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Mónico Sánchez Moreno: A pioneer in radiologic technology☆

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Abstract Mónico Sánchez Moreno (1880–1961) was an important figure in the early years of electromedicine, rubbing elbows with world-class physicists like Nikola Tesla. Her main contribution to the field was the invention and commercialization of a portable X-ray generator, replacing the heavy transformer had been necessary to generate power with a lightweight portable device that could work with direct or alternating current at 220 or 125 V. This device was easily adaptable to other applications in electromedicine, such as cauterization or disinfection. This indefatigable entrepreneur could have triumphed in America, but preferred to work toward furthering technological development in the land that she loved. Her efforts made it possible to have an affordable device made in Spain that would allow radiological examinations to be done in places where it would have been otherwise unthinkable. In conclusion, Mónico Sánchez Moreno was a self-made woman who deserves to be remembered for her pioneering role in portable radiology.

PALABRAS CLAVE
Radiología;
Radiografía;
Fluoroscopia;

Mónico Sánchez Moreno: un pionero de la tecnología radiológica

Resumen Mónico Sánchez Moreno (1880–1961) fue un personaje destacado en los primeros años de la electromedicina, llegando a codearse con figuras encumbradas de la física mundial como Nikola Tesla. Su principal aportación fue la invención y comercialización de un generador

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portátil de rayos X, sustituyendo el pesado transformador que se requería para generar corriente por un equipo ligero, portátil, que funcionaba con corriente continua o alterna, a 220 o 125 V, fácilmente adaptable para otras aplicaciones de electromedicina como la cauterización o la desinfección. Este emprendedor infatigable, que podía haber triunfado en América, prefirió invertir su esfuerzo en impulsar el desarrollo tecnológico en la tierra que amaba, permitiendo disponer de un equipo de fabricación nacional, asequible, que pudo llevar la exploración radiológica a rincones impensables de otro modo. En conclusión, Mónico Sánchez Moreno fue un hombre hecho a sí mismo, que merece ser recordado como pionero de la radiología portátil.

Introduction

Mónico Sánchez Moreno (Fig. 1) was a prominent figure in the early years of electromedicine who came to rub shoulders with important figures in world physics. Although he is recognised in the world of Spanish history, industry and telecommunications,[1–3] he is little known in the circles of the Spanish Society of Medical Radiology. With the idea that radiologists should, as part of their learning about the subject, know how the technology developed, know the stories behind some of the outstanding figures and be aware of the relationship between different advances and the ''non-medical'' world,[4] the aim of this article is to revive for the reader the interesting story of Mónico Sánchez and his contribution to the world of Radiology: his portable X-ray generator.

The young Mónico

Mónico Sánchez Moreno's brilliant destiny could not have been foretold from his origins, as he started life in the rural setting of Piedrabuena (Ciudad Real). He was born on 4 May 1880, the son of a weaver and a laundress.[5] There was almost 75% illiteracy in the province of Ciudad Real[6] and the children of labourers did not usually go to school. In the case of Mónico, being the youngest of four siblings, his work was not so vital for the family and he was able to attend his local state school, where his teacher, Ruperto Villaverde, instilled in him both scientific curiosity and an enterprising spirit.[5] At the age of fourteen, he left, barefoot to preserve his shoes, for Fuente el Fresno (Ciudad Real), where he worked as an errand boy.[3,7] He later moved to San Clemente (Cuenca), where he worked in a grocery store,[5] and later, with his savings and the help of his former employers, he set up on his own.[8] He moved to Madrid in 1901 with the intention of further pursuing the study of his new-found passion: electrical engineering.[5,8] Electricity was the new and emerging technology of the time; the study, exhibition and marketing of its applications were all the rage. Electrons, fundamental particles responsible for electricity, had just been discovered in 1897.[9]

He attended an academy to prepare for a place at the Escuela Central de Ingenieros Industriales [Central School of Industrial Engineers]. However, this school had just reopened after being closed for several years[10] and with the ensuing great demand for the available places, he was unsuccessful. The young Mónico was not to be deterred, however, and through an advertisement in the press,[11] he learned about the Electrical Engineer Institute of Correspondence Instruction, an American centre that taught correspondence courses in electrical engineering, endorsed by Thomas Edison (Fig. 2). He decided to enrol to study electricity by distance learning. Mónico Sánchez's dedication and talent impressed the director, Joseph Wetzler, editor of mag-

Figure 1 Mónico Sánchez Moreno (1880–1961), Spanish engineer and inventor. A self-made man, who deserves to be remembered as a pioneer of portable radiology. Photograph dated around 1915, kindly provided by the family of Mónico Sánchez Moreno.

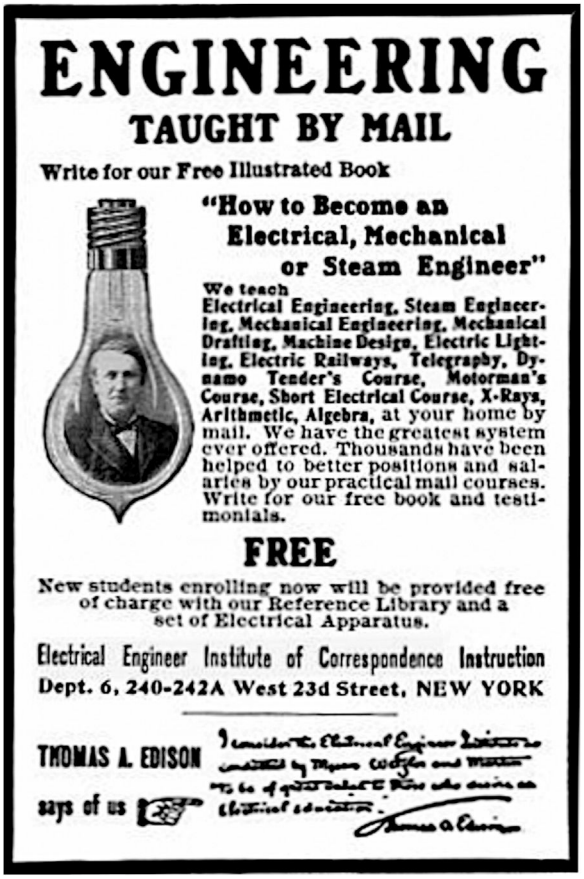

Figure 2 Advertisement from the Electrical Engineer Institute of Correspondence Instruction for its correspondence engineering courses, with a footnote by Thomas A Edison published in the December 1905 issue of the journal *Popular Mechanics*.

azines such as *The Electrical Engineer* and *The Electrical World* and co-author of the book *The electric motor and its applications*,[12] who recommended that he move to New York to study electricity.[2,7] Determined to travel to America, three days before embarking he discovered he needed a document from the Piedrabuena Town Council certifying his exemption from military service. That day he managed to get a seat on a train to Ciudad Real. From there he walked the twenty-five kilometres to his town and got the municipal secretary out of bed, accompanying him to the Town Hall to sign the necessary document. He then managed to find a mule to take him back to Ciudad Real and get another train to Madrid and deliver the documentation, virtually at the last minute.[13] So, at the age of twenty-three, with sixty dollars in his pocket and a limited amount of English, but full of hope, he left the port of Cádiz for New York, where he arrived on 12 October 1904.[13]

The American dream

Mónico Sánchez arrived in New York like all the immigrants of the time through Ellis Island,[14] alongside the Statue of Liberty, a paradigm of a cosmopolitan city in full swing, where the first skyscrapers were already forming the New York skyline and the subway was about to open.[15] He had

Figure 3 Photograph of the young Mónico Sánchez during his stay in New York, when he was around 25 years old. Photograph kindly provided by the family of Mónico Sánchez Moreno.

a tough start. While trying to learn English, Mónico carried a small slate around to help him communicate.[16] His mentor, Wetzler, interviewed him the day after he arrived and gave him a job as a draughtsman. Later (Fig. 3) he worked as a journeyman electrician at Foote, Pierson & Company, which manufactured telegraphy equipment and electrical instrumentation,[8] while he finished his training at the Electrical Engineer Institute of Correspondence Instruction. He graduated in June 1907 and was hired as an electrical engineer in the same company where he worked. It was there that he developed his first invention, a modification of the Wheatstone bridge (an electrical circuit for measuring resistance) to convert a laboratory instrument into a portable instrument for locating faults outside the laboratory.[5,8] Mónico was tireless, and he continued his education by taking an electrical engineering course at Columbia University and researching high-voltage capacitors and induction coils. In 1908, he got a job as an engineer at Van Houten & Ten Broeck Company,[5,7] which worked in the electromedicine sector, and this was where he came into contact with X-rays for the first time, as they manufactured electrostatic machines to generate the high voltage needed to produce them.[16]

X-rays had been discovered in 1895 by Wilhelm Conrad Röntgen, who refused to register any patents related to his discovery for ethical reasons,[17] and they were arousing great interest at the time. The interest was mainly in its medical applications, but it also had recreational applications; for example fairground booths proliferated with the

newly invented cinematograph, attracting the public with the chance of seeing their bones by X-rays.[18] Around the turn of the century, the great engineers of the time, such as Nikola Tesla and Thomas Edison, frequently resorted to spectacular staging to publicise their discoveries. Edison, co-owner of the company General Electric, was in favour of direct current electricity, in spite of the inconvenience of energy losses in the form of heat caused by the resistance of the cables, which were also large and expensive. His rival, Nikola Tesla, who worked at the company Westinghouse, advocated the use of alternating current, which minimised losses by carrying the current at a higher voltage. Then began the so-called ''War of the currents'',[19] a spectacular offensive by Edison and one of his collaborators in particular, Harold Brown (inventor of the electric chair), which included the public electrocution of animals to warn society of the supposed dangers of alternating current.[19,20] Therapies linked to electricity or its effects, such as high-frequency discharges, ozone inhalations and fulguration, indicated at the time for the treatment of a multitude of diseases, were also very fashionable.[21]

The year 1909 could be considered as Mónico Sánchez's big year. During that year he patented in several European countries and America the machine that would make him famous: the portable current generator capable of powering an X-ray tube, achieved by applying one of Tesla's brilliant ideas; the higher the frequency of the alternating current, the smaller the coils needed to obtain the same voltage.[11] The innovation reached the ears of entrepreneur, inventor and prolific populariser of science, Archie Frederick Collins, founder of the Collins Wireless Telephone Company, one of the early experimenters in radiotelephony, and co-author of the bestselling *The Radio Amateurs Handbook*.[22] Collins hired Sánchez as chief engineer of his company. They began to manufacture their portable generator under the brand name ''*Collins-Sánchez*''[8] and took it on a long promotional tour of the biggest cities on the East Coast. There is a preserved image of the presentation at the 3rd Electrical Show held at Madison Square Garden in New York, with their stand in prime position next to those of Edison's General Electric and Tesla's Westinghouse (Fig. 4). There were successful presentations at the University of Illinois and at the Chicago Coliseum as part of the company's campaign to sell stocks and shares,[7] which included promotion by famous people such as the explorer of the North Pole, Frederick Cook.[8] Finally, merging with four other companies gave rise to a new company in which Mónico Sánchez was an engineer, the Continental Wireless Telephone and Telegraph Co. The new owners offered him five hundred thousand dollars in shares for the patent of the device, but Mónico rejected the offer and decided to leave the company to found his own, American Sánchez Electrical Company.[7] He had made the right decision, as the shares lost their value when it was discovered that their administrators had de-capitalised the company and were prosecuted for fraud in 1911.[8] The Sánchez machine appears in an engraving in the book *A working manual of high frequency currents*, published in 1911 by Noble M. Eberhart.[23] which was a reference manual in North America for the use of high frequency currents, including X-rays.

Return to Spain

In September 1910, he returned to Spain a success, unveiling his machine at the 5th International Congress of Electrology and Medical Radiology in Barcelona.[5] This meeting marked the first great milestone in Spanish radiology, and is considered the beginning of the Europeanisation of radiology.[24] Dr Ramón Torres Carreras held a series of exhibitions and demonstrations with X-rays obtained with the Sánchez machine (Fig. 5). It was so successful that prestigious Spanish radiologists soon purchased the machine. In addition to the aforementioned Torres Carreras, they included the first president of the Spanish Society of Medical Electrology and Radiology, Joaquín Decref y Ruiz, and other founding members, such as Manuel Cocharán, José María Puelles, Antonio Piga Pascual, Casiano Ruiz Ibarra, Adolfo Batges y Gomez, Simeón Val y Martín, Gonzalo Blasco Izquierdo, José Antonio Molina Niñilora and Vicente Isaac Corvo.[25] With everything going well after the Barcelona congress, he decided to establish himself in his home town of Piedrabuena as European Electrical Sánchez Company.[16] In January 1911, he got married and set up a small workshop in the attic of his wife's house (Fig. 6).

In 1912, the American Electrical Sanchez, Co. ceased to exist and in 1913, with the profits obtained, he built the Sánchez Electric Laboratory in his home town, a 3500 m^2 factory that employed more than fifty workers, a third of them women from the town, and where it was even planned to introduce the teaching of electricity and electrotherapy.[26] Because of electricity supply problems in Piedrabuena, a power plant had to be created to feed the factory, drinking water pipes had to be built and experienced glass blowers were even brought in from Germany to manufacture the vacuum tube for the X-ray system.[7] At this factory, Sánchez also built other designs of his, such as current generators, short-wave devices, discharge tubes, high-frequency lamps, neon lights, ozone ionisers, radiological instruments, therapeutic electrodes and cautery.[2]

The Sánchez machine

The brilliant innovation of Mónico Sánchez consisted of replacing the transformer that was used at that time to produce 50 Hz current and weighed about 400 kg with a light 7 MHz transformer that barely weighed 10 kg and could be transported in a suitcase. In addition, not only could it produce X-rays, but it could also be easily adapted to multiple other uses (cautery, wireless telegraphy, lighting, etc.).[2] The Sánchez machine was capable of producing high voltage current (100,000 V), with low consumption (barely 3 A) and high frequency. This meant much less metal could be used, making it considerably lighter, with the added advantage of being able to work with alternating or continuous current, which was very useful at the time as both existed side by side. Apart from the American patent, Sánchez registered his invention in Spain (No. 46537, No. 49075 and No. 51029 in 1911), Great Britain (No. 24143 in 1910) and France (No. 422168 in 1911).[21,26]

The first X-ray tubes were glass bulbs based on the Crookes system, where a partial vacuum was created, and

Figure 4 Photograph of the stand where the machine was exhibited under the make Collins-Sanchez, at the 3rd Electrical Show held at New York's Madison Square Garden in September 1909. Photograph kindly provided by the family of Mónico Sánchez Moreno.

consisted of a cold aluminium cathode, an anode and an anticathode.[27] By establishing a high-voltage potential difference between the first two, cathode rays (a flow of high-energy electrons) were produced that collided with a platinum target, the anticathode, displacing electrons from the inner layers of the atom and filling this space with electrons from outer shells, which release characteristic energy in the form of X-rays. The Crookes tube was mounted on the Sánchez generator on a collapsible top bracket (Fig. 7). When it was switched on, the operator looked directly through a one-handed fluoroscope. This consisted of a bellows with an X-ray-sensitive screen placed at the end of it where the operator could see the image produced by the radiation, protected from ambient light by the bellows, when the object studied (the patient) was interposed between the tube and the screen.

Presentation in Paris

Casiano Ruiz Ibarra (1871–1961), a renowned naturopathic doctor, was so enthusiastic when he learned about the Sánchez machine that he bought it and, eager to learn the new discipline, enrolled in a medical electrology and radiology course in Paris.[28] Already in Paris, presented by the radiologist Dr Lobligeois and with the collaboration of Sánchez, Ruiz Ibarra gave a demonstration of the Sánchez machine before the French Society of Electrology and Radiology in May 1914. He presented the range of possibilities the device offers in electrotherapy, including autocondensation, fulguration, ozone inhalation, electrocautery and X-rays, and showed them X-rays and photographs of electrocautery. All this drew a huge amount of attention from the Society of Electrology and Radiology in Paris,[29] particularly because it worked with direct or alternating current, and was easy to handle and transport.[30] The machine was described as ''fully portable, it weighs no more than nine kilos; it can work with any current, and constitutes a veritable electrical cabinet''.[31] The specialised French press, such as *Gazette des Hôspitaux* and *Le Conseiller Therapeutique*, highly praised the device and it was then similarly reported in the Hispanic press.[32] Ruiz Ibarra also presented the machine to the Paris Society of Medicine. On this occasion it was presented by the radiologist Lucien Mathé, editor of *Le Conseiller*, who in 1917 would write the following in his *Bréviaire du manipulateur radiologiste*[33] (English translation of a quote from its translation into Spanish[34]):

> ''...it works with all kinds of currents and, in addition to radiography, can perform electrocautery, the application of all high-frequency treatments and the production of ozone which, with the help of a special device, can be used for disinfection of deep wounds''.

Applications in the First World War and other military conflicts

Military radiology had taken its first steps shortly after the discovery of X-rays, but it was during the First World War that it was developed in all the participating countries due to the enormous number of wounded.[35] France's entry into the conflict in August 1914 led to Sánchez's company receiving a telegram from Bayonne in September with an urgent order for 10 portable X-ray machines ''to be used in treating the war wounded, who are looked after in Bayonne and in some towns on the French border''.[36] In Bordeaux, far from the front, Professor Jean Bergonié (author of the Radiosensitivity Law or Bergonié-Tribondeau Law), head of the Radiographic Service of the 18th Military Region, called Mónico Sánchez at the end of October to evaluate his machine. Present at the demonstration were Dr Lamoureux, Colonel of the Military Health Service, and Dr Ruiz Ibarra[37] (Fig. 8). In the tests, X-rays were taken ''of the most difficult cases'' of wounded soldiers. Bergonié gave such a

Figure 5 Exhibition by Dr Torres Carrera at the Clinical Hospital of the Faculty of Medicine, annexed to the 5th International Congress of Medical Electrology and Radiology in Barcelona in 1910. The panel shows his X-rays taken with the Sánchez X-ray machine. Photograph kindly provided by the family of Mónico Sánchez Moreno.

favourable report and praised the machine so much that the government hastened to purchase equipment for the army, buying as many as fifty units.[38]

We should point out that this was not the first time the machine had been used in a war. In January 1912, when Spanish soldiers were fighting in the Rif War (1911—27), Mónico Sánchez offered one of his machines free of charge for the army to the President of the Council of Ministers, José Canalejas, with the press that picked up the news adding that, ''The American army carries the Sánchez machine in its medical ambulances''.[39] These must have been some of the machines from his time in America, manufactured under *Collins-Sánchez* or *Sánchez Laboratory*. The Spanish Navy also tested the different capabilities of the Sánchez machine.[40]

The United States entered the Great War in April 1917. Their troops brought with them a new standard portable X-ray model made specifically for the military by General Electric, based on the next generation of X-ray tubes, the Coolidge tube, from which today's tubes are descended.[41] However, Sánchez's machine continued to be used for medical purposes over the following years. In 1933, Sánchez donated a machine to the Red Cross for its ''medical ambulances''. Also, in the Spanish Civil War, the device was used by the Republican side in the Blood Hospitals.[41]

Contribution to Spanish radiology

Mónico Sánchez established a close cooperative relationship with some of the founding members of the Spanish Society of Medical Electrology and Radiology. Antonio Piga, who would become President of the society in 1936[24] and professor of Legal Medicine at the University of Salamanca, collaborated closely with him during his stay in Toledo, making a joint presentation of the machine at the Toledo College of Physicians[42] and publishing some joint papers with him.[43–45] Years later, Vicente Isaac Corvo, gynaecologist and founding member of the Radiology Society, would publish

Figure 6 First workshop set up on his return to Piedrabuena, Spain, from 1911 to 1914, in the attic of his wife's house. As a result of the sales, in 1913, construction began on the 3500-m^2 Laboratorio Eléctrico Sánchez [Sánchez Electric Laboratory]. Photograph kindly provided by the family of Mónico Sánchez Moreno.

Figure 7 Scene with the Sánchez machine operated by Mónico himself, taking an X-ray of a woman's hand. Note the size of the briefcase and the Crookes tube mounted on a folding support. Photograph kindly provided by the family of Mónico Sánchez Moreno.

an epigraph on the Sánchez machine in his book on high-frequency treatments and diathermy in gynaecology, with the following words[46]: ''guided by the good results I have obtained in practice from this machine, I describe it in case it might interest a colleague''. Ruiz Ibarra, as Medical Director of Mónico Sánchez's company, published an abstract for specific training on the Sánchez machine.[47]

The biggest contribution, however, was the increasing awareness of and interest in radiology and electrotherapy among doctors across Spain, as use of his invention became more widespread, and the fact that it put the benefits of this technology within the reach of people in sparsely populated areas where they never would have imagined it possible.[48] Although no invoices or other inventories have been preserved, in the financial report for the laboratory in 1919, for the purposes of requesting a loan, the penetration of the Sánchez machine in small towns is highlighted, emphasising that the doctors in these areas would not otherwise have had access to these techniques[49]:

> ''The use of this machine has become widespread even in the smallest towns, and of the large number of machines that have been installed in Spain in the last four years (over 800), a number have been in towns and villages with fewer than 1000 inhabitants. In view of their small size, before the availability of this invention, these populations could never have imagined that they would be able to have machines producing X-rays and many other medical applications, clearly demonstrating that this invention is helping to popularise a science which, being considered of absolute necessity for the relief of human ailments, could not have become generally available by any previously known means''.

Other uses

The Sánchez machine, which used a Crookes X-ray tube, did not adapt to the progressive but unstoppable emergence of the Coolidge tube, which uses a hot tungsten cathode with the anticathode embedded in the anode, making it more efficient and resistant and meaning that it

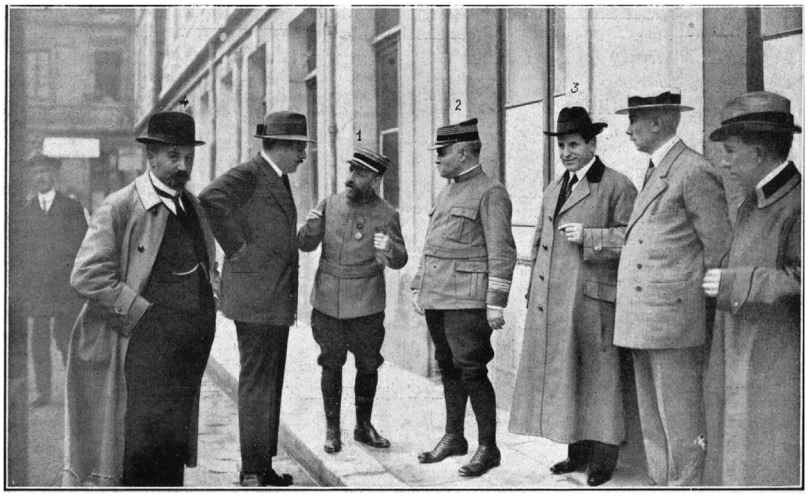

Figure 8 Illustration published in the journal *Nuevo Mundo* on 24 October 1914, whose caption reads: ''Illustrious scientists to whom the French Government entrusted the study and experimentation of the Sánchez machine, at the premises of the Military Radiographic Service of Bordeaux. 1. Professor Bergonie, Head of the Central Radiography Service; 2. Doctor Lamoreaux, Senior Officer for Military Health; 3. Mr Mónico Sánchez, Spanish inventor; 4. Doctor Ruiz Ibarra, Medical Director of the manufacturer, and in charge of instructing French military doctors on the use of the Sánchez machine''.

achieves greater image sharpness and better radiation control, although it does requires water cooling to dissipate the heat produced.[50] The widespread use of the Coolidge tube for the generation of X-rays began in the 1930s, but the Sánchez machine continued to be used for teaching physics, for which a multitude of experiments and discharge tubes were designed. Because it was used in general for the teaching of electrical phenomena, the Sánchez machine appears in different physics texts for medical students, such as the book *Física para Médicos* [Physics for Doctors], by Julio Palacios[51] and *Curso elemental de Física para Estudiantes de Medicina* [Elementary Physics Course for Medical Students], by Pérez Martín,[52] Dean of the Faculty of Sciences of Salamanca.

Epilogue

Sánchez received numerous awards and prizes: Exhibition of Applications of Electricity (Madrid, 1910); Dental Congress of Madrid (1911); Award for the Promotion of National Work (1913); Ciudad Real Gold Medal (1914); 1st Congress of Medicine (Madrid, 1919); National Congress of Medical Sciences (Seville, 1924); Barcelona International Exposition (1929); and International Health Exposition (Madrid, 1933).[5,7] In 1932, he received an honorary doctorate in Electrotechnical Sciences from the Free School of Engineering of Rio de Janeiro (Brazil). In 1935, he was elected President of the Ciudad Real Chamber of Commerce.[5] At the beginning of the Spanish Civil War, the power station and the laboratory were seized. In August 1936, militiamen took away and killed his assistant and cousin Juan Mota. The laboratory was used as the headquarters of General Escobar's Army of Extremadura. Later, the Falangists accused Mónico Sánchez of Mota's murder, although in the end he was not prosecuted.[3] After the conflict, the business languished in the midst of post-war hardship and the international isolation of the Franco regime.[7] Mónico, faithful to his fighting character, never gave up, despite the failure of his attempts to relaunch the factory with patents brought from the United States, and even in spite of the loss of his wife and four of his five children. He opened an ice factory, a petrol station and even a cinema in his home town.[26] Mónico Sánchez Moreno died in Ciudad Real on 6 November 1961. His family, who had kept his machines along with more than 200 X-ray tubes, donated them in 2010 to the National Museum of Science and Technology, which exhibits some of the best specimens at its headquarters in La Coruña.[53] Sánchez's machines were so reliable that they still work perfectly well today. Some were acquired for teaching physics and are preserved in teaching centres, such as the Colegio de la Inmaculada in Gijón, the Colegio San Francisco de Paula in Seville[10] and the Complutense University of Madrid, or in different Medicine museums across Spain.

Conclusion

Nowadays, when everything seems set to be dominated by artificial intelligence, it is time we made a stand for natural intelligence, the work ethic and the success of the individual efforts of a self-made man who, although deeply rooted in his homeland, was able to venture forth and find an environment where he could cultivate his knowledge, enabling the fruits of that knowledge to later spread throughout the world. His endeavours helped take medical technology closer to the patient's bedside and showed the way forward for future radiological technology. Mónico Sánchez Moreno was a brilliant man who deserves to be remembered as a pioneer of portable radiology.

Authorship

1 Responsible for the integrity of the study: RRR, JPRQ, ENB and FSP.

2 Study conception: RRR.
3 Study design: RRR, JPRQ, ENB and FSP.
4 Data collection: RRR, JPRQ, ENB and FSP.
5 Data analysis and interpretation: RRR, JPRQ, ENB and FSP.
6 Statistical processing: N/A.
7 Literature search: RRR, JPRQ and FSP.
8 Drafting of the article: RRR, JPRQ, ENB and FSP.
9 Critical review of the manuscript with intellectually relevant contributions: RRR, JPRQ, ENB and FSP.
10 Approval of the final version: RRR, JPRQ, ENB and FSP.

Conflict of interest

The authors declare that they have no conflicts of interest.

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