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The New Light: Roentgen's Unusual Demonstrations and the Development of Diagnostic Radiology in North America

Andrew M. Silverstone

Introduction

Radiology's power has brought many miracles to society. Following Wilhelm Conrad Roentgen's demonstration of X-rays in 1895, the use of diagnostic imaging revolutionized the practice of medicine, allowing doctors to diagnose and treat what was previously unseeable. The public and scientific community were dazzled by these invisible rays, and often naive to their inherent dangers. By the 1930s, veterinarians in North America began integrating radiology into their practice.

Roentgen Revisited

Radiology is an integral component of modern veterinary practice, affording an inexpensive, non-invasive, and accurate means of diagnosis and treatment. Although X-rays were discovered in 1895, their use in veterinary medicine was not commonplace until furthered by educational and technological advances of the United States, beginning in the 1940s. Wilhelm Conrad Roentgen (1845-1923), Professor of Physics, is considered to be the "Father of Radiology" for his application of X-rays to imaging. Roentgen made his observations in Germany at the University of Würzburg. The history of the research that led to Roentgen's demonstration is intriguing and includes the work of Sir Isaac Newton, Benjamin Franklin, Michael Faraday, and several other scholars. His research represents the culmination of experiments and observations on electricity and magnetism, which began with the ancient Greeks and encompassed a body of investigation spanning 2500 years.[1]

On Friday afternoon, November 8, 1895, Roentgen was working by himself in his laboratory, as was his custom. He was experimenting with the effects of invisible cathode rays (electrons) escaping from evacuated glass tubes with thin aluminum windows (Lenard's tubes) and illuminating fluoroscopic salts, thereby darkening photographic plates. Roentgen then moved his observations to the thicker-walled Hittorf-Crookes tubes, which lacked aluminum windows. He was speculating that the cathode rays might be able to escape from the tube and cause the illumination of a cardboard screen painted with fluorescent barium platinocyanide. For this experiment Roentgen selected a pear-shaped tube and covered it with pieces of black cardboard. Roentgen placed a cover over the tube, as he did not want its strong glow to obscure the illumination of the cardboard screen. The tube was connected to a Ruhmkorff coil and then the room darkened. A high-tension discharge was passed from the coil to the tube, and no visible light was observed to be escaping from the tube.[1]

Roentgen was preparing to stop the current and proceed with his experiment, when he was shocked to see a faint flickering glow shimmering on one of his worktables. The mysterious light resembled a mirror's reflection of a spark or perhaps the light emitted by the induction coil. The incredulous Roentgen re-fired the charges through the tube. He observed this fluorescence again, appearing as faint green clouds whose movements fluctuated with the coil's discharge. Roentgen then lit a match to light up the room and was surprised to find the barium platinocyanide screen as the source of the light. Intrigued by the mysterious light, Roentgen repeated the experiment, varying the distance of the screen from the tube and even turning the painted surface of the fluorescent screen away from the tube. Amazingly, the light persisted with each variation. After Roentgen judiciously searched his laboratory to discover any other possible sources of the light, he concluded that something was emanating from the evacuated tube and illuminating the fluorescent screen. Furthermore, the illumination was occurring from much farther away than that which he had observed while using the thinly shielded Lenard tubes.[1]

Roentgen speculated that if the light was capable of escaping through the lightproof cardboard box, then perhaps it would be able to pass through other materials. To test his theory, he placed various objects made from different materials between the screen and the inducted tube. For the most part the objects had little effect on the intensity of the glowing screen, however, lead and platinum did appear to cause a complete obstruction of the rays. While holding these various objects in front of the tube, Roentgen expected his hand to create a shadow on the screen. Instead, after several minutes of exposure, he was shocked to notice on the screen the ghostly image of his hand's opaque bones through seemingly transparent flesh.[1]

Being a diligent experimenter, Roentgen now had to determine a way to document these evanescent images. Recalling that a photographic emulsion was darkened by cathode rays, he replaced his screen with a photographic plate and was able to create permanent images. Roentgen noticed that if a platinum plate were left in place on top of the photographic plate during an exposure, the space covered by the platinum would appear lighter when the plate was developed. Based on his observations, Roentgen concluded that he had discovered a new form of light, invisible to the eye.[1]

Roentgen's reaction to his discovery was to remain secluded in his laboratory for seven weeks, keeping his findings to himself. The scientific community already knew of the emission of phosphorescence from this type of vacuum tube, so Roentgen was convinced that the radiation he was working with had not been previously documented. Before publicizing his observations, Roentgen diligently devised several experiments to validate his conclusions. Wanting no distractions, he began practically to live in his laboratory. He began taking his meals there and even had his bed moved into the room. During this time he disclosed his findings to only one friend, Theodor Boveri, by modestly stating, "I have discovered something interesting but I do not know whether or not my observations are correct."[1]

Roentgen built a permanent darkroom for himself in the form of a sheet-metal cabinet measuring seven feet high and four feet wide. The rays passed through a circular aluminum sheet, which was inserted into one side of the zinc-walled chamber. The aluminum sheet measured 18 inches in diameter and one millimeter thick. Roentgen entered and exited the booth through a zinc door situated opposite the side housing the aluminum disc. On the outside, a vacuum tube was focused onto the disc's center. A lead plate was hung on the zinc wall between Roentgen and the tube, fortuitously protecting Roentgen from the harmful effects of radiation, which were yet to be discovered.[1]

Roentgen convinced his wife to partake in one experiment. Using a 15-minute exposure, he made a photograph of her hand. The developed image was of lightly colored bones surrounded by the darker shadow of flesh. Mrs. Anna Bertha Ludwig Roentgen was wearing two rings, which stopped most of the rays and were clearly visible as dark cylinders. Mrs. Roentgen shuddered at the shock of seeing the bones of her own hand.[1]

The Light That Never Was

Once Roentgen was confident of the validity of his observations, he described his findings as "X-rays," in the 1895 paper "On a New Kind of Rays, a Preliminary Communication." Prior to demonstrating his findings, Roentgen published his paper rather quickly to stimulate discussion by the scientific community. He was aware that, due to the Christmas holiday, several weeks would pass before he would have the opportunity to demonstrate his findings to the Würzburg Physical Medical Society. Before it was even published, Roentgen mailed copies of his paper and prints of his X-ray pictures to several renowned physicists for their scrutiny. Anticipating the notoriety he was about to receive, the reclusive Roentgen was quoted as saying to his wife, "now the devil will be to pay."[1] In his article, the choice of 'X' was made due to its representation of an unknown quantity. His paper included radiographs of his wife's hand, a piece of metal, a compass, and a set of weights.[2] This work, first titled, "Eine Neue Art von Strahlen," appeared in the German journal, *Sitsungsberichte der Würzburger Physik-medic*, December 28, 1895. News of his discovery, which some heralded as "the new light," was cabled around the world. In an article titled, "The Light That Never Was," *The Saint Louis Post Dispatch*, January 7, 1898, was the first newspaper in the United States to carry an article on Roentgen's findings.[1a]

As outlined in his paper, the conditions and properties necessary for the generation of X-rays continue to serve as the basis for radiation physics. Amazingly, Roentgen drew these conclusions after a mere seven weeks of carefully conducted observations and experiments.

On January 23, 1896, the reticent Roentgen gave a presentation of his discovery for the Würzburg Physical-Medical Society. In his demonstration, Roentgen credited the scientists before him who had investigated cathode rays, including Sir William Crookes, Heinrich Rudolf Hertz, and Philipp Lenard. He was applauded several times by a packed audience who decreed the new rays should be named "Roentgen rays." Roentgen issued two more communications over the next year-and-a-half. In the papers, he so meticulously described the properties of X-rays that the renowned English physicist, Silvanus P. Thompson, remarked, "Roentgen had so thoroughly explored the new properties of the new rays by the time his discovery was announced, that there remained little for others to do beyond elaborating on his work." Roentgen declined opportunities of financial gain from his discovery, and was quoted: "According to the good tradition of the German university professors, I am of the opinion that their discoveries and inventions belong to humanity and that they should not in any way be controlled by any one group."[1]

Roentgen received numerous worldwide accolades for his work. The British Royal Society bestowed upon him the gold Rumford medal in 1896. The Franklin Institute in Philadelphia awarded him the Elliot-Cresson medal, and Columbia University decorated him with the Barnard medal upon recommendation by the American Academy of Sciences. The first Nobel Prize for Physics was bestowed upon him in 1901. Normally, Roentgen did not attend ceremonies in his honor; however, he traveled to Stockholm to receive his prize from the Swedish Crown Prince. Roentgen donated the honorarium of 50,000 kroner to the University of Würzburg. The German Emperor presented Roentgen with the Royal Order of Merit, which carried with it the title of nobility. In accepting this award, Roentgen declined the status of personal nobility. In the fervor of World War I, Roentgen was persuaded to donate his gold medallions to the German cause, a choice he later regretted.[1]

His wife of almost 50 years died in October 1919, but he continued to communicate his feelings with her photograph long after her death. In 1920, Roentgen, Professor of Physics at the University of Würzburg, retired from his position. He maintained his laboratory and continued experiments until his death on February 10, 1923, in Munich.[1] Roentgen arranged for his personal documents relating to his findings to be destroyed after his death, accounting for some of the discrepancies regarding the dates and events surrounding his work.[3]

Early Radiology in Europe

The early X-ray machines had three components: a six- to ten-celled Bunsen or Grove battery, a Ruhmkorff induction coil used to initiate a three- to six-inch spark, and a Crookes' tube. Eventually, the Wimshurst machine replaced the coil and battery, and the Tesla coil replaced the Ruhmkorff coil. At the turn of the century, a complete Roentgen apparatus with a fluorescent screen cost approximately one hundred dollars. The Eastman Materials Company introduced photographic paper, which replaced the use of glass plates. This paper could be bent to conform to the shape of the body part being imaged, allowing closer contact with the photographic paper.[4]

In February 1896, the first related articles to appear in the British journal, *The Veterinarian*, were by J.A.W. Dollar, and they conveyed his excitement at the practical implications of Roentgen's images. In a subsequent article, Dollar described Roentgen's findings in great detail. At the time, many believed vibrations of so-called "luminiferous ether" generated visible light. X-rays behaved much differently from ultraviolet light, and there was speculation that X-rays were either very fine particles which traveled in perfectly straight lines at tremendous velocity, or were a very long form of ether waves. Nikola Tesla demonstrated that a magnet was able to deflect the waves, giving credence that X-rays indeed had a material form.[4]

Also in February 1896, photographic plates of high-quality animal radiographs were first produced and published in a monograph by two veterinary school faculty at the University of Vienna, Eduard Valenta and Josef Maria Eder. As director of the Imperial Teaching and Research Institute for Photography and Reprography, Eder had access to Vienna's most powerful induction unit. Eder, also a chemist and physicist, derived his interest in radiographs from the standpoint of a scientific photographer. Due to the low power capacity of the unit, the images Eder created were of thin objects, which included snakes, rats, frogs, fish, and newborn rabbits. Images were also made of wood, metals and gems. Objects with medical implications, including gallstones, foreign bodies, and fractures, were also radiographed. The first radiographs of an Egyptian mummy were also made. The first stereoradiograph of a mouse was performed with Eder's colleague, physicist Ernst Mach.[5]

At this time other veterinary articles appeared in France (Lemoine), England (Hobday and Johnson), and Berlin (Troester). *The Archives of Skiagraphy* was the first X-ray journal, and its premier edition included a "motion picture" of the movement of a frog's leg taken with a fluoroscope. At the time, radiographs were called skiagrams or skiagraphs, from the Greek prefix *skia* meaning shadow, because the images were considered to be shadowgraphs.[6]

The medical community quickly realized the value of Roentgen's discovery. The initial focus for the use of X-rays with bone fractures, calculi, and foreign bodies quickly grew to include their curative effects. By late 1896, veterinarians had already published six of the over 1000 papers related to the use of X-rays in medicine.[3] In Europe, veterinarians were already using radiation for treatment of benign and malignant lesions. Most treatments, however, were directed against benign, superficial masses or chronic inflammation and infection.[7] This was due in part to the relative ease in administering smaller doses of radiation. Although intensifying screens and contrast media were employed at this time, it would be many years before radiographs of diagnostic quality were routinely obtained. The early machines behaved erratically, were quite noisy, and required protracted exposure times.

The *Journal of Comparative Pathology and Therapeutics* (1896) published a paper, "The New Photography in Veterinary Practice," which described the identification and removal of a foreign body from a cat's elbow joint. Chloroform and hobbles were used to keep the cat from moving during the two-and a half-minute exposure time. Later, the same author, Professor Hobday of the Royal Veterinary College, studied the feasibility of imaging the stifles of unanesthetized horses. He concluded that the ability to restrain horses to allow an adequate exposure time was feasible; however, based on his observations on equine cadavers, the current machines lacked sufficient power for the desired penetration of the bone.[8]

In 1897, Austria's Vienna Veterinary High School became the first veterinary school to own an X-ray machine. By 1901, the school was making radiographs of small and large animal patients and documenting the occurrence of canine skin lesions induced by radiation. However, diagnostic imaging was not at the forefront of X-ray uses, as X-ray generators lacked sufficient power to image large animals. Early veterinary radiation research focused on X-ray's therapeutic effects. The Rockefeller Foundation donated a substantial grant to the Vienna Veterinary High School in 1927 for the establishment of a Veterinary Roentgenologic Institute. Professor Alois Pommer was the first director, and served in this position from 1938 until his death in 1958.[3] His work included discovering which diseases were suitable for X-ray therapy, examining radiation's biological effects, and describing radiation therapy protocols.[8] Many aspects of his treatment protocols still serve as the basis for those used today.[3]

Richard Eberlein, Director of the Royal Veterinary Academy and Surgery Clinic in Berlin is considered the "Father of Veterinary Radiology." His first paper addressing the use of X-rays in veterinary medicine was published within a year of Roentgen's discovery. Professor Eberlein was a close friend and colleague of Roentgen, and in 1905 and 1906, he was the only veterinarian ever to chair the Roentgenological Congress. In 1911, at the Seventh Roentgenological Congress, he warned of the dangers of X-rays.[3] Unfortunately, the medical community was still quite dismissive of the inherent dangers of working with radiation.

Paul Henkel wrote the first text on veterinary radiology, which was published in 1926 in Berlin. This book, written in German and never translated into English, described and illustrated the physics, anatomy, radiation therapy, and diagnostic applications involved.[3]

America's First Radiograph

The first radiograph made in the United States was at North Carolina's Davidson College in 1895. In the fall of 1895, physicist Henry Louis Smith conducted a demonstration of Crooke's tubes to his students. Three juniors, Osmond Barringer, Eben Hardie, and Pender Porter, who were present, later learned of Roentgen's works. Risking expulsion, the students bribed a janitor to gain entry to the physics laboratory and brought with them a cadaver's finger they had procured from the Medical College's dissecting room. Using a three-hour exposure, they were able to produce an X-ray image of the finger and other items.[9,10]

Smith received tremendous notoriety for the images he created, and less than a year later he was called upon to help a dying child who had been diagnosed with tonsillitis. Using X-rays, Smith determined that the girl, Ellen Harris, had swallowed a sewing thimble. The surgeons, as yet unaware of X-rays, were incredulous and refused to operate until Smith demonstrated how he created the image. The girl's life was saved by the operation.[9]

Veterinary Radiology in North America

The use of X-rays by veterinarians in North America during the early 1900s is not well documented. Editorial comments in the American Veterinary Review of 1910 referred to the use of a radiograph in detecting an iron rivet that a puppy had ingested. This case helped to reaffirm the value of X-rays in veterinary practice. Radiographs were used at The Ohio State University by W.F. Guard to examine a fractured equine phalanx in 1912. The first paper published on veterinary radiology in America was in 1915 by H.E. Kingman, Sr., Professor of Surgery at Colorado Agricultural College (now Colorado State University). In his work, he described the bony changes observed on radiographs of lame horses.[10] In 1915, the veterinary hospitals at Iowa State College and the Colorado Agriculture College acquired X-ray machines.[3]

The use of diagnostic X-rays increased with the development of small animal practices in the 1920s. Angell Memorial Hospital of Boston, Massachusetts acquired its first X-ray machine in 1923. In 1927, J.C. Horning of Houston, Texas published the first paper in America describing small animal radiology. His work highlighted the imaging of the thorax and fractures through the usage of fluoroscopy. Improvements in the equipment quality made taking X-rays more reliable, relatively cheaper, and safer; however, the public (and indeed the medical community) was still largely ignorant of radiation's dangerous effects.[3,10] Few wore protective clothing while taking radiographs. Radium spray was being marketed as an insecticide, household cleaner, and furniture polish. In Chicago, X-ray treatments were touted as a "method to restore youthful complexions." Radium drinks were even marketed as elixirs.

It was not until the 1930s that most veterinary colleges, Angell Memorial Hospital, and a handful of small animal practices began to utilize X-ray equipment. Then, in 1937, the North American Veterinarian published a series of articles by Gerry Schnelle of Angell Memorial Hospital. Based on his clinical case experiences at Angell, Schnelle described the radiographic findings and their relation to the final diagnosis. Several conditions were first described in this series, including canine nasal tumors, Legg-Perthes disease, hip dysplasia, and intervertebral disk disease. In 1945, Schnelle also produced the first American textbook on veterinary radiology, *Radiology in Canine Practice*, published by the North American Veterinarian. The second edition, which included cats and a discussion of radiotherapy, was entitled, *Radiology of Small Animals*, and was published in 1950.

Following World War II, Army veterinarians John H. Rust and B.R. Trum publicized to the veterinary community their research on the biological effects of radiation. A very dangerous piece of equipment commonly used at that time was the hand-held fluoroscope. When the hazard of exposure to radiation from using this apparatus became known, use of the fluoroscope declined. From a safety standpoint, it is fortunate that the growth in the use of radiology by veterinarians was slow in the 1940s and 1950s. At this time the machines were still poorly shielded and electronically unreliable, exposure times were quite long, and the dangers of ionizing radiation were yet to be fully respected.[3]

In the 1950s, the American Animal Hospital Association began to sponsor talks and seminars on diagnostic radiology in the small animal practice, furthering its acceptance and use by the veterinary community. Subsequently, all the veterinary schools in the United States developed a curriculum that included radiology and hired faculty members with specific interests in the field. Many of the veterinary radiologists of that early era had been self-taught or had been taught by human specialists.[3]

Veterinary Radiology as a Specialty

Mack Emmerson, the first veterinarian to be trained as a radiologist, was quite influential in developing veterinary radiology into a specialty in North America. After studying radiology with medical students at the Hospital Radiology Department at the University of Pennsylvania's Medical School, Emmerson trained during the mid-1930s under Alois Pommer at the Roentgenologic Institute in Austria. At the University of Pennsylvania in 1939, Emmerson established the first Veterinary Radiology Department at a

North American college, and in 1955 William Harker Rhodes was the first student to enter the program. Rhodes later became an instrumental figure by organizing a community of veterinary radiologists. In the 1950s, the University of Pennsylvania began officially to accept veterinarians into its Graduate School of Medicine as full-time radiology residents. In the 1950s, Emmerson organized the American Board of Veterinary Radiology. In 1959, William Carlson established a program for full-time graduate degree training in radiology at Colorado State University.[3]

In 1962, the American Veterinary Medical Association approved certification status for the American Board of Veterinary Radiology, enabling it to certify specialists. The five founding members included W.C. Banks (Texas A & M), W.D. Carlson (Colorado State University), M.A. Emmerson (Iowa State University), W.H. Rhodes (University of Pennsylvania), and G.B. Schnelle (Angell Memorial Hospital). In 1969, the Board's name was changed to the American College of Veterinary Radiology (ACVR), which of this writing has 201 diplomates. In 1994, radiation oncology was established as a subspecialty, which has 30 diplomates. The ACVR also includes three societies, specializing in nuclear medicine, CT/MRI, and ultrasound. Society members are diplomates, residents in training, and other veterinarians interested in imaging.[3]

Present-day Radiology

The improvement of radiographic techniques and equipment, such as films, screens, systems, automatic processors, high frequency generators, collimators, and image-intensified technology, in the 1970s and 1980s brought even wider applications of diagnostic radiology in animals. NASA engineers met with radiologists in February 1972 and began developing teleradiology, allowing patients in remote locations access to a specialist's opinion.[9] Use of computers now provides even greater advances. Today, computer screens are used to view digitized images of radiographs, computed tomography, MRI, ultrasound, and scintigraphy. The versatility of radiology continues to grow with the integration of new technology.

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