Pigeons and MRI: Tesla Vignettes

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Nikola Tesla's name is familiar to neuroradiologists, but few of us know why our profession and understanding of the brain are better because of him. His achievements were not universally recognized until 1960 (17 years after his death) when the *Conference Generale des Poids et Mesures* decided that the unit for measuring the magnetic field (B) should be called the "tesla." The strength of the magnetic field of the earth at the equator is 31 microteslas, and it is worth remembering that magnets found even in small speakers are as powerful as those found in our MR imaging units (1–2.4T).[1] His research also involved superconducting magnets cooled to a few degrees above absolute zero. Although Tesla was constantly on the verge of becoming rich, he died poor and alone at 86 years of age in a room at the Hotel New Yorker (still at 481 Eighth Avenue). After his death, unknown individuals and/or government forces removed his last inventions and papers from his apartment because they were thought to contain information regarding the "Death Ray," in which the military was interested.[2] This ray, presumably a particle beam, could repel armies and bring down airplanes. The list of Tesla's inventions is long and incredible in its breadth. During his life, Mr Tesla struggled for recognition, and it mostly eluded him, the Nobel Prize being one example. In this Perspectives, I mention some colorful aspects of Mr Tesla's life rather than recounting his incredible accomplishments.

Tesla and Edison

Tesla came to America after living in France for 2 years, and Mr Edison hired him to work at the Edison Machine Works in New York City. Edison's electric power generators producing direct current (DC) worked well only when electricity requirements were small. The power and output of DC are relatively weak, making its transmission over long distances impractical. Tesla solved this issue by perfecting alternating current (AC). Transformers decrease or increase the power of AC as needed, so if long-distance transmission is required, power is amplified, making it more efficient (with DC current, a generator every 3–4 km is needed). When Edison refused to pay him for his inventions, Tesla left and later sold them to Westinghouse. The War of Currents erupted, and Edison tried to instill fear in AC users by calling it extremely dangerous. He went as far as paying children to steal dogs, electrocute them with AC, then scatter their bodies together with flyers alerting the public to the dangers of AC. When killing dogs no longer shocked the public, he killed larger animals (sheep, cows, horses), eventually leading to the electrocution of Topsy the elephant (for a video of this see: http://tinyurl.com/mumu8mq and, for a good description of the process, I suggest reading Jean Echenoz's fictional Tesla biography *Des Eclairs*[3]).

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Additionally, Edison promoted the first successful electrocution of a prisoner by using AC (DC was tried but was not powerful enough to kill a human being) to showcase the dangers of this type of electricity. The subsequent legal battles that erupted nearly caused Edison and Westinghouse to go broke and forced Tesla to forfeit royalties from his patents owned by the latter. When Edison died, Tesla wrote this bitter obituary: "He had no hobby, cared for no sort of amusement of any kind and lived in utter disregard of the most elementary rules of hygiene. . . . His method was inefficient in the extreme, for an immense ground had to be covered to get anything at all unless blind chance intervened and, at first, I was almost a sorry witness of his doings, knowing that just a little theory and calculation would have saved him 90% of the labor. But he had a veritable contempt for book learning and mathematical knowledge, trusting himself entirely to his inventor's instinct and practical American sense."[4] Just before dying, Edison acknowledged that ignoring Tesla's AC patent had been his biggest mistake.

Tesla and Roentgen

Before x-rays were officially named, Tesla investigated them by using single-terminal vacuum tubes (conventional ones use 2 terminals). We know that high-energy electrons emitted by a cathode hit the special material (tungsten, molybdenum) of the anode, "braking" them and secondarily emitting a very small percentage of high-energy x-rays. In Tesla's tube, no target existed. Energy left the electrons encountering a high-field electrical environment resulting from the oscillations of AC, and as they collided with the glass encasement, x-rays were generated. His experiment also worked well by using Geissler tubes that were filled with substances such as inert gasses (these were the forbearers of fluorescent light and the electron microscope). While in New York, he produced images of the bones in his hands and sent them to Roentgen, who ignored them. Tesla also claimed that his design produced x-rays much more powerful than Roentgen's. Because Tesla never published his findings and his research notes were lost during a fire of suspicious nature, he never received credit for the discovery of x-rays. Fortunately, he also became aware of Roentgen's health issues induced by radiation exposure and avoided them himself.

Tesla and Marconi

Although Guglielmo Marconi is credited with having invented the telegraph and received the Nobel Prize for the radio, Tesla discovered both years before Signore Marconi did. Tesla discovered that by using his coils, radio signals could be transmitted over great distances as long as the receiving coil was tuned to the resonant frequency of the transmitting one (sound familiar?). The receiving coil magnifies signals via resonance. Just before Tesla could demonstrate that his invention was able to transmit signal as far as 50 miles, his laboratory suspiciously burned down, causing him to lose his instruments and documents (note that Tesla demonstrated transmission at shorter distances in St. Louis 2 years before

Marconi showed his invention). About the same time as the aforementioned tragedy, Marconi developed a 2-way transmitter whose signals were too weak to cross even a small pond. He solved the problem by using Tesla coils. Marconi claimed ignorance about Tesla's coils when applying for a US patent, and the granting of patents to both inventors was delayed due to arguments on both sides claiming property rights. Aided by rich investors, Marconi's Wireless Telegraph Company thrived in the stock markets, and soon Andrew Carnegie and Thomas Edison became its 2 most important American investors. Shortly thereafter, Marconi amazed the world by transmitting signals wirelessly across the Atlantic Ocean. Because Marconi was using several of Tesla's patents to accomplish this, Nikola was not worried; but he should have been because 4 years later, the United States awarded the patents for the telegraph and radio to Marconi under political pressure from Carnegie and Edison. When Marconi received the Nobel Prize, Tesla was furious and sued Marconi for stealing his patents. Later, the Marconi Company sued the US government because the armed forces had used its patents for communications during World War I without permission or payment. The US Supreme Court eventually ruled that these patents belonged to Tesla (now dead and childless), thus avoiding any payments owed by the government to Marconi's company.[5] Tesla predicted that all of us would carry small, wireless telephones in our pockets; something Marconi did not.

Tesla and Twain

Exactly where Tesla and Samuel Clemens met is not clear; it could have been at the Player's Club (a bar in Manhattan) or in the laboratory. Although Tesla was familiar with Twain's writings, it was not until after the discovery of AC that Twain noticed Nikola. Both men shared friends in high society, including the Johnsons, Kipling, Roosevelt, and Muir. Tesla invited Twain to his laboratory, where the famous writer partook in some electrical experiments that reportedly filled him with vigor and vitality. While Twain was spending time in Austria, he heard about Tesla's experiments on destructive terror (the Death Ray) and wrote urging him to use these to make war impossible in the future by making it available to all (an idea akin to "assured mutual destruction").

Tesla and the FBI

While living in Colorado Springs, Tesla started developing the idea for a particle beam that could be used as a weapon, and though his idea never materialized, it was described in what is known as the "Tesla Papers." Immediately after his death, unknown persons raided his apartment in the New Yorker Hotel, stealing documents for fear that they would fall into Soviet hands. Two days after his death (when he was found by a maid), the FBI confiscated all that was left. The FBI appointed Dr John Trump of the National Research Committee to look into the documents, and he concluded that they were mostly speculative in nature. After World War II, interest in them was revived and the heavily funded "Project Nick" was started in Dayton, Ohio, only to be dropped later. Interest in a beam weapon waxed and waned until the late 1970s, when construction of a large beam weapon by the Soviets came to light. As a response, in the early 1980s, President Ronald Reagan proposed the Strategic Defense Initiative.[6] All attempts to build a Death Ray have failed, and many think that answers to the problems encountered were addressed in the missing "Tesla Papers " (some think that the US Government has them and is hiding them).

Tesla and Birds

No one knows why Tesla was interested in pigeons. This interest is nicely portrayed in *The Invention of Everything Else* by Samantha Hunt.[7] As an old man, Tesla walked every day to Bryant Park (located behind the New York Public Library between 6th Avenue and West 42nd Street, a scene again found in Paul Auster's *Moon Palace*[8]). At that time, pigeons were considered unmeritorious, and perhaps Tesla felt similarly about himself. On the night that he was awarded the Edison Medal (how ironic!), he suddenly disappeared from the banquet only to be found in Bryant Park covered by pigeons from head to evening pumps. Tesla said he considered pigeons to be his "sincere friends." He took sick ones into his apartment and caused cleaning crews to complain of dirt. Just days before his death, he became particularly attached to one and was able to recognize this particular bird and fed it every day (white wings with a touch of gray in their tips, photographs available at: http://www.teslauniverse.com/nikola-tesla-timeline-1922-tesla-pigeon-dies). When the pigeon became sick, Tesla took it with him to his apartment, but attempts to cure the bird failed and it died. Tesla died only a few days after the pigeon, it is said of a broken heart (this may be true because he died of heart failure); he previously stated that he had loved her as a man loves a woman (how sad is that?). Much has been made about the symbolism of the pigeon, comparing it with the dove in religion and its meaning in Tesla's life. Curiously, Tesla's favorite meal was squab.

Tesla, like Einstein, was a generalist, and like Edison, he was self-taught. His thoughts extended into many arenas of human enterprise without dwelling on details of how to accomplish them. Because he almost never published in scientific journals, many of his ideas are now lost. Some of his projects sounded like science fiction but are now reality; others are still within the realm of the impossible but are being reconsidered. Our knowledge has expanded so much that extrapolating what we now know into the world where Tesla lived is simply not possible, so it is hard for us to grasp his achievements. However, it is thanks to them that MR imaging and modern neuroimaging are possible.

Bonus

Two wonderful stories about Edison and Topsy, and Tesla and his pigeons can be found in *Love in Infant Monkeys* by Lydia Millet.[9]

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EDITORIAL

In Memoriam: The Matrix Coil

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In this issue, the results of the Matrix and Platinum Science (MAPS) trial provide level 1 evidence that there is no beneficial effect of the polymer-modified Matrix detachable coil (Stryker, Kalamazoo, Michigan) over standard platinum coils in the recurrence rate of coiled intracranial aneurysms.[1] Although several previous studies indicated similar results,[2-4] this MAPS trial is the death blow for the "bioactive" coil. This is good news for patients and hospitals because the spilling of money by the excessive costs of these coils can now be avoided without compromising patient care.

It took the neurointerventional community more than 10 years (and many millions of dollars) to prove that a marketing concept launched by Boston Scientific (now Stryker) does not hold true in clinical practice. The history of the Matrix coil started in the beginning of this millennium. When the initial monopoly of Boston Scientific with the Guglielmi detachable coil ended with the introduction of similar coils by other manufacturers, Boston Scientific developed the concept of "bioactive" coils to regain market share. The Matrix coil was introduced, and this coil was coated with a bioabsorbable polyglycolic/polylactic acid (PGLA) polymer that was intended to accelerate neointimal healing at the neck of the aneurysm and thus was believed to provide a more stable occlusion at follow-up. The choice of this PGLA coating was primarily to get the device past regulatory hurdles and onto the market. Proof of efficacy of biologic activity was not a priority. PGLA is widely used in sutures as Vicryl (Ethicon, Cincinnati, Ohio) and has an excellent safety profile in humans. With this in mind, Boston Scientific managed to pass the regulatory process of the US Food and Drug Administration by claiming that Matrix was "substantially equivalent" to platinum coils. Although this obtained FDA approval was based on equivalency, marketing that followed was not. On the contrary, Matrix was marketed as a revolutionary new device.

After testing the coil in a few swine,[5] Matrix was launched as a new concept: Instead of aneurysm thrombosis following mechanical disruption of the intra-aneurysmal blood flow, Matrix would provide a durable biologic healing by improved neointimal proliferation and fibrosis. The marketing machine went off on full throttle, heavily supported by several of our peers. The concept of accelerated healing of aneurysms with significantly lower recurrence rates was very appealing, and many physicians started to treat their patients with the new Matrix coil, despite it being almost double the cost of standard coils.

In the meantime, a registry of 100 aneurysms was launched by Boston Scientific to provide extra arguments on sales (Acceleration of Connective Tissue Formation in Endovascular Aneurysm Repair [ACTIVE]). However, the results of this registry were not better than could have been expected from standard coils. On the contrary, many aneurysms were not immediately completely occluded, resulting in an alarmingly high early rebleeding rate of 7% (3 of 41 ruptured aneurysms). In sales meetings with potential Matrix users, the results of this registry were deliberately misinterpreted.[6] Even after published criticism on these misleading interpretations,[7] Moret and Viñuela persisted in peculiar explanations of the results in favor of the Matrix coil.[8] The disappointing findings of the ACTIVE registry have never been published. The marketing machine soon got overheated. At meetings and in scientific reports, the "proof of concept" was repeatedly illustrated: Many physicians reported a white band between the coil mesh and the parent artery called the "white collar sign," interpreted as a thick connective tissue barrier that prevented further aneurysmal filling.[9] Anyone with knowledge of imaging physics readily recognized that this band was caused by the Mach effect, a well-known optical illusion that occurs both with Matrix and platinum coils.[10,11] In a heterogeneous human autopsy study and in several experimental studies in swine and rabbits, the phenomenon of fibrous neck healing by the bioactive Matrix coils was enthusiastically claimed and communicated by Szikora et al[12] and Murayama and Viñuela,[13,14] though scientific evidence was lacking.

To overcome the initial criticism on the Matrix coil[15] and to reduce the reported high friction of the coated coils inside the microcatheter, Boston Scientific applied some minor modifications to the coil and the second-generation Matrix was introduced as Matrix2. After evaluation of this Matrix2 coil in a heterogeneous study including cases from the ACTIVE study, Murayama and Viňuela claimed without statistical evidence that use of Matrix2 coils resulted in improved mechanical performance and anatomic outcome compared with Matrix1 coils.[16] The marketing machine of Boston Scientific thus continued, and Matrix effectively survived the initial period, despite the publication of more clinical studies that failed to show a beneficial effect of the bioactive Matrix coils.[17] Even despite imposed scientific bias in a French registry design toward favorable results for Matrix, a beneficial effect of Matrix could not be shown.[18,19] Finally, the MAPS trial was announced in 2008; and now, 6 years later, the definitive results clearly indicate that Matrix coils are not better than standard platinum coils.

What can we learn from this Matrix saga, with Boston Scientific/Stryker supported by some of our overenthusiastic peers? How can we avoid large sums of public money being spilled on unproven devices to enhance the profits of device companies? We, as doctors, have to get back into the driver's seat, and we should take the lead from the industry in developing devices. Instead of selling our soul to the devil by using unproven devices at high costs from manufacturers with clever and possibly misleading marketing strategies, we should tell the industry what devices to make after adequate scientific hypotheses and clinical tests that convince regulatory bodies like the FDA. In addition, we should be more critical of our overenthusiastic peers involved in cutting-edge technology with a critical eye to the interpretation of their

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