and Joseph Albini (1827-1911). In 1859, he published the Annuario di Medicina Pratica del 1858 (The Yearbook of Medical Practice, 1858), a summary of medical monographs given to the press in Europe that year (Vizioli, 1859). In the same year, he was appointed by the government to study the typhus epidemic in Massa Lubrense, a town near Sorrento. For his merits, he joined the Real Accademia Medico Chirurgica di Napoli (Royal Academy of Medicine and Surgery of Naples), of which he became secretary in 1883. His interests were initially focused on physiology, and in 1868, he was appointed professor of experimental physiology at the University of Naples (Anonymous Author, 1869). He also oversaw the Italian edition of the Ele-

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6 For a long time, due to a cultural paradox, there was no clear distinction between psychiatry and neurology. Inthe nineteenth century, however, the importance and autonomy of neurology became increasingly evident, and as stated by Henry Rouse Viets, "Neurology as we know it today, in practice and in clinic, developed only after he (Moritz Heinrich Romberg ndr) published the first edition of his *Lehrbuch der Nervenkrankheiten*, the first volumein 1840 and a final one in 1846." [Viets HR. (1948), The history of neurology in the last one hundred years. Bull NY Acad Med, 24, 772-783.]. In 1873, thanks to the efforts of Biagio Gioacchino Miraglia (1814-1885), the Società Frenopatica Italiana (Italian Society of Freniatry) was founded. Thus, the fields of psychiatry and neurology were definitively separated. Together with other more famous Italian scientists, such as Cesare Lombroso (1835-1909) and Enrico Morselli [Cascella M. (2016a), Taphophobia and 'life preserving coffins' in thenineteenth century. Hist Psychiatry, 27(3), 345-9.], Vizioli took an active part in this process and, in 1877, organized the II Congress of the Society. Later on, the Società Italiana di Neurologia (Italian Society of Neurology) was founded in Rome in 1907 [Federico A. (2011), Italian neurology: past, present, and future. Funct Neurol, 26(2), 73-76.]

7 The Vizioli family includes other illustrious neurologists among its ranks. In addition to Francesco, his brother Raffaele, also a neurologist at the University of Naples and his close collaborator, as well as his direct descendants,should be mentioned. Among these, Francesco (1893-1974) – son of his brother Raffaele – who established himself in Naples and was Director of the psychiatric hospital, and his son Raffaello, holder of the chair of neurology at the University of Rome.

ments of physiology written by Karl von Vierordt (1818-1884) and performed several pieces of research in the fields of physiology and zoology (von Vierordt, 1868; Vizioli, 1868a).

Vizioli's scientific production was very copious as it covered various aspects of neurology (De Giaxa, 1904). Several citations can be found in manuscripts written by important neurologists of the time but also in articles published in the early decades of the 1900s (Wardell, 1910). The pediatrician John Price Crozen Griffith (1856-1941) cited Vizioli several times in one of his monographs on Friedrich's Ataxia, thanking the Italian scientist for providing him with valuable insights and part of the case series (Crozen Griffith, 1888). Furthermore, Vizioli can also be considered one of the first Italian scientists who became interested in neuropathology. In this regard, he founded the Giornale di neuropatologia (Journal of Neuropathology), the first periodical expressly dedicated to the discipline. During the II Congress of the Società Frenopatica Italiana (Italian Society of Freniatry), he gave a lecture entitled "On the brain locations (of madness)", in which he affirmed that: "using stimuli not diffusible ... I am of the opinion that the brain cortex is unexcitable, and the so-called psychomotor centers do not exist, at least for my own experimental research and that of most physiologists" (Federico, et al., 2010).

In this historical context, therefore, electrotherapy represents an important discipline that, although supporting neurology, can also be recognized as a subject of university teaching. Neapolitan University and Vizioli are the protagonists of this cultural revolution. Notably, in 1877, the Faculty of Medicine of Naples awarded Vizioli the Chair of Neurology and Electrotherapy. The course was inaugurated on 12 December 1878, and in his lecture, the scientist stated that the application of electrotherapy, not only in the fields of neurology but also in different areas of medicine and in combination with other pharmacological treatments, was his primary objective (Vizioli, 1878a).

Although with significant technical and cultural limitations and in the absence of a rigorous study methodology, the Italian scientist proved very far-sighted. Only more than half a century later, other scientists conducted attempts at electrotherapy applications like those previously studied by Vizioli (Turrell, 1936). Based on the use of electric devices, Vizioli accumulated experiences in the treatment of various diseases, such as goiter (De Giacomo & Vizioli, 1883) and facial nerve paralysis (Vizioli, 1884). He also reported significant results applying electricity for sedative purposes and pain therapy (Vizioli, 1868b), enhancing the absorption of drugs, and the treatment of paralysis and intermittent fevers (Schivardi, 1864, p. 61).

The most interesting chapter of Vizioli's research concerns using electricity to identify bullets in gunshot wounds, treat tremors in paralysis agitans, and manage aneurysmal lesions. In a historical period marked by constant war events and in the absence of adequate diagnostic instrumental tools, a paramount problem concerned the identification of bullets, or fragments of them, from gunshot wounds. For this purpose, different devices were designed. The French surgeon Auguste Nelaton (1807-1873), for instance, developed a probe used to treat the Italian patriot Giuseppe Garibaldi who was injured during a battle of the Italian Independence War (Nelaton, 1863). An interesting variant of Nelaton's probe was developed by the Italian surgeon and patriot Rodolfo Rodolfi (Cascella, 2015b). Vizioli became interested in the topic and published, in 1867, a commentary in which he proposed the use of an apparatus equipped with a magnetic galvanometer and a compass connected with a metal wire used as a probe. In practice, it worked as a metal detector (Vizioli, 1867).

In 1879, Vizioli described a case of paralysis agitans (Vizioli, 1879). The term paralysis agitans (shaking palsy) was introduced in 1817 by the British physician James Parkinson (1755-1824) for indicating a progressive degenerative disorder of the central nervous system (Parkinson, 1817). The clinical features were tremor (shaking), impaired muscle coordination, slowing of movement, partial facial paralysis, and general muscle weakness. Although this disorder became known as Parkinson's disease in the 1860s, the term paralysis agitans continued to be used for a long time. The most popular therapeutic options for addressing the clinical manifestations of the disorder, such as the use of belladonna, strychnine, opium, arsenic, silver nitrate, and Calabar bean, showed little efficacy and, in some cases, were particularly toxic. A clinical case regularly discussed by Vizioli in his academic course on electrotherapy concerned a 60-year-old male patient who underwent electrotherapy and manifested a paramount improvement in the tremor. This result was obtained by the application of electricity through cycles of a total duration of two months. About the technique, the flow circuit was built with the positive electrode on the nape or the skin in correspondence to the brachial plexus, and the negative terminal on one of the limbs. As Vizioli (1879) stated, this approach was able to control the tremor only in the recent onset forms but not when it manifested itself as particularly severe.

The field of intervention in which Vizioli reported obtaining the most significant results was the treatment of aneurysmal lesions. The author described a case series of forty patients. The first case was described in 1876

and involved a patient with a large aneurysm ("like a chicken egg") in the brachiocephalic trunk, treated by external application of electricity. After several sessions, Vizioli reported the almost complete disappearance of the lesion. This result allowed the scientist to postulate that the "action of electricity favored the gradual coagulation of the lesion" (Gallozzi, 1876). In 1878, however, a case that was not solved by such a method gave the cue to Vizioli to critically review its approach to treating aneurysms. This patient suffered from an aneurysm of the subclavian artery that extended above the collarbone and showed particularly thin walls, so much that it threatened "to burst at any moment". As the author reported, each application of electrotherapy took place because of the fear of breaking the lesion and causing the patient's death from acute bleeding. After 20 sessions, the lesion volume was reduced considerably, and its walls seemed thicker, so he had assumed the consistency of a small cyst pasty. Nevertheless, despite this improvement, the patient died a few months later, and post-mortem examination demonstrated a large clot from the injury to the left ventricle. After this failure, Vizioli saw the analysis of the results on 24 patients treated up to then. While in most cases, the treatment allowed achieving an improvement in the macroscopic aspects of the lesions, only in 6 patients (25%) there was an improvement in survival. In all cases, however, a marked amelioration in the concomitant painful symptoms was obtained. This consideration led him to reflect on the potential of the analgesic method, which, therefore, could be used with different dynamics for purely palliative ("pain relief and the chance to spend a peaceful night is a noble and valid argument") (Vizioli, 1878b).

Between the end of the 19th century and the first decades of the 20th century, neurology developed by seeking the confirmation of clinical observation in the anatomical-pathological findings. In the Age of Positivism, research must have a solid experimental basis, and empiricism necessarily had to be supplanted by the rigor of the scientific method. Thus, from his previous experiences, Vizioli drew an important lesson: the therapeutic application of electricity must follow a precise work plan. Vizioli understood that considering the characteristics of the tissues treated, the size of the lesion, and the potential of the device adopted is mandatory. Consequently, in collaboration with the physiologist Albini, the scientist began testing therapeutic applications in experimental models consisting of hearts of tortoises that underwent the passage of a direct current of different voltage. At the end of the experiments, the heart chambers were dissected for evaluation of the extent of the coagulation process. Following this methodology, Vizioli (1878b, p. 735) car-

ried out another group of experiments through a model obtained by coating a rubber pump filled with animal blood with skin taken from a human corpse. The purpose was to evaluate the electrical resistance of the skin and to demonstrate that the clot was formed in the area of contact with the electrode (vascular wall lesion area), limiting the accidental departure of emboli.

A summary interpretation of Vizioli's work could lead the reader to consider his experiments to be empirical and based on non-scientific methods. Nevertheless, careful analysis and contextualization within the Italian and international scientific panorama of the time lead us to believe that these studies present interesting elements of originality. These strengths are, above all, the use of many instruments (and modalities) and their application in disparate pathologies and disorders. Furthermore, a detailed description of clinical cases and procedures is evident in the scientific corpora. Finally, the cases reported are numerous and often used in studies by other authors. This last aspect represents international recognition of the author, especially if contextualized to a historical period where scientific collaborations were not encouraged.

When in 1899, Vizioli died, the Superior Council of Education and the University of Naples reshaped the teachings, combining neuropathology with psychiatry and, in turn, the electrotherapy chair became autonomous. The teaching of electrotherapy was assigned to Francesco Paolo Sgobbo[8], a former student of Vizioli who had completed numerous studies on pathology and physiology (Sgobbo, 1892). Moreover, he was previously appointed professor of neuropathology in 1893. Even before the master's death, however, Sgobbo had long experimented with the electrotherapy techniques, focusing above all on its potential application in the diagnostic. These experiences were summarized in a book published in 1897 entitled Elettricità medica: elettrodiagnostica, elettroterapia (Sgobbo, 1897). Furthermore, two years later, he founded the Giornale di Elettricità Medica. Among the various works on the topic, an article on the application of electrotherapy to esophageal scar narrowing (Sgobbo, 1911) deserves to be mentioned. The author described in detail the therapeutic possibilities of electrotherapy techniques during endoscopy for ear, throat, and nose pathologies. Overall, his scientific production includes about 150 publications on electrotherapy and radiology, as well

8 Francesco Paolo Sgobbo was born in Ariano Irpino (Avellino) on 10 August 1860. Immediately after graduatingin medicine in 1885, he became interested in electrotherapy and was appointed assistant doctor at the asylum of Nocera Inferiore (Salerno) (Savignano, 2020).

as other works relating mainly to biology, pathology, and physiology (Savignano, 2020).

Professor Sgobbo held the position for 14 years, and, in 1914, a new chair in Electrotherapy and Radiology and a department were established. This act expanded the fields of electrotherapy by enriching it with the skills of the nascent radiology that, at the time, was not yet distinguished in diagnostic radiology and radiotherapy. Interestingly, in the second edition of his book in 1897, Sgobbo completely changed the plan of the work, dedicating a lot of space to radiology and radiotherapy. The dissertation on physiological aspects is also very interesting (Sgobbo, 1903). Due to the efforts made to bring out radiology as an autonomous science, Sgobbo is considered one of the fathers of Italian radiology. Moreover, Sgobbo (1933) represents an eclectic figure of a scientist as among his various interests were other disciplines, such as medical hydrology and nutrition (Botti, 1928); he also wrote some literary essays.

Despite the premises, the scientific interest in electrotherapy gradually declined, giving way to applications by charlatans. At the same time, both neurology and radiology had incredible development. Mario Bertolotti (1876-1957), a former professor of Radiology at the University of Turin and one of the founders of Italian radiology[9], succeeded Sgobbo when he retired in 1935 (Figure 3). The name (and the discipline) "electrotherapy" had been previously deleted from the diction of the new chair and from that of the department, which was indicated only as "Radiology". Multiple radiodiagnostic instruments, medical therapy, as well as equipment for chemical and microscopic experiments had replaced electrotherapy instruments (Zerboni et al., 1939).

Like his two predecessors, Bertolotti had a solid cultural background in electrotherapy. He dedicated himself to the branch since his stay in France. In the academic year 1901-1902, he worked at the Pitié-Salpêtrière University Hospital and specialized in electrotherapy in the laboratory of the medical faculty of Paris. During his career, he studied the Klippel-Feil syndrome, congenital anomalies of the spine cervical chondrodysplasia, and wrote an important essay on Alexander the Great (Gedda, 1958).

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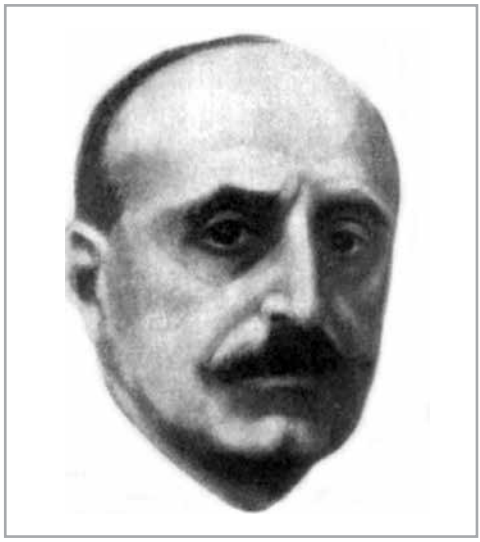

Figure 3. Professor Mario Bertolotti (1876-1957).

In the cabinet of electrotherapy of the University of Naples, over a period of about fifty years, the instrumentation used for electrotherapy has undergone an important evolution. A brief description is provided in a dedicated paragraph.

Electrotherapy devices used

The instruments usable for electrotherapy procedures and experiments were of two types: faradic instruments and galvanic apparatus. Starting from 1840, the faradic generator was the first electromedical used for diagnostic and therapeutic purposes. These instruments referred to the Ruhmkorff coil by modifying it so that the voltage applied to the electrodes was adjustable and pulsating electric pulses of short duration (usually 1 millisecond). The galvanic devices were basically batteries of primary cells delivering 15-25 volts of continuous current regulated by a rheostat; the electrodes were pads of skin or cloth soaked in a saline solution (see Cover Figure). Multifunctional, galvanic-faradic devices were also available. They worked through a combination of galvanic currents with those of the faradic type (Figure 4).

Other devices were the dynamo instruments and the high-frequency machines. Dynamo devices, or magneto-electric machines, worked by delivering pulsating voltages around 20-40 volts. The functioning principle precedes the transformation of mechanical work, received from a source of mechanical energy, into electrical energy in the form of direct current (Figure 5).

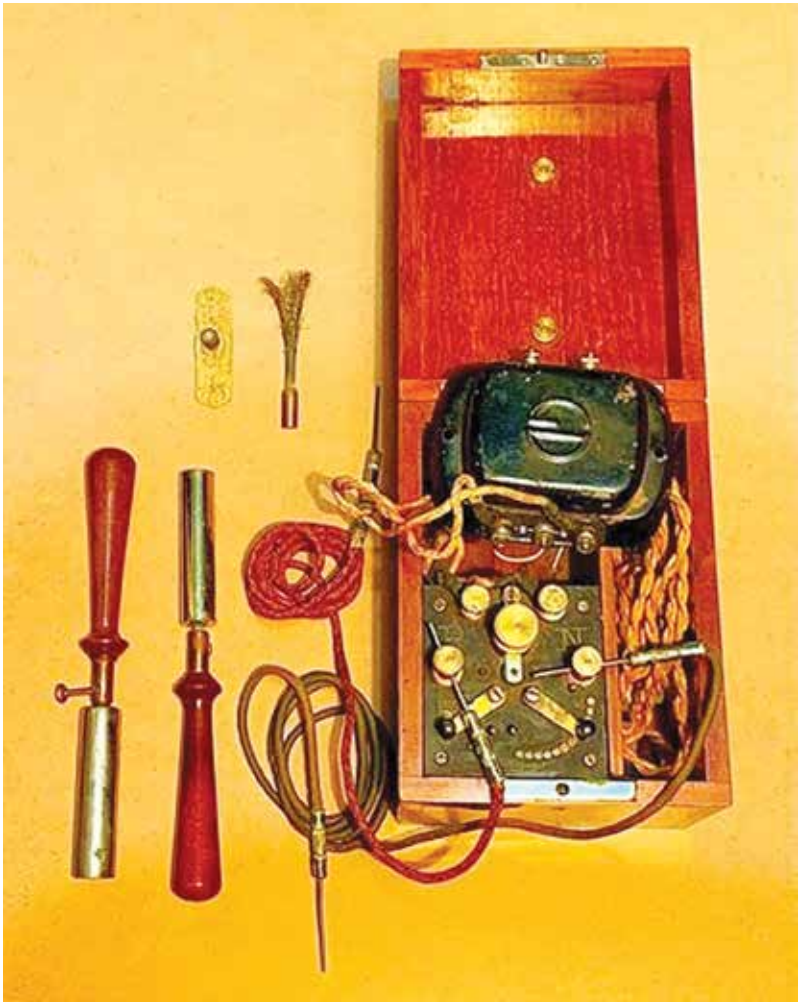

Figure 4. Galvano-faradic instrument. Second half of the 20th century (by the author).

The violet ray devices were developed in the early 20th century based on Tesla-type high-frequency resonant circuits and produced a very high but harmless voltage. The glass electrodes contained low-pressure gas: when placed in contact with the skin, they light up with a pink or violet light depending on the gas contained, and the patient felt a tingling and a slight smell of ozone (Figure 6). Although it was hypothesized that these instruments produced a wide range of beneficial effects also including analgesic proprieties, a certain disinfectant effect, and even anti-hypertensive action devices were only used to show "colored light": they worked like current neon tubes.

Figure 5. The Davis & Kidder Patent Magneto-Electric Machine for Nervous Diseases 1854, manufactured by W.H. Burnap, in 1854. (by the author).

Figure 6. Holo-Electron violet rays apparatus complete of glass electrodes, bakelite handle, and voltage control. About 1920. (bythe author).

At the Gesù e Maria Hospital, the University of Naples was equipped with an elegant electrotherapy department containing numerous devices. Regarding the instrumentation used, Vizioli reported that he had started his experiments with a 12-cell galvanic battery (Leclanché battery) or 30 cells (Daniell battery, modified by Onimus) (Figure 7) and by needle electrodes. His innovation consisted of the galvanometer he improved in order to take into account the electrical resistance of the skin and to apply the tension with greater consistency. Thanks to these measures, burning ("comparable to the bite of leeches") or skin ulcers at the sites of application of the electrodes could be avoided. Other investigations were carried out using the Clarke's magneto-electric apparatus (Figure 8).

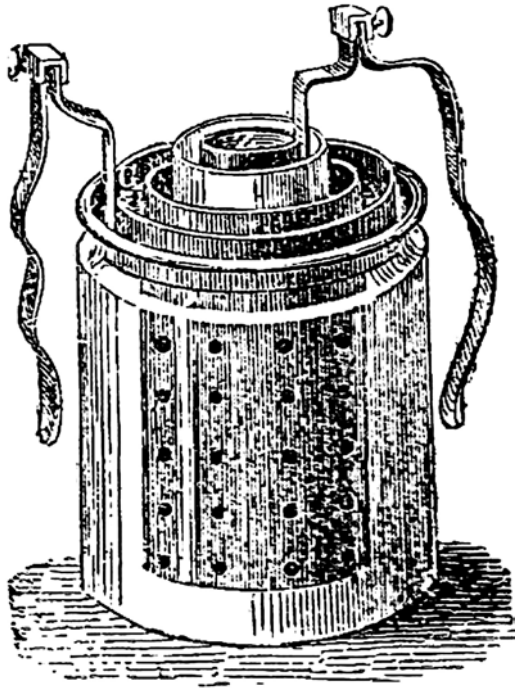

Figure 7. Battery developed by John Frederic Daniell in 1836.
(from: Schivaldi P. (1868), p 67).

According to some sources, in 1896, various instruments belonging to the University of Naples were used for the treatment of war wounded[10]. Among these instruments were accumulators, a Ruhmkorff coil, and a Crookes

10 The Battle of Adwa (Sunday 1 March 1896) was the climactic battle of the First Italo-Ethiopian War between Ethiopia, supported by Russia and France, and Italy. Most of the Italian wounded were transported to Naples.

tube (Savignano, 2020, p.18). The latter, invented by the physicist William Crookes (1832-1919), is a hollow glass tube in the shape of a cone consisting of three electrodes: one anode and two cathodes. The tube was the precursor of the cathode ray tube.

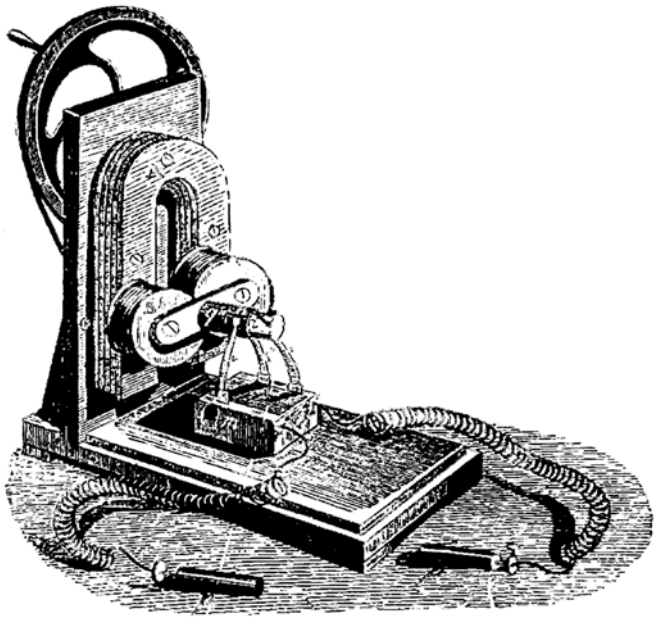

Figure 8. Clarke's magneto-electric apparatus
(from Schivaldi P. (1868), p 129).

Conclusion

Although the history of the use of electricity in the medical field has ancient origins, in the nineteenth century (the "golden age" of electrotherapy), electrotherapy had a great impulse alongside neurology and gradually established itself as an autonomous branch. In Italy, several researchers became interested in the discipline, and a school of electrotherapy was founded at the University of Naples, where electrotherapy was applied for therapeutic and research purposes. The scientific publications produced mostly by Francesco Vizioli and Francesco Paolo Sgobbo over almost fifty years have interesting elements of originality. These strengths are, above all, the use of many instruments (and modalities) and their application in disparate pathologies and disorders, as well as the exhaustive description of clinical cases and techniques,

which served as inspiration for other authors. Several citations can be found in manuscripts written by eminent scientists of the time and in articles published subsequently.

This manuscript could be useful for exploring broader themes in the history of medicine. It would be interesting, for example, to investigate the reasons that led to the scarce development of electrotherapy in the early part of the twenty-first century. The contemporary development of radiology cannot be an exhaustive explanation, as it was clear that many therapeutics and diagnosticians could benefit from these methods.

Disclosure

The author declares that he has no known competing financial interests or personal relationships that could have influenced the work reported in this paper. He also ensures that he has written this original work in its entirety. Finally, the author ensures that no human beings have been involved in the research.

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SAŽETAK

Elektroterapija je upotreba električne energije u svrhu liječenja. U 19. stoljeću, zlatnom dobu elektroterapije, razvoj te discipline bio je dio povijesno-znanstvenog konteksta koji je karakterizirala afirmacija neurologije kao autonomne grane, da bi se naposljetku odvojila od psihijatrije. Nakon razdoblja ograničenoga znanstvenog interesa i razvoja, elektroterapija je u drugoj polovici 20. stoljeća doživjela preporod, a danas je uporaba elektroterapije istražena i prihvaćena u raznim područjima medicine, uključujući, ali ne ograničavajući se na rehabilitaciju, neurologiju, liječenje boli i onkologiju.

Od svoje prve primjene elektroterapija se pridružila neurologiji koja ju je koristila u dijagnostičke i terapijske svrhe. U Italiji je nekoliko znanstvenika provelo eksperimente na tu temu, a važan doprinos razvoju discipline dala je "napuljska škola elektroterapije". Prije svega na poboljšanju su radili Francesco Vizioli (1834. – 1899.) i njegov učenik Francesco Paolo Sgobbo (1860. – 1936.). Unatoč tim premisama, međutim, ubrzo je došlo do nazadovanja elektroterapije kao autonomne znanosti. U međuvremenu se radiologija, koja je izvorno bila povezana s elektroterapijom, sve brže razvijala. Kada je Mario Bertolotti (1876. – 1957.), bivši profesor radiologije na Sveučilištu u Torinu i jedan od utemeljitelja talijanske radiologije, 1935. naslijedio Sgobboa, naziv (i disciplina) "elektroterapija" izbrisan je iz naziva nove katedre, kao i iz odjela koji je označen samo kao Radiologija. Radiodijagnostički uređaji i pribor te oprema za rendgensku terapiju zamijenili su brojne uređaje za elektroterapiju.

Ovaj članak fokusiran je na djelovanje „napuljske škole elektroterapije" od kraja 19. do početka 20. stoljeća. Opisano je djelovanje vodećih osoba koje su dale najveći poticaj proučavanju i primjeni elektroterapije. Na kraju, ukratko su prikazani uređaji korišteni za elektroterapiju.

Ključne riječi: *elektroterapija, elektromedicina, neurologija, psihijatrija, onkologija, nadriliječništvo*