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The Burning Question: Early U.S. Radiology and X-Ray Burns, 1896-1904

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THE BURNING QUESTION:
EARLY U.S. RADIOLOGY AND X-RAY BURNS, 1896-1904

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With a widening field of usefulness the medical employment of x-rays becomes a “burning question,” and this in its most literal sense.

–*London Electrical Review,* 1904, reprinted in *The American X-Ray Journal*

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Thank you to everyone at the International Society for the History of Radiology, especially Uwe Bosch and Stephan Popp. They made it possible for me to present the research this thesis is based on via Skype to their November 7, 2015 conference in Würzburg, Germany. The conference was held in the very auditorium at the University of Würzburg in which Wilhelm Röntgen made his first and only public presentation on his discovery of X-rays on January 23, 1896.

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INTRODUCTION

"DR. HEBER ROBARTS DIES A MARTYR TO SCIENCE," the *New York Times* reported on May 3, 1922:

> BELLEVILLE, Ill., May 2.—Dr. Heber Robarts, 70, internationally known X-ray and radium specialist, died at his home here yesterday. His death indirectly was due to burns received while experimenting with Roentgen rays before present day precautionary measures were known.
>
> At the time of his death, Dr. Robarts was President of the Southern Illinois Medical Society. He was the founder of the Roentgen Ray Society and also founder and first editor of The American X-Ray Journal.[1]

Robarts was one of many. Between 1904 and 1936, dozens of radiologists succumbed to cancer as a result of their work with X-rays. Among the contributors to Robarts's *American X-Ray Journal* who later died of cancer were Drs. J. N. Scott, Charles Leonard, and Mihran Kassabian. Each of these individuals' cancer had been preceded years earlier by an X-ray burn.

Radiology became the subject of substantial historical interest by radiologists themselves in the 1930s. It was in that decade that the American Congress on Radiology issued a remarkably comprehensive anthology on the history of their discipline in the United States. This work, *The Science of Radiology*, was issued in 1933 and was edited by Wilhelm Röntgen biographer Otto

[1] "DR. HEBER ROBARTS DIES A MARTYR TO SCIENCE. Noted X-Ray and Radium Specialist Succumbs to Old Burns in Roentgen Rays Experiments," *New York Times (1857-1922)*, May 3, 1922, ProQuest Historical Newspapers pg. 18.

Glasser. Three years later, Percy Brown, a contributor to the anthology, published his *American Martyrs to Science through the Roentgen Rays* (1936). The contributors to *The Science of Radiology*, including Brown, were not historians. They were physicians, surgeons, and physicists, including Glasser and Brown. As such, they were participants in the medical and scientific fields whose history they were documenting and narrating.

In subsequent decades, trained historians demonstrated interest in the history of radiology, though this interest has been sporadic. Historians' focus has been overwhelmingly on the "big picture" and on cultural manifestations of X-rays. Notable works on the history of radiology include Ruth and Edward Brecher's *The Rays: A History of Radiology in the United States and Canada* (1964), Richard Mould's *A History of X-rays and Radium* (1980), and Bettyanne Kevles's *Naked to the Bone: Medical Imaging in the Twentieth Century* (1997). Kevles's work was one of several works published around the centennial of Röntgen's discovery, such as Thomas Adrian's *The Invisible Light: 100 Years of Medical Radiology* (1995) and *X-rays: The First Hundred Years* (1996), an anthology edited by Alan Michette and Slawka Pfauntsch. As can be inferred from the titles of these works, English-language monographs have tended to be sweeping, seeking to tell the story of radiology from its emergence to the present. A secondary focal point of the historiography of radiology has been the public's reception of Röntgen's discovery and the public's fascination with radiation. This is particularly true of the notable scholarly articles. Examples include Lawrence Badash's "Radium, Radioactivity, and the Popularity of Scientific Discovery" (1978) and Sylvia Poumakian's "Looking Radiant."[2] One of the consequences of historians' focuses is that historians have never taken an in-depth look at the experience of X-ray burns from the perspective of the first U.S. radiologists.

[2] Lawrence Badash, "Radium, Radioactivity, and the Popularity of Scientific Discovery," *Proceedings of the American Philosophical Society* 122, no. 3 (June 1978): 145-154; Sylvia Poumakian, "'Looking Radiant': Science, Photography and the X-ray Craze of 1896," *Victorian Review*, Vol. 27, No. 2 (2001), 56.

Because little attention has been devoted to early radiologists' beliefs regarding X-ray burns, historians have sometimes underestimated the heterogeneity of these beliefs. Historians who discuss X-ray burns often note that early radiologists wondered whether or not X-ray burns were caused by electrical fields. Historians also sometimes note that early radiologists debated whether or not there existed significant individual variation regarding susceptibility to X-ray burns. However, radiologists were divided on every dimension of X-ray burns. They disagreed over what X-ray burns were and what to call them. They disagreed over what caused them. They disagreed over how to avoid them, and whether you could avoid them. They disagreed over how to treat them. They even disagreed over whether or not X-ray burns were dangerous or even desirable.

The heterogeneity of early US radiologists' beliefs regarding X-ray burns resulted in a heterogeneity of protective practices. The degree of this variation in protective measures has not received attention from historians. Early radiologists proposed myriad measures for avoiding X-ray burns, including the use of static machines instead of induction coils for the generation of electricity; interposing a grounded aluminum screen between the X-ray tube and the patient; and asepsis.

By the end of 1896, anyone who worked with X-rays had heard of X-ray burns. Indeed, many early radiologists expressed dismay at how much media attention X-ray burns received. Yet, a surprising number of radiologists refused to accept that these injuries were caused by exposure to X-rays. Until about 1899, most radiologists attributed X-ray burns to exposure to electrical fields. Another theory held that X-ray burns were caused by microbes or particles of dust being pushed into patients' and operators' skin by the force of X-rays. Others attributed X-ray burns to exposure to ultraviolet light. Some attributed X-ray burns to ozone purportedly

produced when exposing patients to X-rays. Some suspected nitrous acid was the culprit. Those who identified exposure to X-rays as the cause of X-ray burns frequently minimized their significance or frequency. They alleged that the tubes that produced burns were defective, implying that those that were not defective did not produce burns. They alleged that operators who produced burns were unskilled, implying that burns were not produced by skilled operators. And they alleged that some patients were idiosyncratically susceptible to developing X-ray burns, implying that most people had little to fear. It was not until about 1904 that U.S. radiologists agreed that X-ray burns were caused by exposure to X-rays. By this time, many had developed significant injuries, many of which would ultimately prove fatal.

This paper describes the beliefs of early U.S. radiologists regarding X-ray burns, and it identifies the protective measures that early U.S. radiologists adopted as a consequence of these beliefs. In the process, this paper demonstrates that early radiologists conspicuously avoided the conclusion that exposure to X-rays was the cause of X-ray burns. It concludes by positing an explanation of this avoidance. I argue that early U.S. radiologists demonstrated a vocational bias against concluding that the technology around which they were forging a new discipline was inherently dangerous. This bias was left unchecked because of the relative dearth of conclusive evidence that X-ray burns were directly caused by exposure to X-rays.

The story of X-ray burns is important in at least two respects. First, X-ray burns definitively shaped the field of radiology. Each of us will be X-rayed multiple times over the course of our lives. In the course of our exposure, we will never see the actual X-ray tube, encased as it is in protective material. The certified technician, wearing a radiation badge, will place a lead apron over us and leave the room. Our exposure will last an instant. These features of our experience of X-ray technology are the legacy of X-ray burns and the cancer that

subsequently developed at their locations.

The second reason the story of X-ray burns is important is that it provides a high stakes example of the human capacity for forging unwarranted convictions. Early radiologists did not have reliable, systematically collected data on X-ray burns. Attempts to collect such data would have been hampered by the great diversity of equipment and practices that prevailed in the early days of radiology. Despite this, early radiologists developed strongly held beliefs about X-ray burns, and they adopted protective measures in accordance with these beliefs. Because of this, the experience of early radiologists with X-ray burns has implications for such timeless issues as the nature of knowledge, whether we can trust experts, and whether we can trust ourselves. The story of X-ray burns, therefore, is a cautionary tale with universal significance.

Sources, Methods, Terminology

This paper is based primarily on *The American X-Ray Journal*. The first experimenters with X-rays published in a variety of journals. This included long-established scientific journals, as well as the journals of the new field of electrical engineering. However, as medical practitioners increasingly adopted the use of X-rays, they desired their own journals. In Britain, the world's first radiology journal, *The Archives of Clinical Skiagraphy*, appeared in May 1896. Germany's *Fortschritte auf dem Gebiet der Röntgenstrahlen* followed in 1897, as did *The American X-Ray Journal* (*AXJ*). *AXJ* was founded in 1897 by Heber Robarts of St. Louis, Missouri. Robarts also helped found the American Roentgen Ray Society, the first professional organization of radiologists in the United States, which met for the first time in December 1900. *AXJ* is one of the most authoritative sources on early U.S. radiology. It offers us a description of

the beliefs and practices of early U.S. radiologists in their own words. Contributors often refer to the beliefs and practices of their colleagues, and so *AXJ* also gives us insights into the beliefs and practices of radiologists beyond those who contributed to *AXJ*. Additionally, articles in the pages of *AXJ* carried the imprimatur of the journal's prestige and would have influenced its readers to adopt similar beliefs and practices. *AXJ* is freely available online through the Internet Archive, and it was through the Internet Archive that I accessed it.

In order to identify relevant material in *AXJ*, I took two approaches. First, I reviewed the table of contents of every edition between May 1897 and November 1904. I made a list of every article the title of which suggested the article discussed X-ray burns. I read these articles to identify those that were relevant to my paper. I then did a word search of every edition of *AXJ* for the word "burn" to identify any additional items that my initial search had overlooked. X-ray burns were the main topic in many of the items I identified. However, X-ray burns were often discussed or mentioned tangentially in articles primarily concerned with other topics. Regarding such material, I made judgment calls as to whether X-ray burns figured substantially enough in the item to merit inclusion in this paper's bibliography. Ultimately, I identified approximately 100 items in the *American X-Ray Journal* that were relevant to an investigation of X-ray burns. However, three of these were unavailable. They were located on pages 1045 through 1050 of volume 10. These pages were missing from the Internet Archive copy. The original document is held by the College of Physicians of Philadelphia Historical Medical Library, and so I contacted them and learned that these pages are missing from the original. I was unable to locate these items, and so they do not appear in the bibliography. Of those items from *AXJ* that appear in the bibliography, a handful do not discuss X-ray burns but are included because they address topics

relevant to the paper such as the state of knowledge regarding electricity at the turn of the twentieth century.

From these approximately 100 items, I copied countless quotations which I sorted into documents corresponding to their location in this paper. This allowed me to produce comprehensive lists of statements in *AXJ* on each of the topics discussed. For instance, one Word document contains every statement in *AXJ* in which a contributor claimed that X-ray burns were caused by exposure to X-rays. Another document contains every statement in *AXJ* in which a contributor attributed X-ray burns to inoculation with bacteria. This brought order to chaos, and it allowed me to provide a chronological account of every major facet of the debate over X-ray burns. However, it is worth noting that early radiologists never had such documents at their disposal. Experiencing the debates over X-ray burns in *AXJ* as they unfolded, readers would have regularly been exposed to contradictory views in the same editions of the journal without the advantage of the retrospective overview provided by this paper.

In addition to the *American X-Ray Journal*, radiologists such as Mihran Kassabian published books on radiology, portions of which I consulted. I also used U.S. newspaper accounts from the period that I accessed through ProQuest. Early U.S. radiologists often complained that the public were overly concerned about X-ray burns and that the popular press fomented this fear. I used these newspaper accounts to provide examples of the kinds of stories that were reaching the public and stoking this allegedly-unwarranted fear. Readily available, easily understood, and sometimes sensational, I felt the temptation to overload this paper with a discussion of them. I tried to limit this discussion to what was essential to my purposes. Insofar as I failed at this, it's a testament to the power of sources with the enumerated attributes to draw the historian into digressions.

For secondary sources on the history of X-rays and radiology, I relied mostly upon the works of Brown, Glasser, Kevles, and Mould listed in the bibliography. Other sources, such as Mathew Lavine's *The First Atomic Age* and Bernard Carlson's *Elihu Thompson* were also consulted to provide context for Röntgen's discovery and early radiology. Finally, I also consulted many reference works, such as encyclopedias of science and technology, which do not appear in the bibliography.

Immediately following their discovery, X-rays became an object of experimentation among electricians, photographers, and physicists in addition to physicians. Some of the individuals who played roles in the debate over X-ray burns fell into one of the former categories. Tesla, for instance, was not a physician, but an inventor and electrician, but he experimented with X-rays and his ideas about X-rays were occasionally discussed in the *AXJ*. However, *AXJ*'s primary intended audience was physicians, and all of the major participants in the debate over X-ray burns that took place in its pages were physicians. (Tesla, for instance, never published in *AXJ*.) To refer to those physicians who sought to incorporate X-rays into their practice following Röntgen's discovery, I use the term "early radiologist". A radiologist is a physician who uses medical imaging technologies such as X-ray machines for diagnosing and treating diseases. However, the first physicians who incorporated X-rays into their practice of medicine did not have a common terminology with which to refer to themselves as a distinct group. They simply regarded themselves as physicians who were on the cutting edge of modern medicine.

Throughout, I use the term "X-ray burn" to refer to the injuries that came to be referred to by that name. As is discussed, this term only gradually acquired universal, or near universal, usage. And of course, what it meant continued to be debated for years following the adoption of

the term. In some places I've adopted the term "the injuries that came to be known as X-ray burns" so as to avoid confusion when discussing individuals who objected to the term. It may be useful to regard the term X-ray burn as meaning, for the purposes of this paper, "injuries to the skin that occur as a consequence of exposure to X-rays." All of the participants in the following debates would have agreed that this was the phenomenon that they were discussing, whichever term they favored. Note, this definition avoids the claim that X-ray burns were caused by X-rays per se.

CHAPTER 1: FROM RÖNTGEN TO RADIOLOGY

X-rays are a form of electromagnetic radiation. On the electromagnetic spectrum, they fall between ultraviolet radiation and gamma radiation. Because X-rays possess greater energy than visible light, they are invisible to the naked eye and can pass through many materials opaque to visible light.

Electromagnetic radiation consists of photons, and photons are produced when electrons lose energy. In incandescent light bulbs, electricity is forced along a filament that slows the electrons down. The electrons lose energy, and some of this lost energy is expressed in the form of photons. Some of these photons are of the visible light band of the electromagnetic spectrum. In other words, light bulbs work by slowing down electrons, and X-ray machines operate on a similar principle.

To produce X-rays, early radiologists used cathode ray tubes. Cathode ray tubes are made of glass and contain a vacuum, or a near-vacuum. At one end, there is a piece of metal by which electrons can be sent into the tube. This is called the cathode. Some vacuum tubes have a piece of metal at the other end that recaptures the electrons. This is called the anode. The cathode and

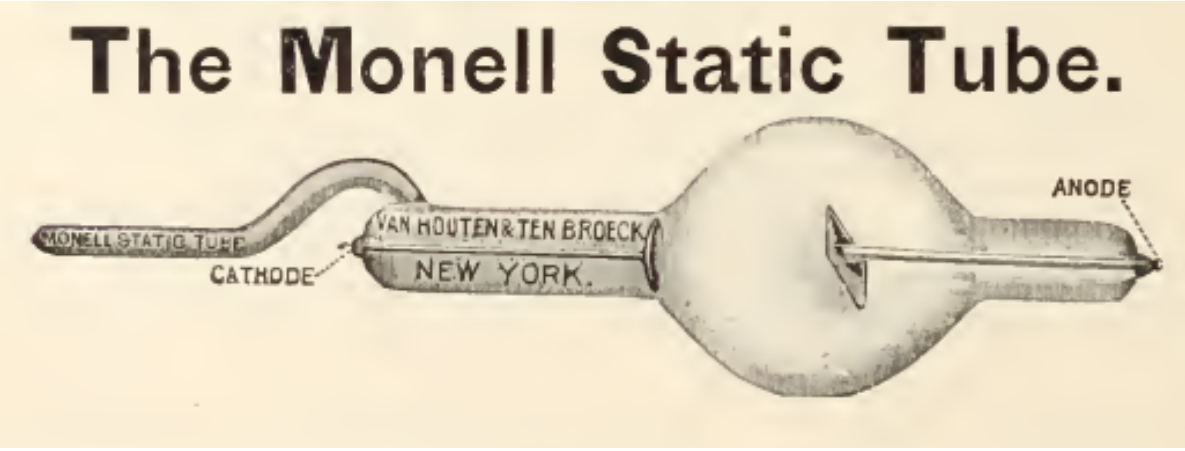

Figure 1: The Monell Static Tube, an example of a vacuum tube used by early radiologists. American X-Ray Journal, Vol. 1, p.110.

the anode (collectively known as electrodes) serve as the entrance and exit for electrons. In the

late-nineteenth century, European and American physicists often used electrical generators to send streams of electrons from one end of a vacuum tube to the other so that they could observe the effects of vacuum conditions on cathode rays, or electrons. Because this equipment was ubiquitous in the laboratories of physicists in the 1890s, it was relatively easy to acquire from manufacturers. This facilitated the rapid adoption of the use of X-rays by physicians following Röntgen's discovery.

When electrons crash into the anode or the glass wall of the vacuum tube opposite the cathode, they slow down, and photons are emitted. Some of these photons are of the X-ray band of the electromagnetic spectrum. Why do X-ray machines produce photons of the X-ray band of the electromagnetic spectrum? Because of the vacuum. The vacuum offers minimal resistance, so the electrons traveling through the vacuum of the tube speed up. The result is that when they collide with the other end of the tube, they have more energy to lose. This leads to the production of X-rays in two ways. First, the electrons that travel across the vacuum tube produce more high-energy photons in their collision with the matter at the other end of the tube than they otherwise would (if there was no vacuum). If they were traveling more slowly—for instance, along a copper wire on their way to colliding with a tungsten filament, as in an incandescent light bulb—they would produce fewer X-rays and more visible light in their collisions because they'd possess less energy. X-rays emitted by the cathode ray electrons upon their collision with the anode or glass wall of the tube are known as bremsstrahlung, or breaking radiation.

The second manner in which X-rays are produced is less direct, but more important. The electrons emitted by the cathode smash into the electrons of the matter at the other end of the tube, be it the glass of the tube or a metal anode (typically made of aluminum or platinum). The electrons that were fired across the tube lose energy and emit X-rays, as described above.

However, because the cathode ray electrons are so energetic, they can displace lots of electrons in the atoms of the matter with which they collide. This means that the electrons of the atoms of the anode or glass wall of the tube also lose energy and therefore emit photons. Why are these photons of the X-ray band of the electromagnetic spectrum? When the electrons displaced are close to the nuclei of their atoms, electrons that are more distant from the nucleus descend closer to the nucleus. In the process, the descending electron loses energy, releasing photons. The cathode ray electrons are traveling so fast that they are able to displace more electrons near the nuclei of the anode or glass wall's atoms than they otherwise would, triggering the descent of high-energy electrons further from the nucleus. Because the descending atoms possess a lot of energy, they emit photons of the X-ray band of the electromagnetic spectrum. Most of the X-rays produced by an X-ray machine are produced in this way, emitted by the electrons of the matter with which the cathode ray electrons collide. X-rays produced in the manner are known as characteristic X-rays.

X-rays were discovered by Wilhelm Röntgen on November 8, 1895. Röntgen was a professor of physics at Würzburg University. On that day, he was observing the effects of sending cathode rays through vacuum tubes, often referred to as Geissler or Crookes tubes in reference to the nineteenth-century scientists Heinrich Geissler and William Crookes. Geissler was a German designer of glass instruments who created a glass tube containing vapor that luminesced when cathode rays were passed through it. Crookes was a British chemist who succeeded in evacuating an unprecedentedly large proportion of the contents of such tubes, i.e., creating a vacuum.

As the rays streamed across the tube, Röntgen noticed that a nearby piece of cardboard, coated with barium platino-cyanide, had begun to glow. Over the following weeks he

investigated the phenomenon, in the process determining that when cathode rays are sent through vacuum tubes an invisible type of "ray," or light, is produced. This type of light was invisible to the human eye and could penetrate objects opaque to visible light, but it reacted with photographic chemicals such as barium platino-cyanide. He shared his findings with the Würzburg Physical and Medical Society on December 28, 1895 and held a public presentation on his findings on January 23, 1896. At this presentation, a colleague declared that henceforth the phenomenon dubbed "X-rays" by Röntgen himself, would be known as "Roentgen rays." The term survives in English in the names of radiological journals and organizations, such as the *American Journal of Roentgenology*. For his discovery, Röntgen was awarded the first Nobel Prize in Physics in 1901.

Röntgen was not the first physicist to produce X-rays, since other physicists were also firing electrons across vacuum tubes. Indeed, "At the turn of the century, physicists were obsessed with electricity…" notes Nelson Craig.[3] Being invisible to the human eye, these X-rays went almost universally unnoticed, but a handful of experimenters had actually already observed the effects of X-rays on photographic chemicals. Philipp Lenard and Nikola Tesla were among them.[4] Indeed, the barium-platino-cyanide-coated cardboard that alerted Röntgen to the existence of X-rays had not been an intended component of the experiment that he was performing, and so his discovery of X-rays was, in this respect, a chance event. However, Röntgen was the first to identify X-rays as a noteworthy phenomenon. "Many scientists before him—Crookes, Goodspeed, Goldstein, Lenard, and others—had made similar observations," writes Glasser, "but had entirely forgotten about them until Röntgen's announcement was made."[5] Lenard and Tesla only realized in retrospect that a major discovery had slipped through their fingers. Being the

[3] Nelson Craig, *The Age of Radiance: The Epic Rise and Dramatic Fall of the Atomic Age* (New York: Scribner, 2014), 8.
[4] For the evolution of Lenard's attitude toward Röntgen, see Mould. For Tesla's near-discovery of X-rays, see Carlson.
[5] Otto Glasser, "Wilhelm Conrad Röntgen and the Discovery of the Roentgen Rays," in Glasser (1933), 4-5.

first to recognize them as worthy of further investigation, Röntgen conducted extensive experimentation into X-rays' properties; named them; and was the first to publish a report on his observations of X-rays.

Röntgen's "On a New Kind of Rays," the paper in which he announced his discovery in December 1895, often dramatically referred to simply as Röntgen's "first communication," is regarded as a landmark in scientific literature. It heralded the field of atomic physics, inspiring Henri Becquerel's discovery of radiation in 1896 and J. J. Thompson's discovery of the electron in 1897. Especially at the time, it was regarded as a model of scientific discourse. The last scientific paper announcing a major breakthrough in physics that could be read and comprehended by non-physicists, it is written in plain language. It is also free of the pretentious and sensationalist rhetoric that the scientific community was striving to identify with pseudoscience at the turn of the century.[6] (Incidentally, part of the paper's status as a perfect embodiment of scientific practice rests in part with the fact that it obscures elements of the discovery it announced. "Nowhere to be found in the article is even an inkling of the serendipity behind Röntgen's discovery: the typical scientific report represents a rational reconstruction of scientific work—bearing scant relationship with what actually happened in the laboratory or field or observatory on a day-by-day basis," write Joseph Harmon and Alan Gross.[7]) Röntgen cultivated his portrayal as the ideal scientist, shunning notoriety as well as speculation. When reporters inquired as to his thoughts upon first observing X-rays, he responded, "I didn't think. I investigated."[8] Rather than immediately announcing his discovery, he had dutifully dedicated the following weeks to carefully identifying and documenting the properties of the new

[6] For a discussion of the uses of the term "pseudoscience" at the turn of the century, and of scientists' effort to distinguish themselves in contrast to what they termed pseudoscience, see Massimo Pigliucci and Maarten Boudry (eds.) *Philosophy of Pseudoscience: Reconsidering the Demarcation Problem* (Chicago: University of Chicago Press, 2013), 128-130.
[7] Joseph Harmon and Alan Gross (eds.), *The Scientific Literature: A Guided Tour* (Chicago: The University Press, 2007), 148.
[8] Kevles, 19.

phenomenon. So thorough was Röntgen's research that it would be years before other scientists could identify properties of X-rays not already identified by Röntgen.[9]

However, despite the extensive nature of Röntgen's experimentation with X-rays, and his detailed observation of their properties, basic questions remained regarding X-rays for years to come. As mentioned above, J. J. Thompson's discovery of the electron came in 1897. It was only in the decade after Röntgen's discovery that the nature and properties of photons were identified, and the term wasn't coined until 1926 (by American chemist Gilbert Lewis). With atomic theory in its infancy, the discipline of radiology emerged before a basic understanding of the nature of the phenomenon that defined it.

Among those properties of X-rays that remained unknown as the first radiologists rushed to secure their place at the cutting edge of scientific medicine were those properties that made X-rays dangerous. Electrons and X-rays are forms of ionizing radiation. Ionizing radiation consists of radiation that displaces electrons in matter with which it collides. Other forms of ionizing radiation include gamma rays and alpha radiation. Gamma rays, like X-rays, are a type of electromagnetic radiation. They fall beyond X-rays on the electromagnetic spectrum. Alpha radiation consists of two protons and two neutrons (in other words, a helium nucleus). As we've seen, the displacement of electrons is integral to the production of X-rays. However, in human tissue, this displacement of electrons, or ionization, can damage tissues. Prolonged or repeated exposure to ionizing radiation can induce cancer, and many radiologists would find that their efforts at healing others would produce dire consequences for themselves. By 1959, 359 deaths worldwide could be attributed to exposure to X-rays.[10]

[9] Otto Glasser, "Wilhelm Conrad Röntgen and the Discovery of the Roentgen Rays," in Glasser (1933), 6.
[10] Craig, 13.

It was years, even decades, before many early radiologists developed cancer. However, the first symptoms of overexposure to X-rays can appear within days, and early radiologists began experiencing injuries inflicted by the ionizing radiation with which they worked as early as 1896. These more immediate injuries came to be known as X-ray burns, and it was in the context of tremendous enthusiasm for the emerging field of radiology, but a limited understanding of the nature of X-rays, that the first radiologists would struggle to understand these injuries.

The Advent of Radiology

Physicians had long sought to perceive the internal conditions of their patients without opening them up. This is because any perforation of a patients' skin remained inevitably painful and dangerous until the mid-nineteenth century, when surgical anesthesia and aseptic practices first appeared, and inevitably risky until the 1940s, when antibiotics came into widespread use. Therefore, the preferred method of ascertaining what was happening inside a patient's body was auscultation, or listening. For this purpose, the stethoscope was devised in 1819 by French physician Rene Laennec. Other devices followed over the course of the nineteenth century, including the ophthalmoscope, the oesophagoscope, and the rectoscope that expanded the dimensions of the human body visible to physicians without surgery.[11] These devices were for the eyes, but they did not allow perception *through* flesh. Until X-rays, physicians could only hear through flesh. With the discovery of X-rays, they could now see through it.

[11] Roy Porter, *The Greatest Benefit to Mankind: A Medical History of Humanity* (New York: W. W. Norton Company, 1998), 605.

The momentousness of this development is partly a matter of biology. Kevles writes that "An unacknowledged competition was underway in the last decades of the nineteenth century between the domestication of sound and light. With the invention and almost instant commercialization of the telephone in 1876, sound seemed to take the lead."[12] Her portrayal of this competition neglects a crucial difference between human sight and human hearing. The superiority of the eye to the ear as means of aiding physicians was not simply a matter of circumstance, of which tools happened to be available for the job. "In fact, vision is a dominant sense for human beings; we rely on vision more than any other special sense. This is indicated by the fact that 70% of all the sensory receptors in our body are found in the eyes, and almost half of the cerebral cortex is involved with some aspect of processing vision," writes Douglas Light in *The Senses*.[13] X-ray apparatus made the inside of the human body readily discernable via a non-surgical method to the preferred perceptory organ of human beings, a fact that helps account for the rapidity of the emergence of a discipline founded on the use of the new technology. That people favor vision over other senses is reflected in the fact that technologies that utilize sound waves to render phenomena perceivable to human beings are frequently used to convert aural information into visual information. Consider, for instance, the sonogram.

Physicians, especially surgeons, were quick in grasping the significance of Röntgen's discovery for medicine. Within less than a year of their discovery, the *Boston Daily Globe* reported that X-rays were regarded as an established dimension of medical practice:

> X-ray photography has acquired a permanent place in surgery. It has been only a little more than six months since Roentgen's discovery was announced, and yet

[12] Kevles, 13.
[13] Douglas B. Light, *The Senses* (New York: Chelsea House, 2005), 55.

there is said to be no hospital of any importance in the civilized world where photography by means of the cathode ray is not in daily use.

At the Massachusetts general hospital not a day passes without the application of the new photography….[14]

In 1902, Chicago physician H. Preston Pratt, who was then serving as editor of the *American X-Ray Journal*, noted the expansion of the use of X-rays as reflected in the increased demand for static machines. Static machines were a type of electric generator that early radiologists used to provide electricity for their vacuum tubes. "Five years ago," he wrote, "there were but three houses in America that made static machines, although electro-therapeutics was largely taught in special schools. Now, there are more than 25 manufacturing houses, some of whom like Van Houten & Ten Broeck, Waite & Battery and Optical Co., R. W. Wagner Manufacturing Co., Electro-Therapeutic Manufacturing Company, and others that can not keep up with the demand for x-ray machines."[15]

X-rays enabled a dramatic improvement in the capacity of physicians to locate foreign objects in the human body. A spectacular instance is provided by the case of a man from Hamburg. Years before the discovery of X-rays, this man had attempted suicide with a revolver. Brought to the hospital, he recovered. However, "After his discharge he returned, complaining of pains in the head and declaring he had a bullet in his head. The doctors refused to believe him, but as he kept constantly repeating his statement, he was treated as a madman and locked up in

[14] "AS USED IN BOSTON. X-Ray Photography Has Been Found of Service," *Boston Daily Globe (1872-1922)*, August 6, 1896, ProQuest Historical Newspapers: The Boston Globe pg. 8. Kevles portrays this rapid adoption as superficial. According to her, there was significant regional variation in the frequency with which X-ray machines were used, and "Among the majority of physicians at the turn of the century…radiographs remained curiosities not directly related to what they would automatically do when confronted with an emergency." (Kevles, 38, 41)

[15] H. Preston Pratt, "X-Ray Prophecy," *The American X-Ray Journal*, Vol. 10, No. 3, June 1902, 1069.

the Nietleben lunatic asylum." The man was confined to the asylum for four years before he agreed to stop complaining of the alleged bullet's presence and was released. However, "When released from the lunatic asylum he came to Berlin. Here a well-known doctor who had heard of his case examined his head with Roentgen rays and discovered that the unfortunate man's story was perfectly true." The story ran in the *Boston Daily Globe* under headline "PROVED SANE BY X RAYS."[16] Stories of lodged, misplaced, or otherwise-wayward objects located with X-rays became (and remain) numerous. In the recent words of one group of physicians, the discovery of X-rays led to the derivative discovery that "men are always losing things!"[17]

Medical applications for X-rays quickly multiplied. In particular, X-rays facilitated more accurate diagnoses involving the skeleton. This was noted in the very first edition of *AXJ* by Dr. George Frederick Shrady of New York, who wrote that "The best results so far from the x-ray have been obtained in cases of dislocated bones, of fractures, and in the discovery of imbedded bullets."[18] "The skeleton was laid bare in the warm and breathing body…" he wrote.[19] X-rays revealed to European militaries that the foot injury experienced by soldiers known as *pied forcé* involved a toe fracture.[20] Edmund Kells, D.D.S., of New Orleans, called for their incorporation into dentistry in 1896 and produced the first dental radiograph in the United States.[21] And Dr. Francis Williams of Massachusetts pioneered their use in the diagnosis of conditions of the lungs, such as tuberculosis, no later than 1897.[22]

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[16] "PROVED SANE BY X RAYS," *Boston Daily Globe (1872-1922)*, August 17, 1896, ProQuest Historical Newspapers: The Boston Globe pg. 6.
[17] Rich E. Dreben, M.D.; Murdoc Knight, M.D.; and Marty A. Sindhian, M.D.; *Stuck Up!: 100 Objects Inserted and Ingested in Places They Shouldn't Be* (New York: St. Martin's Press, 2011), 1.
[18] George Shrady, "The X-ray in Surgery," *American X-Ray Journal*, Vol. 1, No. 1, May 1897, 19.
[19] Ibid., 19
[20] Bettyann Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (New York: Perseus Publishing, 1998), 40.
[21] Ibid., 43; C.M. Kracher, "C. Edmund Kells (1856-1928)," *Journal of the History of Dentistry*, 2000 Jul, 48(2), 65-9.
[22] Juan A. del Regato, *Radiological Oncologists: The Unfolding of a Medical Specialty* (Reston, Virginia: Radiology Centennial, Inc., 1993), 17-18; Kevles, 78-79.

Early radiologists describe these "early days," as they referred to them, as intoxicating. George Shrady wrote in May 1897 that "It is not necessary to speak of the world-wide astonishment with which this new discovery was received, nor of its probable benefit to the medicine and surgery of the future."[23] Dr. John Pitkin of Buffalo, New York wrote in September 1898 that "It is safe to say that no scientific discovery was ever received with greater rejoicing by suffering humanity than the enunciation by Professor Roentgen of the possibilities he had discovered that the x-ray possessed…."[24]

Early radiologists were confident regarding the future of their vocation. In September 1898, Alfred Prentice declared, "…the use of the x-rays in surgical diagnosis is destined to become general."[25] In June 1902, then-editor Charles Renner authored an article entitled "X-Ray Prophecy" in which he celebrated the progress of the field of radiology:

> Readers of THE AMERICAN X-RAY JOURNAL will remember four years ago we predicted that no work on surgery would sell that ignored the x-rays. The prediction was treated with silent contempt.
>
> We predicted that successful operators and skin specialists would be compelled to use the rays or go out of business. They laughed at the suggestion.
>
> It is like a stampede now.[26]

[23] George Shrady, "The X-ray in Surgery," *American X-Ray Journal*, Vol. 1, No. 1, May 1897, 19.
[24] John T. Pitkin, "Injurious Effects of the Roentgen Rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 386.
[25] Alfred C. Prentice, "The Cause of the Effects Produced by Exposure to the Roentgen Rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 389.
[26] Renner, Charles. "X-Ray Prophecy." *The American X-Ray Journal*. Vol. 10, No. 3, June 1902. 1069.

CHAPTER 2: X-RAY BURNS

The First X-ray Burns

"…[R]eports soon started and spread throughout the profession and lay public of a grave danger accompanying the use of these x-rays, owing to the fact that they produced so-called virulent burns by exposure to them," noted Dr. Julius Mount Bleyer of New York in August 1898, famous for having been the first to propose lethal injection as a method of execution in 1888.[27] "From their early use, and even now occasionally, there has followed a severe lesion at first apparently of the skin, but later involving the deep tissues as well," noted Alfred Prentice in September 1898.[28] Bleyer and Prentice were describing what would become known as X-ray burns.

X-ray burns were first encountered as early as January 1896, and by the middle of 1896, many radiologists had experienced X-ray burns. The first published case of an X-ray burn appeared in April 1896.[29] By 1897 experiences with X-ray burns were being widely published, and by 1900 at least 170 cases of X-ray burns had been documented.[30] In 1902, Dr. G. E. Pfahler, Assistant Chief Resident Physician and Skiagrapher to the Philadelphia Hospital, reported that "Nearly every one who makes frequent fluoroscopic examinations or demonstrations with x-rays suffers more or less from a dermatitis of the hands."[31]

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[27] J. Mount Bleyer, "The X-rays and Their Safe Application. Destruction of X-ray and Other Infections by Electro-Sterilization," *The American X-Ray Journal*, Vol. 3, No. 2, August 1898, 377; Anthony Galvin, *Old Spark: The Electric Chair and the History of the Death Penalty*,

[28] Alfred C. Prentice, "The Cause of the Effects Produced by Exposure to the Roentgen Rays," *The American X-Ray Journal*. Vol. 3, No. 3, September 1898, 388.

[29] U. V. Portman, "Roentgen Therapy," in Glasser (ed.), 213.

[30] U. V. Portman, "Roentgen Therapy," in Glasser (ed.), 214. Kevles puts the number much lower, writing that "By 1911 more than fifty cases of X-ray damage, including mutilation, sterility, and death, had been noted." (Kevles, 48.)

[31] G. E. Pfahler, "Protection of X-Ray Workers' Hands," *The American X-Ray Journal*, Vol. 10, No. 1, 1034.

The first X-ray burns were encountered in January 1896. The very first victim of an X-ray burn may well have been Emil H. Grubbe of Chicago. "I was, in all probability, one of the earliest experimenters with the new rays," he wrote in 1933. Grubbe was already experimenting with cathode ray tubes when news of Röntgen's discovery was announced. He proceeded to duplicate Röntgen's experiments. In retrospect, Grubbe realized that "having worked with Crookes tubes in the study of fluorescence before December 28, 1895, my body had been exposed to x-rays some time before Rontgen made his announcement." Consequently, "…at the beginning of the last week of January, 1896, I had developed a dermatitis on the back of my left hand…."[32]

By the end of 1896, many early radiologists had reported their first cases of X-ray burns. Several contributors to *AXJ* recounted these experiences in the journal's pages. This included H. Preston Pratt and J. Mount Bleyer. Pratt also recounted the case of an X-ray exhibitionist. X-ray exhibitionists were businessmen who offered the public the opportunity to be X-rayed for a fee. They also X-rayed themselves in order to demonstrate how the machine worked. Eventually, this could result in an X-ray burn. This particular exhibitionist first experienced X-ray burns in 1896. N. Stone Scott reported that his first case of an X-ray burn occurred in January 1897.

Dr. H. Preston Pratt of Chicago encountered X-ray burns for the first time in April 1896. This was while experimenting on guinea pigs. This research was conducted in collaboration with his colleague, a Professor Wightman. Pratt recounted the experience years later in a paper presented to the American Roentgen Ray Society in September 1901. The paper was published in the April 1902 edition of *AXJ*. He recounted that "My attention was first called to the x-ray burn in April, 1896, when Prof. Wightman and myself inoculated Guinea pigs with the bacilli of

[32] E. H. Grubbé, *Radiology 21*: 159, 1933; in Brown, 12-13.

tuberculosis and exposed them to the x-ray, which took the hair off from the pigs in patches, leaving a sore."[33]

J. Mount Bleyer also encountered X-ray burns for the first time in the middle of 1896. Writing in August 1898, he reported that "as far back as May, 1896… I had been as unfortunate as others to inflict several patients with these burns…."[34]

The case of an X-ray exhibitionist who developed X-ray burns around this time also appeared in *AXJ*. The case was described in 1903 by H. Preston Pratt. "The patient," he reported,

> was a healthy man, aged thirty-two years, who in exhibiting an apparatus exposed his right hand to the x-rays for two or three minutes each day for a week without bad results. Again after three weeks he exposed his right hand in the same way for three weeks for a period of four hours daily. He now observed that the skin of the hand became very red and puffed up, but without pain. Inflammation gradually developed and he stopped work.[35]

The patient eventually fell under the care of Dr. T. C. Gilchrist of Johns Hopkins.

N. Stone Scott also recorded his first encounter with X-ray burns in *AXJ*. It did not occur until the following year. The case involved a mixed-race woman whom Scott described as a "quadroon." The woman's hand had been crushed in "the hot mangle of a laundry." As Scott described it, on "December 18, 1896, the hand was viewed several times in the fluoroscope, and two skiagraphs were taken." Soon after, the woman presented with an X-ray burn. As Scott recalled, on "January 14, 1897, almost a month after the examination, she presented herself with

[33] H. P. Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1021.
[34] J. Mount Bleyer, "The X-rays and Their Safe Application. Destruction of X-ray and Other Infections by Electro-Sterilization." *The American X-Ray Journal*, Vol. 3, No. 2, August 1898, 380.
[35] H. P. Pratt, "An X-Ray Burn," *The American X-Ray Journal*, Vol. 13, No. 3, September 1903, 266.

an inflammation…."[36]

The first published accounts of injuries caused by exposure to X-rays appeared in March 1896. In that month, Thomas Edison invented the fluoroscope. After Röntgen's discovery, experimenters used photographic glass plates to produce images using X-rays. This recorded a fixed image, similar to a photograph. Edison's fluoroscope, on the other hand, used a fluorescent screen that did not permanently record an image, but allowed the subject to be viewed continuously. For instance, a fluoroscope could be used to view a person's skeleton in motion.[37] The announcement of the fluoroscope was accompanied by the additional news that Edison and his assistant, Clarence Dally, had developed pain in their eyes as a consequence of their extensive exposure.[38]

Published reports of X-ray burns were appearing by the summer of 1896. In his 1901 paper, Pratt recalled that "The first published account that I saw of the x-ray burn came from Berlin by cable, to the *New York Journal*, July 23, 1896…." The report recounted the experiences of a Dr. Markuse:

> Dr. Markuse, whose interior has been photographed thirty times within the last twenty days by the Roentgen process, has lost all of his hair as a result, and his face has assumed a brownish color. The skin has peeled off his breast where the instrument had touched it, and on his back, what was first a sore, finally

[36] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 59-60.
[37] Otto Glasser notes that in fact Röntgen had originally used fluorescent screens, as opposed to photographic plates, when experimenting with X-rays. The practice "reappeared many months later under the name of the Edison fluoroscope, Salvioni cryptoscope, and so forth….Essentially, however, these improvements were only slight modifications of Röntgen's original experiments." Glasser, 5-6.
[38] W. J. Morton, "Effect of x-rays upon the eye," *Nature* 53 (5 March 1896), 421; in Lauriston Taylor, "Roentgen-Ray Protection," in Glasser (ed.).

developed into a bleeding wound, surrounded by burnt looking cuticle. The victim is exhausted.[39]

By 1897, X-ray burns were receiving significant media coverage. In January 1897, the *Boston Daily Globe* ran an article entitled "TO STOP X-RAY BLISTERS." In describing the ideas of one radiologist as to effective preventative measures, the article referred to the "reports of the mysterious and deleterious effects of the X-ray, which have from time to time come from the laborations of experimenters…."[40]

In May, the *Kansas City Star* ran an article entitled "WOUNDED BY X-RAYS." The article had originally appeared in the *New York Herald*. It described the case of an Alfred Kahnweiler. Kanhweiler had a disease of the spinal cord. X-rays taken in January confirmed the diagnosis his doctors had already made. He received two exposures, one of 55 minutes, another of 25 minutes. During the second exposure, he experienced tingling. A few days later, "severe itching" began and the skin grew "red and inflamed." The skin eventually peeled off and "about three weeks ago the healing ceased[,] leaving a spot one by two inches in size that would not heal any further[.] The pains were constant and severe." Though Mr. Kahnweiler began to experience relief after the damaged tissue was excised, the *New York Herald* reported that the incident "is another case which shows that there is danger in the use of the X-rays…"[41]

The *New York Times* reported several cases of X-ray burns in July. On the 14th, it reported the case of George McCullough of Muncie, Indiana. George McCullough was Chairman

[39] H. P. Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1021; Glasser mentions reports of X-ray burns from as early as April, but he does not mention when, or if, these were published. (Glasser, 11) Whether they were or not, it is worth noting that Pratt recalled no published reports before July 1896.
[40] "TO STOP X-RAY BLISTERS," *Boston Daily Globe (1872-1922)*, January 31, 1897, ProQuest Historical Newspapers: The Boston Globe pg. 16.
[41] "WOUNDED BY X RAYS," *Kansas City Star*, May 9, 1897, ProQuest Historical Newspapers pg. 2.

of the State Republican Central Committee. In May 1897 his knee had been X-rayed. "…[T]he X rays….burned the flesh so that the skin sloughed off of an area nearly as large as one's hand."[42]

On the 30th the *NYT* ran an article entitled "BURNED BY THE X RAYS. Pitiable Condition of Miss Josie MacDonald After Being Photographed by Them." The article reported the case of Ms. Josie MacDonald. MacDonald had received an X-ray in June. The X-ray had been performed by her dentists in order to diagnosis the condition of her jaw, which was causing her "intense pains." She was X-rayed twice, the second exposure lasting twenty minutes. The article continued:

> A few days afterward Miss MacDonald's face began to swell and grew black.
>
> The hair on one side of the patient's head began to fall out, and in a short time that part of her scalp was bare. Her face was blistered, and sores formed all the way down her neck, shoulders, and arm. A scab formed over the blister, and when it fell off it disclosed the raw flesh. Her left ear swelled up, and she lost her hearing on that side. Constant applications of oil have been necessary day and night to allay the pain arising from exposure of the flesh to the air.[43]

The following day, the *NYT* ran an article entitled "ROENTGEN RAY DANGERS." It reported that

> Cases of severe 'burns' are many and notorious. Its destructive action has been discussed by high electrical authorities and the press has published their views.

[42] "MR. McCULLOUGH IMPROVING," *New York Times (1857-1922)*, July 14, 1897, ProQuest Historical Newspapers pg. 2.
[43] "BURNED BY THE X RAYS. Pitiable Condition of Miss Josie MacDonald After Being Photographed by Them," *New York Times (1857-1922)*, July 30, 1897, ProQuest Historical Newspapers pg. 1.

> Everybody ought to know by this time that the Roentgen ray apparatus…is liable to produce serious injury….The lamentable case of MISS MACDONALD is perhaps the most serious yet reported, but there have been many other victims of the ray.[44]

X-ray burns would remain a subject of newspaper coverage for years to come. For instance, in April 1899, Grand Forks, North Dakota's *Grand Forks Daily Herald* reported that Parisian Mme. Mochert was suing her doctor because she had received a burn after he had X-rayed her.[45] In November 1901, the *Boston Daily Globe* ran three articles on the case of Dr. John Weldon of Willimantic, Connecticut. After developing X-ray burns in 1899, he sued the manufacturers of his device, and in November 1901 he was awarded $6750 in damages. It was the first lawsuit for X-ray burns initiated in Massachusetts.[46] In another instance, the *New York Times* ran an article in May 1907 describing the case of a Spiro Condouris. Condouris alleged that he developed an X-ray burn after receiving an X-ray in 1904. He initiated a lawsuit, claiming $25,000 in damages.[47]

The attention that X-ray burns received by the public annoyed many early radiologists. "The fright that has gone out and been accepted by some as true, of 'x-ray burns' should be stilled," asserted Robarts in June 1898.[48] "…[T]here is needless cause for alarm among the

[44] "ROENTGEN RAY DANGERS," *New York Times (1857-1922)*, July 31, 1897, ProQuest Historical Newspapers pg. 6.
[45] "BURNED BY ROENTGEN RAYS," *Grand Forks Daily Herald*, April 6, 1899, ProQuest Historical Newspapers pg.7
[46] "X-RAY MACHINE IN COURT. Willimantic Doctor Says He Was Burned by Device," *Boston Daily Globe (1872-1922)*, November 8, 1901, ProQuest Historical Newspapers: The Boston Globe pg. 6; "X-RAY EXPERTS TESTIFY. Evidence Concluded In the Suit of Dr Weldon for $20,000 for Being Burned While Using Machine," *Boston Daily Globe (1872-1922)*, November 9, 1901, ProQuest Historical Newspapers: The Boston Globe pg. 8; "VERDICT FOR DR WELDON. Willimantic Physician to Receive $6750 From Otis Clapp & Sons for Being Burned by X-Ray Machine," *Boston Daily Globe (1872-1922)*, November 14, 1901, ProQuest Historical Newspapers: The Boston Globe pg. 4.
[47] "SAYS X-RAY BURNED HIM. Greek Sues Physician for $25,000 Damages," *New York Times (1857-1922)*, May 14, 1907, ProQuest Historical Newspapers pg. 8.
[48] Heber Robarts, editor's note, *The American X-Ray Journal*, Vol. 2, No. 6, June 1898, 286.

laity," claimed E. A. Florentine.[49] "Had not the vulgar and incorrect word 'burn' been used," he wrote, "probably no such bugbear would have followed. The lay assisted by unscientific press writings added much to stimulate the popular prejudice, but when the matter finally reached the courts the climax seemed to have been reached."[50]

Many early radiologists believed that fear of X-ray burns hampered the progress of their field. In February 1898, S. H. Monell of Brooklyn wrote, "I believe that continued agitation of this subject hurts a good cause, and does not advance the science."[51] Probably referring to the case of Frank Balling, the first case in the United States in which a radiologist was successfully sued for inflicting an X-ray burn, Florentine wrote in February 1901, "A verdict against an unforeseen error, resulting from practically an unknown cause would naturally tend to retard the progress of any great discovery."[52] H. Preston Pratt recollected that "This state of affairs began to check progress for a while, preventing further investigation."[53]

In response, many early radiologists downplayed the frequency and seriousness of X-ray burns. Editors Heber Robarts and H. Preston Pratt were among the most strident in minimizing the risk of X-ray burns. In August 1897, Robarts informed readers that "I have continuously made use of the x-rays since July, 1896, and have in no instance observed the slightest inconvenience."[54] In the same article, Robarts noted that he was not alone. In a paper delivered before the Pan-American Medical Congress held in Mexico City on November 9, 1896, Carl Beck informed listeners that "Although having made more than 300 skiagrams since February, 1896, and knowing of many others, I have never observed any ill effect that could be traced to the rays. I once exposed myself to the rays for more than five successive hours, and did not note

[49] E. A. Florentine, "A Review of Cases of X-ray 'Burns,'" *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 852.
[50] Ibid., 849.
[51] S. H. Monell, "Burns and Technique in X-ray Work," *The American X-Ray Journal*, Vol. 2, No.2, February 1898, 164.
[52] Florentine, 849.
[53] H. P. Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1021.
[54] Heber Robarts, editor's note, *The American X-Ray Journal*, Vol.1, No. 3, August 1897, 56.

the slightest reaction." Similarly, Robarts noted that W. J. Morton of New York reported that "Never in my experience, and I have continuously taken x-ray pictures of every sort since the first announcement, more than a year ago, have I seen the slightest injury to a tissue result."[55] Writing in July 1898, Robarts said of X-ray burns "It is never serious…."[56]

While Robarts emphasized that X-ray burns were rare, Pratt claimed that they were rarely dangerous. In April 1901 Pratt wrote "The area of the x-ray burn is limited, and it is not dangerous except with excessive use."[57] In December 1902 he wrote, "Never be afraid of an x-ray burn."[58] And in describing an early X-ray burn in September 1903, he minimized the applicability of the lessons to be drawn from it by attributing the burn to "an imprudent use of the x-ray."[59]

Early radiologists such as Robarts, Beck, Pratt, and Morton, regarded X-ray burns as the rare and not-very-serious consequences of improper use of X-rays by untrained operators. "With skilled technique," wrote a likeminded colleague in February 1898, "the question of x-ray burns becomes as obsolete as the customs of the Aztecs."[60]

However, X-ray burns continued to appear into the early twentieth century. Indeed, many radiologists' first encounter with X-ray burns did not occur until 1900 or later. This includes J. N. Scott, Mihran Kassabian, and L. A. Pierce.

Mihran Kassabian first encountered X-ray burns in the spring of 1900. The case involved a young blind woman. The woman had undergone a procedure known as "Mule's operation, in which the contents of the eyeballs are removed, and replaced by glass (gold) balls and sometimes

[55] Ibid., 58.
[56] Heber Robarts, "Localization of Foreign Bodies in the Eye," *The American X-Ray Journal*, Vol. 3, No. 1, July 1898, 345.
[57] H. P. Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1030.
[58] H. P. Pratt, editor's synopsis of H. Preston Pratt, "The Technique of X-ray Therapy," a paper delivered the third annual meeting of the American Roentgen Ray Society, *The American X-Ray Journal*. Vol. 11, No. 6, December 1902, 1263.
[59] H. P. Pratt, "An X-Ray Burn," *The American X-Ray Journal*, Vol. 13, No. 3, September 1903, 266.
[60] S. H. Monell, "Burns and Technique in X-ray Work," *The American X-Ray Journal*, Vol. 2, No.2, February 1898, 170.

artificial eyes." Kassabian had not performed the operation, but was "making some experiments with the x-rays in cases of ophthalmological operations…." Kassabian hoped to be able to "see the position of glass balls in orbital cavities." The woman was exposed three times for a cumulative thirty minutes. Kassabian recounted the consequences:

> Two weeks after, according to her story, she noticed that the hair on her right temporal region, which had been nearest to the tube, was falling off.
>
> I saw her in the Hospital the third week after the x-ray photograph was taken, and her hair was brittle and could be pulled out easily.
>
> This was the *first* case that came under my personal observation.[61]

J. N. Scott first encountered an X-ray burn in the summer of 1900, at which time he wrote, "In three years work I have had no so-called 'burns' until recently." Two months earlier, he "made a ten minute exposure of a patient's neck…." Scott was probably investigating alleged injuries to the patient's neck suffered in a train wreck, though he does not confirm this. He wrote of this patient,

> she was very nervous and inclined to be hysterical—age 23. About one year ago she had been in a railroad wreck and nervous symptoms dated from then.

[61] Mihran Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 784.

About three hours after the exposure, the side of the face next the tube (sic) became red and swollen, and she complained of considerable pain. The swelling and pain subsided in five days, and one week after the first exposure I made a second, and she fainted at the end of five minutes. She was accustomed to faint after any excitement.

Six hours after this exposure her face began to swell again, this time the swelling lasted two weeks, and the skin came off….[62]

Likewise, L. A. Pierce first encountered an X-ray burn in February 1901. In an article in *AXJ* of that month, he reported that

On January 20th., 1900, one, A. L. Bancroft, of Los Angeles, came to me with a history of injured right shoulder of eighteen months standing, and wanted a radiograph of the same, stating several physicians said his shoulder was dislocated, and others, said it was not; he stating that when doctors disagreed, who could settle the point except the x-ray.

He stated that in about two weeks a bright red spot, some three or four inches in diameter, appeared upon his right breast, above and to the right of the nipple, which later produced a sore and was hard to heal. He, also, claimed sharp pains

[62] J. N. Scott, "X-Ray Burns," *The American X-Ray Journal*, Vol. 7, No. 2, August 1900, 757.

ran down his right leg to knee; then below this point to heel, and finally to bottom of foot. Also, his beard on the right side of his face, fell out, but finally returned.[63]

In the first years of the twentieth century, radiologists were beginning to recognize that exposure to X-rays was potentially deadly. In April 1902, Pratt noted that "More than one man has sacrificed his life in the development of the x-ray. To my knowledge there has been five or six deaths."[64] Unfortunately, Pratt did not say to whom he was referring, never mind the circumstances of their deaths. However, he was probably referring to cases of X-ray patients such as James Punzo of New York. In July 1897 Punzo had been shot in the head. In order to enhance the case against Punzo's assailant, the prosecutor ordered an X-ray in order to demonstrate the location of the bullet. Exposed for thirty-five minutes at a distance of an inch and a half, Punzo died shortly afterward despite having previously appeared to have recovered from his injury. The coroner attributed his death, at least in part, to his exposure to X-rays.[65] Having advised "Never be afraid of an X-ray burn" just months earlier, Pratt seems to have been satisfied to attribute these deaths to the irresponsible techniques of "tyros."[66]

An additional possible instance of the deadly potential of X-rays was reported in *AXJ* in March 1904. The case was reported in a letter from Texas physician A. S. Garrett. The letter had originally been published in *The Medical World*. "About five weeks ago," he reported,

a prominent business man of our town, who was in fine health with the exception of a chronic eczema which gave him no trouble except occasional itching, was

[63] L. A. Pierce, "Case of Tissue Injury by X-Ray and Result of Prosecution in Court," *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 856.
[64] H. P. Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1021.
[65] Kevles, 45-6.
[66] H. P. Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1021.

> induced to take x-ray treatment for his eczema. He took the treatment given him by a physician who lives in a neighboring town. The doctor gave him several exposures, and burned him over a space of about 10x12 inches on his back on both sides of the spinal column, including the spinal column, and extending up to the neck. The true skin all sluft off, leaving a red, raw, discharging surface. He was also burned on the left portion of abdomen (sic), about 4x6 inches; also over the left lumbar region, about 4x8 inches, but not quite so deep. The burns discharged very profusely, and were the most sensitive sores I ever observed. They were very red, and often the most simple dressing would cause severe pain, and would have to be removed in a few minutes. At times the itching was so severe that nothing but full doses of morphin (sic) would control him. After about three weeks' suffering, delirium set in, which continued for about five days till death relieved him of his suffering.[67]

X-ray Burns Inspire the Therapeutic Application of X-rays

Early radiologists were excited not only about the potential of X-rays to diagnosis disease, but to treat it. The capacity of X-rays to damage tissue inspired the first experiments into the therapeutic uses of X-rays. As noted, Emil Grubbe was perhaps the first person to ever experience an X-ray burn. In response to his injuries, he sought treatment from a Dr. J. E. Gillman. "…[B]ecause this inflammatory reaction suggested to him the possibility of therapeutic effects," Gillman subsequently sent Grubbe a patient of his in order to test for any such effects.[68]

[67] A. S. Garrett, "Death from X-Ray Burns," *American X-Ray Journal*, Vol. 14, No. 3, March 1904, 94-5.
[68] U. V. Portman, "Roentgen Therapy," in Glasser (ed.), 212.

H. Preston Pratt was also among the first to test the therapeutic potential of X-rays. In September 1901 he presented a paper entitled "The Value of the X-Ray as a Therapeutic Agent" to a meeting of the Roentgen Society of America in Buffalo. The "x-ray burn," he wrote, had served as "indisputable proof of the power of the x-ray to something," and it thereby "called the attention of the profession to its therapeutic value."[69]

Several factors converged to reduce the frequency of X-ray burns resulting from diagnostic uses of X-rays. As will be seen, radiologists who disagreed on many other aspects of X-ray burns often agreed that patients ought to be kept 7" or more from the tube and that exposures should be as short as possible. These practices were facilitated by advances in technology that rendered long exposures less necessary when applying X-rays diagnostically. Writing in 1933, Lauriston Taylor noted this diminished necessary exposure time. For the first radiologists, "to radiograph the spine required exposures up to one and one-half hours, and skin burns were a frequent result." Indeed, "that the radiologist was not more frequently affected by the scattered radiation from such exposures was attributable to the fact that during them he might retire to another room to see other patients and even go out for lunch."[70] Exposures of such length were quickly rendered unnecessary in diagnostic applications of X-rays by advances in technology and consensuses regarding technique.

It was the advent of therapeutic applications of X-rays that kept the issue of X-ray burns relevant for so long. Therapeutic exposures were necessarily of greater duration than diagnostic exposures. Indeed, many radiologists regarded X-ray burns as either inevitable or even desirable when utilizing X-rays for therapeutic purposes. For instance, as late as 1902 Dr. W. J. Morton was recommending the X-ray "tanning" of patients being exposed to X-rays for therapeutic

[69] H. Preston Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1021.
[70] Lauriston Taylor, "Roentgen-ray Protection," in Glasser (ed.), 333.

purposes.[71] When a contributor to the *London Electrical Review* wrote "With a widening field of usefulness the medical employment of x-rays becomes a 'burning question,' and this in its most literal sense," the author was referring to the expanding therapeutic applications of X-rays.[72] The advent of therapeutic applications of X-rays prevented "the question of x-ray burns" from becoming "as obsolete as the customs of the Aztecs."

Restricting Who Could Use X-rays

Radiology underwent a process of professionalization in its first decade and beyond. This process entailed establishing professional journals and organizations. It also consisted of establishing criteria for membership in such organizations. Members of the American Roentgen Ray Society had initially been of a variety of professional backgrounds. Photographers, exhibitionists, and electricians were welcome. However, by 1905, the organization had set as its goal the development of a medical specialty on par with surgery. One third of its membership was expelled.[73]

Experimentation with X-rays was not initially circumscribed to physicists and physicians. Photographers, for instance, were among the first to employ X-rays. Poumakian writes that "X-ray apparatus was relatively affordable to buy and fairly simple to construct. X-rays could be easily produced at home, at photography shops and at fairs and exhibitions, and volunteers lined up to have their purses or hands X-rayed by the 'wonderful,' 'magic,' and 'organic'

[71] Author not identified, "Tanning as a Preventive of the X-Ray Burn," *The American X-Ray Journal*, Vol. 11, No. 3, September 1902, 1152. This is an excerpt from an article from *Modern Medical Science*, which itself was a summary of an article by William Morton that appeared in the *Medical Record*.
[72] Author not identified. "The Medico-Legal Aspect of X-Rays," *The American X-Ray Journal*, Vol. 14, No. 6 (June 1904), 186. Reprinted from the *London Electrical Review*.
[73] Kevles, 85. She cites Raymond A. Gagliardi, "Radiology: A Century of Achievement," *American Journal of Roentgenology* 165 (June 27, 1995), 2.

phenomenon."[74] Electricians also provided services involving X-rays. In July 1903, Pratt complained that "…there has been a number of electricians who were unacquainted with medical science, but who found their income could be considerably increased by giving x-ray treatments."[75]

Physicians quickly began to claim a monopoly on the medical applications of X-rays. State laws that identified medical treatments that could only be performed by physicians were gradually interpreted as applicable to the use of X-rays.[76] And, as mentioned, radiological organizations gradually restricted their membership to those with specialized training.

One of the motivations for restricting who could use X-rays and for what purposes they could use them, was the difficulty of interpreting radiographs. This difficulty is illustrated by a story recounted in Bettyanne Kevles's *Naked to the Bone* (1997). In 1896, H. S. Ward published *Practical Radiography*. The frontispiece included a dramatic radiograph of the human heart. Unfortunately, the image was upside down. It remained upside down, notes Kevles, "through twenty years of reprints."[77]

However, a major motivating factor in restricting who could practice radiology was the risk of X-ray burns. For instance, in calling for greater regulation of the use of X-rays in July 1903, Pratt called attention not to the difficulties of interpreting radiographs, but to the potential for injury. He complained that electricians were circumventing medical law by designating their procedures "examinations" rather than "treatments," and pointed out that "The effect of the x-rays upon the body is of course uninfluenced" by designating the procedure an "examination."[78]

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[74] Sylvia Poumakian, "'Looking Radiant': Science, Photography and the X-ray Craze of 1896," *Victorian Review*, Vol. 27, No. 2 (2001), 56.
[75] H. P. Pratt, "Dangers of X-Rays," *The American X-Ray Journal*, Vol. 13, No. 1, July 1903, 202.
[76] Ibid., 202. Pratt complains that such laws were being circumvented by those who provided radiographs but did not offer diagnoses, thereby claiming not to be offering medical treatment.
[77] Kevles, 92.
[78] H. P. Pratt, "Dangers of X-Rays," *The American X-Ray Journal*, Vol. 13, No. 1, July 1903, 202.

Later that same year, in response to further revelations regarding the injuries experienced by Thomas Edison and his assistant Clarence Dally as a consequence of their work with X-rays, a contributor to *Advanced Therapeutics* wrote, "It will act as a timely warning…against the employment of the x-ray by charlatans and those of limited experience in its use….With these two classes of operators there is a danger which the public should appreciate."[79] The danger that Edison's and Dally's experiences warned of was physical injuries, including burns.

CHAPTER 3: X-RAY BURNS?

What Were X-ray Burns Like?

In 1904, Dr. John Pitkin of Buffalo, New York, authored a series of articles on X-ray burns. By this time, radiologists had been dealing with X-ray burns for about eight years. Pitkin

[79] Author not identified. "Dangers of the X-Ray." *The American X-Ray Journal*. Vol. 13, No. 4, October 1903. 301. Reprinted from *Advanced Therapeutics*..

himself had experienced them. Among other things, his articles described the nature and progression of an X-ray burn.

Pitkin noted that radiologists and their patients typically did not experience any sign that they were being injured while they were being exposed to X-rays. The symptoms of injury were delayed. "As you are all well aware, the operator receives no warning from the tube, experiences no sensations while being injured," he wrote.[80]

Pitkin described X-ray burns as progressing in four stages. The first stage was the preparatory stage. This was the "…stage of first impressions." This stage consisted of slight swelling, hair loss, and itching. There might also be slight discoloration. "His face is like the tan," wrote Pitkin. Though not painful, "Such symptoms should be looked upon as harbingers of an impending storm."[81]

Pitkin described the second stage as the "Premonitory, or threatening stage." In this stage, the swelling became more serious. This involved "…edematous swelling of the subcutaneous cellular tissue, causing the hands and face to become puffy, as they do in Bright's disease, rendering the fingers and palm of the hand stiff and awkward, effacing anatomical markings, and giving a general rotundity of contour."[82] The skin may turn yellow, brown, or black.[83]

Pitkin reported that recovery was possible from the second, or "premonitory," stage, writing, "From this stage the operator may recover…."[84] Indeed, he believed that when treating cancer, the operator should bring about an X-ray burn of the "premonitory" stage. "It is by keeping diseased parts of the patients who have malignant ailments in this stage of irritability,

[80] John T. Pitkin, "Dangers to the X-Ray Operator," *The American X-Ray Journal*, Vol. 14, No. 2, February 1904, 44.
[81] Ibid., 44.
[82] Ibid., 44.
[83] Ibid, 45.
[84] Ibid., 45.

edema, tanning, or redness, and partial anesthesia, that the greatest number of cures can be effected," he noted.

Exposure beyond the level necessary to bring about the second stage brought an X-ray burn up to the third stage. This was the "Stage of Inflammation and Disintegration." At this stage, the itching grew intense. "The pathognomonic symptoms of x-ray inflammation, as experienced by myself after seven years' exposure in the x-ray field, were extreme itching, with constant desire to rub, scratch or dig into the affected parts. If the itching of the alleged seven years' itch could be crowded into a few months' time it would not be more aggravating." The hair of the affected surface fell out, and rashes, pustules, and ulcers appeared. The ulcers oozed, and the oozed substance sometimes had a "putrid smell." In Pitkin's words:

> Eruptions, scarlatiniform rash, military papules, pustules and vesicles came in successive crops. They resulted from the more or less destructive inflammatory involvement of the follicles and their cellular elements. Like thorns in the flesh, or other foreign bodies, they were thrown off, leaving the skin honeycombed with small ulcers oozing a hydro-serous discharge, alkaline in reaction. This discharge may be odorless or have a putrid smell, according to the severity of the process.[85]

Pitkin's own X-ray burns reached this stage. In describing his condition, he notes that his fingernails became brittle and deformed, and their appearance changed. Combined with other changes, his hand was left deformed:

[85] Ibid., 45.

> The nail of the ring finger came off, but was renewed. The nails of all the digits, except the thumb, became deformed, brittle and deficient in their usual luster. The shape of the hand was permanently changed, the rugae of the skin, the ridges of the nails, the knuckles and palmar arch are more prominent than they were formerly.[86]

X-ray burns were sometimes accompanied by lethargy and other symptoms. Reporting on his own experiences, Pitkin wrote, "I suffered with malaise, daily chill and fever (mild), headache, sore throat (mild), nausea and vomiting (one attack, quite severe), vertigo (mild), and one attack of dyspnea (severe but short), probably from cardiac impairment of function. There was a fine rash like that of typhoid fever scattered over the entire body.[87]

X-ray burns healed notoriously slowly, if at all, but they did sometimes heal. What followed was what Pitkin called the fourth stage, the stage of chronic skin diseases. Again, he reported his own experiences, writing that, "Five months after the onset of the attack the parts had healed…."[88] However, the affected surfaces were permanently changed. Because "…the sweat and oil glands that have moistened and lubricated your skin from the days of your inception are gone forever," victims suffered from "Chronic scale skin diseases and other conditions…."[89] Regarding facial injuries, "Small cicatrices form at the labial commissures, drawing the angles of the mouth downward, giving the operator a sad expression of countenance."[90] In addition, affected parts could be hypersensitive, or they could become insensitive. Hair might be lost, or it might grow back thickly and erratically. There might be

[86] Ibid., 47.
[87] Ibid., 47.
[88] Ibid., 47.
[89] John T. Pitkin, "Dangers to the X-Ray Operator, Chapter 3," *The American X-Ray Journal*, Vol. 14, No. 3, March 1904, 73.
[90] Ibid., 73.

bleeding. Sufferers might even experience a "Temporary decrease in sexual power," or "Small abscesses at the roots of the teeth."[91]

What to Call them

"The nomenclature of this effect or of the results following the abuse of the x-rays varies," noted Dr. Mihran Kassabian of Philadelphia in October 1900. The terms in use, he wrote, are "very numerous."[92] "Among the various…names given this so-called 'burn,'" wrote another contributor to *AXJ*, were "'X-Ray' Dermatitis, White Gangrene, 'X-Ray' Blisters, Electric Burns, and many others."[93]

As these quotations demonstrate, radiologists disagreed on what to even call the injuries they and their patients had begun to experience in 1896. These disagreements reflected in part the diversity of views regarding the cause of these injuries.

The unsettled nature of the terminology with which to refer to X-ray burns is reflected in the titles of *AXJ* articles from before 1900 that address X-ray burns. The first *AXJ* article on X-ray burns was entitled "X-ray Injuries."[94] Subsequent article titles refer to "Injurious Effects," "Roentgen Ray Burns," "Roentgen Ray Dermatitis," "The Ill Effects of Roentgen Rays," and "Injury from the Vacuum Tube."[95]

The first use of the term "X-ray burn" in *AXJ* did not occur until March 1898.[96] The article was written by *AXJ* editor Heber Robarts, and he made clear that he disapproved of the

[91] Ibid., 74.
[92] Mihran Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 785.
[93] E. A. Florentine, "A Review of Cases of X-ray 'Burns,'" *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 849.
[94] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 57-66.
[95] See bibliography.
[96] Heber Robarts, "Source of X-rays," *The American X-Ray Journal*, Vol. 2, No. 3, March 1898, 226-227. This is a summary by Robarts of an article by Trowbridge and Burbank from *The American Journal of Science*.

term, referring to "the so-called x-ray burn." Robarts used the term in a similarly qualified manner in the July edition, as did Dr. J. N. Scott of Kansas City, Missouri.[97] It is used without qualification for the first time in August 1898 by Julius Mount Bleyer.[98]

Several early radiologists objected to the term "X-ray burn." In addition to Robarts, Mihran Kassabian, Jos Hoffman, and E. A. Florentine voiced their disapproval. In June 1898, Robarts objected that "The use of the word x-ray to the word burn is a misapplication of the term and conveys a false impression. No one has ever demonstrated that the x-rays burn."[99] Similarly, Mihran Kassabian wrote in October 1900 that "'*Burn*' is not a proper word to use….The definition of 'Burn' according to dictionaries are (sic) not applicable to the x-ray injuries."[100] In December 1900, Jos Hoffman wrote, "…these conditions…are not a 'burn'…."[101] And in February 1901 E. A. Florentine described the term "burn" as "vulgar" and "incorrect."[102]

These objections were at least in part based on differing understandings of X-ray burns. For instance, Robarts did not believe that X-rays were harmful to tissue. Indeed, this "agent…offers greater hope than any medicinal agent gave in its early use" precisely because "It is an agent that can be used with perfect impunity to the tissues," he wrote in October 1897.[103] "Effort has been made to destroy animal tissue with the x-rays with failure in every instance," he claimed in June 1898. Furthermore, "Dr. Carl Beck made an exposure of four hours without any ill effect and this has been repeated in a number of instances…." On the other hand, he argued, electrical fields could induce electrolysis in tissue. "In the neighborhood of the tube," he wrote, "and in the field of the wasting electric discharge injuries will occur and they will occur also if

[97] J. N. Scott, "Practical X-radiance," *The American X-Ray Journal*, Vol. 3, No. 1, July 1898, 322; Heber Robarts, "Localization of Foreign Bodies in the Eye," *The American X-Ray Journal*, Vol. 3, No. 1, July 1898, 345.
[98] Julius Mount Bleyer, "The X-rays and Their Safe Application. Destruction of X-ray and Other Infections by Electro-Sterilization," *The American X-Ray Journal*, Vol. 3, No. 2, August 1898, 379.
[99] Heber Robarts, editor's note, *The American X-Ray Journal*, Vol. 2, No. 6, June 1898, 286.
[100] Mihran Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 785.
[101] Jos Hoffman, "X-ray in Lupus Vulgaris," *The American X-Ray Journal*, Vol. 7, No. 6, December 1900, 810.
[102] E. A. Florentine, "A Review of Cases of X-ray 'Burns,'" *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 849.
[103] Heber Robarts, untitled, *The American X-Ray Journal*, Vol. 1, No. 4, October 1897, 81-83.

exposed for a considerable time anywhere along and near to the conducting wires." Robarts proposed the term "potential injury."[104]

Similarly, Mihran Kassabian's opposition to the term "X-ray burn" reflected his understanding of the cause of X-ray burns. Burns are caused by the absorption of heat or a chemical reaction with oxygen.[105] Kassabian did not believe that the injuries that came to be called X-ray burns were caused by either of these. Patients could experience burns through their clothing without their clothing being burned. If X-ray burns were caused by heat or oxidation, the patient's clothing would burn in addition to, or instead of, the patient. "I wonder why the clothes of the patient are not burned?" he asked rhetorically.[106]

Kassabian believed that the injuries that came to be called X-ray burns were caused by the X-rays themselves. Just as X-rays produced a chemical reaction with photographic chemicals, they produced a chemical reaction in human tissues that inflamed the tissue. Kassbian therefore preferred the term "dermatitis." Dr. Robert Greg also favored the term "dermatitis" for similar reasons. He analogized to sun burns, writing "The sun produces what is known as a sun burn, but technically is an erythema in the true sense. It is not a burn, because it occurs several hours after exposure and produces pigmentation of the skin similar to that of the x-rays, so that it must be due to the chemic or actinic rays." Gregg therefore favored the terms "erythema" or "dermatitis."[107]

Such objections notwithstanding, radiologists gradually accepted the term. Kassabian conceded that "…it is employed by professional men as well as the laity."[108] Its general acceptance is suggested by the fact that from 1900 through 1904 a dozen *AXJ* articles carried the

[104] Heber Robarts, editor's note, *The American X-Ray Journal*, Vol. 2, No. 6, June 1898, 286.
[105] Kassabian invokes the dictionary definitions of burn but does not state them.
[106] Mihran Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 785.
[107] Robert S. Gregg, "X-Ray Burns," *The American X-Ray Journal*, Vol. 14, No. 1, January 1904, 12-13.
[108] Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 785.

term in their titles.[109] One such article, Robert Gregg's "X-Ray Burns," begins, "It is well known that the x-rays produce what is known to the laity as a burn, but technically is a pure and simple dermatitis." Three sentences later, he reverts to calling the injuries burns and continues to do so throughout the article.[110] W. S. Newcomet perhaps best captured the prevailing attitude toward the debate over nomenclature in August 1904. "Although some objection has been raised to its use," he wrote, "it seems to fill the sense in this instance, just as when used for an ulceration caused by some chemical."[111]

CHAPTER 4: ELECTRO-DERMATITIS

The Diversity of Views Regarding the Cause of X-ray Burns

"It has been evident for a year past that the x-rays are sufficiently powerful to produce under some conditions most disastrous results, but very diverse views have been held as to the cause, the frequency, the kind of apparatus most likely to produce them, and the best way to avoid them," wrote Dr. N. Stone Scott of Cleveland, Ohio in an August 1897 article in *AXJ*.[112] As we've seen, early U.S. radiologists frequently downplayed the significance of X-ray burns. Nevertheless, the advent of X-ray burns initiated a lengthy discussion among these same

[109] See bibliography. Note, authors who use the term in the title of their articles did not necessarily use it without qualification. See J. N. Scott's August 1900 article, for instance.
[110] Robert S. Gregg, "X-Ray Burns," *The American X-Ray Journal*, Vol. 14, No. 1, January 1904, 12-13.
[111] W. S. Newcomet, "Pathological Changes in Tissue Under the Influence of the X-Ray," *The American X-Ray Journal*, Vol. 15, No. 2, August 1904, 246.
[112] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 57.

radiologists. As Scott's statement illustrates, opinions on their nature, cause, and effective protective measures varied widely.

Early radiologists proposed more than half a dozen theories that attributed X-ray burns to something other than exposure to X-rays. Some of these theories were defended into the twentieth century. Chapters 4 through 7 discuss these theories. The heterogeneity of early U.S. radiologists' beliefs regarding the cause of X-ray burns is important because it reveals their motivations and explains their actions. Those who experienced X-ray burns often believed that X-ray burns were caused by something other than X-rays, and they took protective measures based on these erroneous beliefs.

The Dangers of Electricity

In the late nineteenth century, centralized power stations were still new. Röntgen made his discovery only thirteen years after Thomas Edison opened the first permanent central power station in the United States in 1882. Such central powers stations as existed did not consistently provide access to sufficient electricity for the production of X-rays. Early radiologists, therefore, had to generate their own electricity.

Because radiologists supplied their own electricity, they were conspicuously cognizant of its presence in their work. This is evident in the titles of their publications. For instance, S. H. Monell's 1897 textbook is entitled *Manual of Static Electricity in X-Ray and Therapeutic Uses*.[113] An 1897 pamphlet of the American Roentgen Ray Society entitled "The Roentgen Rays: Their Production and Use" seems to have been retitled in 1898. The new title was "The

[113] S. H. Monell, *Manual of Static Electricity in X-Ray and Therapeutic Uses*, New York: William Beverley Harison, 1897.

Roentgen Rays: Their Production by Static Generators and Methods of Application."[114] And Mihran Kassabian's 1907 textbook is entitled *Roentgen Rays and Electro-Therapeutics*.[115]

Such textbooks and pamphlets often provided detailed descriptions of how to generate electricity. That 1897 pamphlet from the American Roentgen Ray Society described itself as "addressed to any person who may be interested in the subject of the Roentgen rays and the approved methods of producing and making use of them. It presents the claims of a form of static machine which has had a successful trial of more than a year, and which stands to-day, all things considered, as the most practical high voltage generator yet produced, suited not only for use with Crookes tubes but also for all purposes for which static machines are employed."[116] Subsequent pages described the functioning of static machines. In Kassabian's textbook, his discussion of X-rays begins with a detailed description of the electrical devices required for their production.[117]

Early radiologists' cognizance of electricity's presence in their work was reflected in how they described themselves. S. H. Monell was "Founder and Chief Instructor of the Brooklyn Post-Graduate School of Clinical Electro-Therapeutics and Roentgen Photography."[118] H. Preston Pratt described himself as an "electro-surgeon."[119] Two other early radiologists even proposed renaming X-rays to reflect the centrality of electricity in their production. They proposed naming them "electric rays…."[120]

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[114] *The Roentgen Rays: Their Production and Use* (Boston: American Roentgen Ray Society, 1897). The version of this pamphlet in Google Books includes a title page that identifies the pamphlet as "The Roentgen Rays: Their Production by Static Generators and Methods of Application." This page is stamped "1898."
[115] Mihran Kassabian, *Roentgen Rays and Electro-Therapeutics*. Philadelphia: J. B. Lippincott Company, 1907.
[116] *The Roentgen Rays: Their Production and Use*, pg. 3.
[117] Mihran Kassabian, *Roentgen Rays and Electro-Therapeutics*, Philadelphia: J. B. Lippincott Company, 1907, 169-189.
[118] S. H. Monell, *Manual of Static Electricity in X-Ray and Therapeutic Uses*, New York: William Beverley Harison, 1897.
[119] H. P. Pratt, "X-Ray and Its Adjunct Treatment," *The American X-Ray Journal*, Vol. 12, No. 6, June 1903, 169. This is a paper presented at the May 30, 1903 meeting of the Chicago Electro-Medical Society.
[120] Heber Robarts, "Source of X-rays," *The American X-Ray Journal*, Vol. 2, No. 3, March 1898, 226-227. This is a summary by Robarts of an article by Trowbridge and Burbank from *The American Journal of Science*.

X-rays were discovered at a time when electricity, and those who sought to understand its potential applications, were often portrayed as frightening in popular culture. Mary Shelley's *Frankenstein*, in which scientist Victor Frankenstein utilizes the power of electricity to reanimate the dead, remained popular into the twentieth century, at which time it was adapted for film, most famously in Universal's 1931 production.[121] Similarly, H. P. Lovecraft's "From Beyond," written as late as the 1920s and published in the 1930s, imagined the unveiling of vast hitherto unknown and foreboding dimensions of reality through the harnessing of the power of electricity. "…[H]e now remained mostly shut in the attic laboratory with that accursed electrical machine," records the protagonist of his former friend.[122]

The fantastical aside, the dangers of electricity were real enough at the turn of the twentieth century. "Accidental electrocutions made front-page news, as did terrifying explosions caused by poorly insulated wires laid alongside gas mains. Articles warned about possibly malignant effects of electricity on the human body: blindness, for example, from reading by incandescent light," writes Linda Simon.[123] "…American cities and even smaller towns embraced the new technology with a speed and enthusiasm that Europeans soon found both fascinating and reckless," writes Ernest Freeberg.[124] A series of electrical fires, including one in downtown Boston on Thanksgiving Day 1889, caused widespread concern. So did the case of John Feeks, a telegraph lineman from New York who was electrocuted to death, and whose corpse was left hanging in the wires above the street for half an hour.[125] In 1888 the state of New York had decided to harness electricity's power to kill when they passed an Electrical Execution

[121] *Frankenstein*, Dir. James Whale, Universal Pictures, 1931, film.
[122] H. P. Lovecraft, "From Beyond," The H. P. Lovecraft Archive. http://www.hplovecraft.com/writings/texts/fiction/fb.aspx. Accessed: October 14, 2015, 7:32 a. m.
[123] Linda Simon, *Dark Light: Electricity and Anxiety from the Telegraph to the X-ray* (New York: Harcourt, Inc., 2004), 5.
[124] Ernest Freeberg, *The Age of Edison: Electric Light and the Invention of Modern America* (New York: The Penguin Press, 2013), 47.
[125] Freeberg, 179-182.

Bill. In 1890, the state executed convicted killer William Kemmler under the new law. He became the first victim of the electric chair, creating a media sensation. Many newspapers portrayed the execution as a botched spectacle, and George Westinghouse, referring to Kemmler's own murder implement, told a report that "They could have done better with an axe."[126] The immediate public response to execution via electricity was such that many predicted that the Kemmler execution would be the last electrocution execution.

Today, many of us have practically unlimited access to electricity. We therefore take it for granted. If we marvel at the speculations of futurists such as Ray Kurzweil regarding future technological developments, we do not marvel at these developments as advances in the applications of electricity per se. Nor do we conceive of our ubiquitous electronic devices as tools for converting electrical energy into other types of energy, though our future and present technologies are as fundamentally dependent upon electricity as early radiologists' X-ray apparatus. The Large Hadron Collider would be as inoperable as a late-nineteenth-century Crookes tube if someone unplugged it, so to speak. It seems likely that at least part of the explanation of the diminished explicit cognizance of the role of electricity in technology, at least within the scientific and medical communities, is that, at the time of the discovery of X-rays, a lot less was known about it. "Concerning the fundamental nature of electricity itself, there is still no certainty..." noted the author of an article from an electrical engineering journal that was reprinted in *AXJ*.[127]

Electricity as the Cause of X-ray Burns

[126] *New York Times,* August 7, 1890; quoted in Mark Essig, *Edison & the Electric Chair: A Story of Light and Death* (New York: Walker & Company, 2003), 256-7.
[127] Author not identified, "Thirty Years' Progress in Electro-Magnetic Theory," *The American X-Ray Journal*, Vol. 14, No.3, March 1904, 93. Reprinted from *Electrical World and Engineering*.

"A number of operators have advanced the theory that the burns are caused by static or other electrical discharge," noted N. Stone Scott in his overview of the incidence of X-ray burns in August 1897.[128] Cognizant of its centrality to their work, and operating at a time when electricity retained a degree of mystery and danger, early radiologists quickly directed their suspicion upon electricity as the cause of X-ray burns. Brown suggested that this explanation of X-ray burns was quickly abandoned, writing, "This tenet was abandoned…after some months of heated discussion…."[129] However, as late as September 1899 the view that X-ray burns were caused by electrical fields still appeared in *The American X-Ray Journal*. Indeed, the most popular explanations of X-ray burns until about 1898 attributed them to "electrolysis," or a damaging of tissues as a consequence of exposure to an electrical current. For instance, in September 1898 John Pitkin described it as "the general consensus of opinion" that "all of the bad results are attributable to the electricity unconsumed in [X-rays'] generation…."[130]

Articles attributing X-ray burns to the presence of electrical fields appeared in *AXJ* between August 1897 and September 1899. Among the proponents of the theory that X-ray burns were caused by electrical currents were Heber Robarts, Charles Leonard, S. H. Monell, J. N. Scott, John Pitkin, and Alfred C. Prentice.

The first article in AXJ to advocate the theory that X-ray burns were cause by electrical currents appeared in August 1897. It was written by the journal's founder and editor Heber Robarts. Robarts believed that when a screen capable of blocking the passage of electricity but through which X-rays could travel was interposed between the patient and the X-ray tube, X-ray burns were not produced. Robarts inferred that if the patient must be reached by the electrical

[128] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 58-9.
[129] Percy Brown, *American Martyrs to Science Through the Roentgen Rays* (Springfield, Illinois: Charles C Thomas Pub Ltd., 1936), 14-15.
[130] John T. Pitkin, "Injurious Effects of the Roentgen Rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 387.

field in order to be burned, electrical fields must be the cause of such burns. “Any substance capable of shielding the body from these electric streamers, but pervious to the x-rays, not interfering with their free passage through the body in the least, immures the body from all injury,” he explained.[131]

In December 1897, Robarts reported on an article by Charles Leonard. Leonard’s reasoning was similar to that of Robarts. Robarts explained that Leonard believed that, “The x-ray depends for its production on the physical phenomena of electric induction, and it is certain than any conductor of electricity, as the patient’s tissues, if approached sufficiently near to the x-ray tube, *i.e.*, within the field of electric induction, will have a current of electricity induced in it which may be capable of destroying its vitality.” In other words, everyone recognized that if you placed a conductor near an operating X-ray tube, a current could be produced in the conductor. Since people are conductors, if you placed a person too close to an operating X-ray tube, a current could be produced in the person. Since electrical currents are capable of damaging tissue, such a phenomenon could be responsible for X-ray burns. Furthermore, experiments purportedly showed that X-ray burns only took place in the presence of electrical fields. Reiterating a point made in his own article, Robarts continued, "A substantiation of this theory is seen in the fact recently made known, that a sheet of aluminum if grounded and placed between the tube and patient, will prevent the burn, while interfering in no way with the x-ray phenomena. The induced currents are formed in the aluminum and carried by the wire to earth without injury to the patient.”[132] Inadvertent electrolysis, or damage to tissue via the accidental induction of an electrical current in the bodies of the operator or patient, was the most likely cause of “so-called” X-ray burns.

[131] Heber Robarts, editor’s note, *The American X-Ray Journal*, Vol.1, No. 3, August 1897, 56.
[132] Heber Robarts, *The American X-Ray Journal*, Vol. 1, No. 6, December 1897, 138. This is a summary of an article by Charles A. Leonard originally published in the *Journal of the American Medical Association*.

In November 1898 Charles Leonard expressed this perspective in his own words in *AXJ*. He wrote that, "It is an accepted axiom of surgery that in making a differential diagnosis, all known agents shall be excluded before we can logically base an explanation of a new phenomenon upon the hypothetical action of an unknown agent. We must exclude all facts before dealing with hypothesis." It was well-known, claimed Leonard, that "…electricity is capable of devitalizing and destroying tissue...." Therefore, "It must be first proved that the Roentgen ray dermatitis is not the result of this devitalizing action, before we have the right to attribute it to an unknown action of the Roentgen rays."[133] However, experimentation led Leonard to conclude that this "devitalization" was impossible when a screen was used that permitted the passage of X-rays but conducted electricity to the ground. He wrote, "It is impossible to produce a 'burn' when a protecting shield of aluminum is employed which collects the static electricity and conducts it by a grounding wire to earth, although the Roentgen efficiency of the ray is unaltered."[134] Furthermore, Leonard claimed that X-ray burns were more severe when the patient was placed on an insulating surface, a surface that does not conduct electricity. This left the electric charge with nowhere to go, and so it built up in the patient. He wrote that the danger of "…severe effects and devitalization are…increased, and the effect of the exposure exaggerated, by placing the patient on an insulated platform so that the electrical effect is augmented."[135] This purported fact supported the theory that X-ray burns were caused by exposure to electrical fields, not X-rays.

S. H. Monell agreed. In February 1898, he too pointed out that everyone already recognized that passing an electrical current through human tissue could damage the tissue. "It is to my mind absolutely certain that the x-ray does not inflame a tissue through which is passes,"

[133] Charles Lester Leonard, "Roentgen Ray Dermatitis," *The American X-Ray Journal*, Vol. 3, No. 5, November 1898, 453.
[134] Ibid., 456.
[135] Ibid., 454.

he wrote, "but nothing is more certain than that a sufficiently energetic electric current passing to tissues…will vesicate (sic), and can be made to produce intenser (sic) and deeper inflammatory action…."[136] Monell was primarily concerned with establishing that X-ray burns were rare and not severe, but a careful reading indicates that Monell also attributed X-ray burns to an inadvertent electrolysis. For instance, Monell describes the experience of an X-ray exhibitor who developed an X-ray burn only after very long exposures at very close proximity to the X-ray tube. Monell pointed out that "The current was pushed to its utmost….A powerful spark was used and the hand was often in actual contact with the bulb." Monell concluded that the X-ray burn occurred because "The operator was sufficiently skilled in handling tubes, but was not familiar enough with static apparatus to *regulate the current* and avoid an excess."[137]

J. N. Scott also subscribed to the theory that X-ray burns were the consequence of inadvertently inducing electrolysis in patients' and operators' tissues. The key for Scott was the distance of the patient and operator from the X-ray tube. Scott believed X-ray burns did not occur at distances of more than six inches. According to Scott, "…if you hold any part of the body within one to six inches of a wire carrying such a high voltage of electricity…there will be a current of electricity passing to the part exposed." And "…if a part is exposed for five minutes within two or three inches, or for twenty minutes at four to six inches, it will generally produce an electrolysis…." Conversely, outside of six inches, electrolysis could not take place: "…there is absolutely no danger in using the x-ray if the part exposed is held seven inches or more from the tube and conducing wires."[138] The reason that being further than six inches away from an operating X-ray tube kept one safe from electrolysis was that electrolysis could not take place at this range no matter how powerful the apparatus was. "A current of so great power as of two

[136] S. H. Monell, "Burns and Technique in X-ray Work," *The American X-Ray Journal*, Vol. 2, No.2, February 1898, 170.
[137] Ibid., 166.
[138] J. N. Scott, "X-rays," *The American X-Ray Journal*, Vol. 2, No. 3, March 1898, 223.

million volts can not pass to the part exposed if placed seven or more inches away," he wrote. He added, "I operate a Crooke's tube on an average of one hour every day, and stand within about two feet of the tube and have never noticed any effect." If X-ray burns did not occur at distances at which electrolysis could not take place, X-ray burns were likely the consequence of electrolysis. Scott was therefore persuaded that "The so-called burning is an electrolysis and is not caused by the x-ray at all, but by the current of electricity."[139] In July, Scott reiterated that the "so-called burning" was actually caused by "electrolysis," and wrote that "all the injurious effects such as burning are caused by the current of electricity."[140]

Alfred Prentice performed his own experiment in order to "study" the problem of X-ray burns.[141] He reported on his experiments in an article in *AXJ* in September 1898. His description makes clear that the role of electricity stood out to him. He subjected a guinea pig to X-rays on three occasions. He noted that on the second occasion an electric current was produced in the table upon which the guinea pig sat. "During this time the table on which the pig rested became strongly electrified, and no doubt the pig was electrified as well," he wrote.[142] On the third occasion, "although neither the pig nor table came in contact with the electrical apparatus, both became so strongly electrified that a spark was produced between the edge of the table and my finger held near…."[143]

Prentice's experiment did not rule out exposure to X-rays as the cause of X-ray burns. The guinea pig was exposed to both electricity and X-rays on all three occasions. Though Prentice kept a second guinea pig as a control, this guinea pig was subjected to neither electrical

[139] Ibid., 223.
[140] J. N. Scott, "Practical X-radiance," *The American X-Ray Journal*, Vol. 3, No. 1, July 1898, 322.
[141] Alfred C. Prentice, "The Cause of the Effects Produced by Exposure to the Roentgen Rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 389.
[142] Ibid., 389.
[143] Ibid., 390.

currents nor X-rays.[144] Nonetheless, despite the experiment's ambiguity, Prentice believed the results best supported the theory that X-ray burns were the consequence of exposure to electrical currents. And when he coupled his experiences with the statements of authorities such as Monell, Prentice concluded that the problem had been solved. "All these statements combined with the evidence of direct experiment tend to the conclusion that not the x-rays themselves, but the direct actions of the electric currents upon the fluids and tissues are the real factors in the damage done," he wrote.[145]

The final item in *AXJ* to advocate the theory that X-ray burns were caused by electrical fields appeared in September 1899.[146] This was an account of the experiments of a Brodier and a Salvador into the cause of X-ray burns. An electrical field is produced when generating X-rays. Brodier and Salvador believed that this field caused electrolysis in human tissue and that this was the cause of X-ray burns. In their experiment, Brodier and Salvador demonstrated that when a battery was placed in the vicinity of an operating X-ray apparatus, an electrical current was produced in the battery. This remained the case even when the X-rays were prevented from reaching the battery. As reported in *AXJ*:

> To test this conclusion, they placed an electrolytic cell consisting of copper sulphate (sic) in the neighborhood of the Roentgen tube, with its electrodes near those of the vacuum tube. After a quarter of an hour the electrodes were connected with a galvanometer, and a deflection was obtained indicating a current

[144] Presumably the control guinea pig was intended to aid in discerning potential subtle consequences of exposure, such as increased drowsiness. It turned out that the effects were readily discernable without a control. After developing a burn and losing its hair, the experimental animal died.
[145] Alfred C. Prentice, "The Cause of the Effects Produced by Exposure to the Roentgen Rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 391.
[146] Brodier and Salvador, "Electrolysis Induced by Roentgen Tubes," *The American X-Ray Journal*, Vol. 5, No. 3, September 1899, 627. This article originally ran in *Comptes Rendus* on June 19, 1899 and London's *Elec.* on July 7.

> in the external circuit proceeding from the copper facing the anode of the vacuum tube to the copper facing the cathode, thus confirming their conclusions. As no difference is observed when all the Roentgen rays are hindered from reaching the electrolyte, the effect is not due to them directly."

The account of Brodier and Salvador's experiment did not explain how the production of an electrical current in a battery is proof of the capacity to injure human tissue. It also did not explain how they managed to prevent the X-rays from reaching the battery, yet allowed the electrical field to reach it. Nonetheless, the experiment purportedly explained "the cause of Roentgen ray burns."[147]

[147] Ibid., 627.

CHAPTER 5: PARTICLE BOMBARDMENT

Not X-rays and Not the Electrical Fields Surrounding the Tube

While the theory that attributed X-ray burns to the electrical field surrounding the tube was the most popular explanation of X-ray burns until around 1898, it was only one theory among many that attributed X-ray burns to something other than X-rays. As already mentioned, early radiologists proposed at least half a dozen theories as to the cause of X-ray burns. Chapters 5, 6, and 7 provide detailed descriptions of these additional theories of the cause of X-ray burns.

Minute Particles as the Cause of X-ray Burns

"One observer believes the particles floating in the air are bombarded into the skin by the x-ray," noted N. Stone Scott in his August 1897 article.[148] This idea, that X-ray burns were caused, at least in part, by particles of dust being driven into the skin, was often discussed in *AXJ*. One possibility was that the particles were tiny pieces of the apparatus itself. Perhaps minute particles of the cathode or anode were detached during the production of X-rays. Some types of vacuum tubes contained aluminum windows, which were openings in the glass wall of the vacuum tube covered with aluminum, and perhaps these particles were driven through the

[148] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 58.

window of the tube and into the patient. Another possibility was that the dust that was driven into the patient by the X-rays did not originate from the apparatus, but consisted of dust particles floating in the air between the patient and the tube. Perhaps X-rays collide with these particles of dust and carry them into the patient, where they become deposited in victims' skin. Another possibility was that the dust particles were already on the victims' skin and the X-rays drove them into it.

Among those whose names became associated with these ideas in the pages of *AXJ* were Nikola Tesla, N. A. Clive, Julius Mount Bleyer, and H. Preston Pratt. Bleyer, Clive, and Pratt attributed X-ray burns to these particles. Tesla did not, but he was often cited by those who did, as explained below. Additionally, Robert Gregg, who believed that X-ray burns were caused by the chemical properties of X-rays, also believed that X-rays drove particles of dust into the skin and that this could be harmful.

"Nicola Tesla was one of the first to advance the hypothesis that matter was thrown from the tube outward into space," noted John Pitkin in 1904.[149] When radiologists discussed the theory that X-ray burns were caused by particles of dust being driven into the skin, they frequently cited Tesla. This is because Tesla believed that during the production of X-rays, particles of the cathode broke off. Tesla even believed that these particles could be pushed through the aluminum window of the Hittorf and Lenard types of glass vacuum tubes. These types of tubes had windows sealed with aluminum in order to maintain the vacuum within the tube but which permitted the passage of cathode rays in order to observe their properties outside of a vacuum.[150]

[149] John T. Pitkin, "Dangers to the X-Ray Operator," *The American X-Ray Journal*, Vol. 14, No. 1, January 1904, 10.
[150] Otto Glasser, *Dr. W. C. Röntgen* (Springfield, Illinois: Charles C Thomas, 1972), 34.

Dr. J. T. Dunn of Louisville, Kentucky summarized Tesla's views in a paper read before the Kentucky State Medical Society in 1899. The paper was subsequently published in both *The Louisville Monthly Journal of Medicine and Surgery* and *AJX*. Dunn quoted an article by Tesla published in *Electrical Review* in which he had written,

> According to the evidence I am obtaining, the tube when in action is emitting a stream of small particles; there are some experiments which seem to indicate that these particles start from the outer wall of the bulb; there are others which prove that there is an actual penetration of the walls, and in case of a thin aluminum window I have now not the least doubt that some of the finely disintegrated cathode matter is actually forced through.[151]

Tesla did not believe X-ray burns were caused by particles. In fact, he believed that the X-rays carried such particles all the way through the patient and were detectable on the photographic plate used to create the radiograph. If the particles were reaching the plate, they were penetrating the subject. "I am getting more and more convinced," he had written in the *Baltimore American*, "that we have to deal with a stream of material particles which strike the sensitive plate with great velocities."[152] He speculated that this phenomenon might be used to carry medication into the patient: "Thus it may be possible to project a suitable chemical into any part of the body."[153]

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[151] J. T. Dunn, "Exhibition of Skiagraphs: Report of Cases," *The American X-Ray Journal*, Vol. 6, No. 3, March 1900, 735. Reprinted from *The Louisville Monthly Journal of Medicine and Surgery*. Originally read before the Kentucky State Medical Society in 1899.
[152] Alfred C. Prentice, "The Cause of the Effects Produced by Exposure to the Roentgen Rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 391. Prentice cites the *Baltimore American* as the source of this quotation.
[153] Ibid., 391.

However, a few radiologists speculated that these particles could be dangerous. This included Robert Gregg. Gregg believed that X-rays caused X-ray burns through their "chemical properties." However, he also wrote that "…dust particles…are thrown off from the surface of the tube," and he believed that "This is often the cause of secondary infection."[154]

Others went further. They believed that such particles were in fact the cause of X-ray burns. This group included Julius Mount Bleyer, N. A. Clive, and H. Preston Pratt. Bleyer described his views in an article in *AXJ* in August 1898. He also expressed his views in a discussion that took place at a meeting of the Roentgen Society of the United States in December 1900 which Heber Robarts reported on in the January 1901 edition of *AXJ*. Clive's views were summarized by Heber Robarts in a September 1898 article, and H. Preston Pratt described his own views in an article in April 1902, in additional to other articles.

Julius Mount Bleyer described his beliefs regarding X-ray burns in an article in *AXJ* in August 1898. Bleyer believed that X-ray burns were caused, in part, by particles of dust being pushed into the skin by the X-rays. He believed that X-rays produced by Rhumkorff coils were especially powerful, evidently believing that only powerful X-rays could produce such an "inoculation," as he called it. In Bleyer's words:

> It is a known fact, that the use of the Rhumkoff coil, in connection with the generation of these rays, is an apparatus which gives an exceedingly high electro-motive force and amperage, and therefore such high discharges when exhibited produce certain physical conditions surrounding the atmosphere of the patient or person who is exposed to these x-rays. To sum up these physical facts, we find that this high discharge is leveled against the subject, carrying with it from the

[154] Robert S. Gregg, "X-Ray Burns," *The American X-Ray Journal*, Vol. 14, No. 1, January 1904, 12-13.

> surrounding septic atmosphere, certain particles floating therein, also surcharged with bacteria and foreign material upon the clothing and skin which are at all times present, setting up sometimes an infection and at other times an inflammatory condition from these forced driven materials under the skin exposed to this phenomena (sic).[155]

Bleyer also described his views on X-ray burns at a meeting of the Roentgen Society of the United States in December 1900. The occasion was reported on by Heber Robarts in the January 1901 edition of *AXJ*. W. A. Florentine of Saginaw, Michigan had just delivered a paper entitled "A Review of Cases of X-ray Burns." Florentine was agnostic on the causes of the burns. However, he dismissed the theory that X-ray burns were caused by the electrical field surrounding the X-ray tube, but not the theory that X-rays themselves were to blame. In response, Bleyer described his own views. In Robarts's words: "Dr. Bleyer stated that he had discovered years ago that the x-ray burn was a secondary effect. That the x-ray was applied to the surface of the skin when it was surgically unclean and the burns did not appear at once but a few days after the application of the x-rays the skin began to show certain conditions. These when examined proved to consist of particles of matter."[156]

N. A. Clive published his views in an article in *Health* that Robarts summarized in *AXJ* in September 1898. "Dr. N. A. Clive," wrote Robarts, "suggests that the power of electricity applied to the skin for driving remedies into the tissues (cataphoresis) has become one of the most useful means in neuralgias and other nervous disorders as well as for anasthesia (sic) in dentistry." If electricity could carry "remedies" into tissues, perhaps X-rays had a similar ability.

[155] Julius Mount Bleyer, "The X-rays and Their Safe Application. Destruction of X-ray and Other Infections by Electro-Sterilization," *The American X-Ray Journal*, Vol. 3, No. 2, August 1898, 378
[156] Heber Robarts, "Roentgen Society of the United States," *The American X-Ray Journal*, Vol. 8, No. 1, January 1901, 825.

X-rays "possess the power to penetrate all the tissues….May it not carry with it the cataphoric effect to a certain extent…?" Robarts wondered. "We may not get the cataphoric effect to the extent of producing the taste of a remedy applied to the skin treated with the ray as with the direct current; but we may possible get it to a sufficient degree to produce a dermatitis when the things capable of producing the trouble find lodgment on the skin," wrote Robarts. Perhaps, therefore, the X-rays carry "unclean things" into the skin of the patient.[157]

Pratt agreed that X-ray burns were caused, in part, by the projection of particles of dust into patients' and operators' skin. In September 1901 he presented a paper to the Roentgen Society of America in which he claimed that "impurities in the atmosphere are driven into the body" by X-rays.[158] In December 1902 he presented a paper to the American Roentgen Ray Society in which he warned of "the large amount of effete matter thrown into the system" by X-rays. Such "effete matter" could contribute to "a fatal toxemia."[159] In May 1903, Pratt delivered a paper to the Chicago Electro-Medical Society in which he attributed X-ray burns to microbes, but also "other impurities."[160]

Pratt also believed that particles were responsible for the eye pain that radiologists reported after extensive use of the fluoroscope. He believed that the X-rays broke minute particles of the fluoroscope loose and carried them into the eyes of operators. In a paper delivered to the American Roentgen Ray Society in Buffalo in September 1901, he stated, "Owing to the rapid discharge from the x-ray tube, the eyeball is placed on a strain, especially if

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[157] Heber Robarts, "Dermatitis, &c., from X-rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 415. This is a summary of an article that originally appeared in the journal *Health*. I was unable to review the original article in *Health*, and so there is a degree of ambiguity regarding whether or not Robarts was describing his own views or those of Clive in regard to the possibility that X-ray burns are caused by particles being driven into the skin.

[158] H. Preston Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1030.

[159] H. Preston Pratt, editor's synopsis of H. Preston Pratt, "The Technique of X-ray Therapy," a paper delivered the third annual meeting of the American Roentgen Ray Society, *The American X-Ray Journal*, Vol. 11, No. 6, December 1902, 1263.

[160] H. Preston Pratt, "X-Ray and Its Adjunct Treatment," a paper presented at the May 30, 1903 meeting of the Chicago Electro-Medical Society, *The American X-Ray Journal*, Vol. 12, No. 6, June 1903, 170.

the fluoroscope is being used in making examinations, particles which are freed from the screen during decomposition and are driven along in the direction of the x-ray force, striking the eye, setting up an acute conjunctivitis, which seems to be one of the detrimental troubles that x-ray operators have to contend with."[161]

[161] H. Preston Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1030.

CHAPTER 6: X-RAY INNOCULATION

Germ Theory

Röntgen's discovery took place at the height of the germ theory revolution. Earlier in the century, the theory that infectious diseases are caused by bacteria had been gaining adherents. German anatomist and histologist Jacob Henle advocated the germ theory of infectious disease in 1840 in his *On Miasmas and Contagions*. Among those experimenters that agreed with Henle was Louis Pasteur, who demonstrated the role of microbes in fermentation. Joseph Lister incorporated Pasteur's ideas into medicine, becoming "the Father of Antiseptic Surgery." And in the 1880s, Robert Koch formulated Koch's Postulates, by which specific microbes could be proven to be the cause of specific diseases. By 1895, when Röntgen made his discovery, pathologists were using Koch's Postulates to verify the microbial origins of one infectious disease after another.

Naturally, then, early radiologists speculated as to the effect of X-rays on microbes. "Can the Mysterious Fire Slay the Deadly Bacteria?"[162] asked a *Boston Daily Globe* headline of February 1896 reporting on the work of Boston-area radiologists. Some came to believe it could. Jos Hoffman believed that "The irritant bring to the diseased tissues an increased blood supply,

[162] "BOSTON X-RAY PICTURES," *Boston Daily Globe (1872-1922)*, February 16, 1896, ProQuest Historical Newspapers: The Boston Globe pg. 25.

so that they may resist the attacks of the germs, which finally are expelled or destroyed."[163] "The x-ray is a germicide…" declared H. Preston Pratt in a September 1901 paper.[164]

Others rejected the notion that X-rays had bactericidal properties. N. A. Clive had written in 1898 that "…the x-rays does not (sic) destroy germ life as does electricity. It may be said to be entirely stripped of this power."[165] Eventually, in the first years of the twentieth century, it would be determined that X-rays have "no direct bactericidal effects except by extremely long exposure…."[166]

Microbes as the Cause of X-ray Burns

At least two contributors to *AXJ* subscribed to the view that X-ray burns were caused, at least in part, by microbes. These contributors were Bleyer and Pratt. They believed that X-rays carried bacteria from the air or from the patient's skin into the patient's body. This view was first described in *AXJ* by Bleyer in August 1898, and Pratt advocated it in the pages of *AXJ* in 1902, though his views seem to have evolved by the end of the year.

As we've seen, Julius Mount Bleyer was among those early radiologists who believed X-rays drove particles of dust into the skin and that this contributed to X-ray burns. However, like other early radiologists who subscribed to this view, he also believed that X-rays could carry microbes into the skin. For Bleyer, both particles of dust and microbes were pushed into the skin by the X-rays, and this caused X-ray burns. Indeed, for Bleyer the injuries that came to be known as X-ray burns were not burns at all. "…[W]e all have fallen into [a] fallacious position by

[163] Jos Hoffman, "X-ray in Lupus Vulgaris," *The American X-Ray Journal*, Vol. 7, No. 6, December 1900, 811.
[164] H. Preston Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1030.
[165] Heber Robarts, "Dermatitis, &c., from X-rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 415. This is a summary of an article that originally appeared in *Health*.
[166] U. V. Portman, "Roentgen Therapy," in Glasser (ed.), 1933, 211.

calling this phenomena (sic) as produced by these x-rays, burns, when they are nothing less nor more, than an inoculation."[167] Just as the X-rays carried particles into the skin, they carried microbes as well. These particles and bacteria originated in the air, on the patient's clothing, and even on their skin. "To sum up these physical facts," he wrote, "we find that this high discharge is leveled against the subject, carrying with it from the surrounding septic atmosphere, certain particles floating therein, also surcharged with bacteria and foreign material upon the clothing and skin which are at all times present, setting up sometimes an infection and at other times an inflammatory condition from these forced driven materials under the skin exposed to this phenomena (sic)."[168]

The reasoning that led Bleyer to this conclusion is far from clear. Bleyer cited research conducted at the turn of the twentieth century into the causes of fatality among people burned in fires. Often, victims of such burns died even though their burns did not appear to have produced any fatal damage. "We already know that many deaths are due to burns produced from other causes than by the x-rays," he wrote. "This fact has puzzled scientists to account for deaths which occurred among persons suffering from burns, even where the injuries received seemed wholly inadequate to produce fatal results. The havoc caused by skin diseases might be much greater, but generally a cure could be effected, whereas, in the majority of cases of severe burns the end would be fatal."[169]

Some researchers at this time believed that such deaths were the result of poisoning. Bleyer claimed that a Dr. Kijanitsin had "found in the blood" of burn victims "a poison (ptomain (sic)) that is not present in normal bodies." Bleyer cited research that concluded that such poisoning was *not* caused by external bacteria being introduced into the burn wound. "The belief

[167] Julius Mount Bleyer, "The X-rays and Their Safe Application. Destruction of X-ray and Other Infections by Electro-Sterilization," *The American X-Ray Journal*, Vol. 3, No. 2, August 1898, 377-8.
[168] Ibid., 378.
[169] Ibid., 378.

of Lustgarten that bacteria causing impurities, which settled into the wounds, were the generators of the poison, was shown by the experiments of Ajello and Parascandolo to be unfounded," he wrote.[170] Yet, in the next paragraph he asserts that external bacteria contribute to producing the poison that allegedly kills some burn victims. He wrote, "The poison may be regarded as the product under the influence of high temperature of the albumen, *and the direct importation of bacterial poisons from without*, &c."[171] (My italics.) Bleyer doesn't explain how he reached a conclusion that he just claimed had been disproven.

Nonetheless, Bleyer regarded this research as supporting his interpretation of the cause of X-ray burns. The key seems to have been the delay in symptoms. He wrote, "I lay much stress upon this important point due to these x-ray phenomena. That the x burn always appears many days after the application of this force or light to a part of the body, and does not show absolutely any early manifestation,—as minutes or hours thereafter, but days elapse, even as late as 18 days thereafter."[172] The incubation period, buttressed by contemporary theories of the causation of fatality in burn victims, persuaded Bleyer that X-ray burns were caused by microbes that caused "a dangerous inoculation or poisoning."[173]

Pratt agreed. X-ray burns, he believed, were caused by both particles and microbes being pushed into the skin by the X-rays. In 1902, in discussing the cause of X-ray burns, he wrote, "The microbes and impurities in the atmosphere are driven into the body…."[174] In December 1902 he presented a paper to the American Roentgen Ray Society in which he warned of "…the large amount of effete matter thrown into the system…." Such material included microbes and

[170] Ibid., 379.
[171] Ibid., 379.
[172] Ibid., 379.
[173] Ibid., 380.
[174] H. Preston Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1030.

therefore "…may produce a fatal toxemia."[175] Similarly, in 1903 he wrote, "…the cause of so many septic burns…" was "…microbes and other impurities being driven into the body."[176] However, by the end of 1902, Pratt seems to have concluded that X-ray burns facilitated infections, but that they were not themselves infections. This is discussed further in chapter 9.

[175] H. Preston Pratt, editor's synopsis of H. Preston Pratt, "The Technique of X-ray Therapy," a paper delivered the third annual meeting of the American Roentgen Ray Society, *The American X-Ray Journal*, Vol. 11, No. 6, December 1902, 1263.
[176] H. Preston Pratt, "X-Ray and Its Adjunct Treatment," a paper presented at the May 30, 1903 meeting of the Chicago Electro-Medical Society, *The American X-Ray Journal*, Vol. 12, No. 6, June 1903, 170.

CHAPTER 7: OZONE, UV, WASTE BUILDUP, AND "THE TUBE ITSELF"

Early radiologists contemplated a wide variety of potential explanations of X-ray burns. Though the following explanations attracted few adherents, they were nonetheless contemplated and discussed. Reviewing these explanations further illustrates the heterogeneity of opinions regarding X-ray burns. This heterogeneity of explanations is important because early radiologists took different preventative measures depending on their understanding of the causes of X-ray burns, as will be discussed in the following chapters.

Some early radiologists suspected that X-ray burns were caused by ozone. These radiologists believed that ozone was created when X-rays came into contact with tissues or that the tube itself produced and emitted ozone. Among those radiologists who subscribed to this view was Tesla. "Tesla considers the injury due to ozone generated at the point of contact of the x-ray," noted N. Stone Scott.[177] In November 1898, Elihu Thomson, in listing the explanations given for X-ray burns, noted that "Others have said that ozone given off near the tube is to blame…."[178] And in February 1901, E. A. Florentine referred to the belief that the cause of X-ray burns "lies…in some result of [X-rays'] production such as liberating of ozone…."[179]

Though he quickly abandoned the notion, Mihran Kassabian's suspicion as to the cause of X-ray burns first fell upon the chemicals used in developing photographic plates. "First I thought this condition was due to the chemical action of the developer…" he wrote in October 1900.[180] Kassabian was not alone in noting the similarity between X-ray burns and burns that resulted from exposure to photographic chemicals. During a discussion at the December 1900

[177] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 58.
[178] Elihu Thomson, "Roentgen Ray Burns," *The American X-Ray Journal*, Vol. 3, No. 5, November 1898, 451.
[179] E. A. Florentine, "A Review of Cases of X-ray 'Burns,'" *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 850.
[180] Mihran Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 785.

meeting of the Roentgen Society of the United States, reported on in the January edition of *AXJ*, "Dr. Kinraide, of Boston, gave his experiences in photography, stating that he had had all the effects of a bad x ray burn (sic) without any X-Ray apparatus whatever."[181]

At least two radiologists suspected that nitrous acid was produced during the process of producing X-rays. For instance, at that same December 1900 meeting of the Roentgen Ray Society of the United States, "Dr. Kinraide in reply to a question from one of the physicians present stated that nitrous acid was produced by the discharge…."[182] Dr. Cunningham agreed, saying, in the words of the transcript, that he "frequently had to ventilate the room to get rid of the nitric acid."[183] They suspected that this acid might be the cause of X-ray burns, Kinraide noting that, "the peculiar brown color observed was identical with stains produced by nitrous acid."[184]

Dr. H. Westbury also presented a theory regarding the cause of X-ray burns at the First Annual Meeting of the Roentgen Society of the United States. Westbury's suspicion fell upon the Crooke's tube. He claimed that "the trouble is in the tube itself…." He proposed that some tubes possessed a minute flaw or deviation in design, or some other small but distinguishing feature, which rendered the X-rays that it produced capable of burning tissue. "…[T]here is some little difference which causes the rays to burn…" he wrote. This comported with Westbury's belief that most tubes did not produce rays capable of burning. X-ray burns "…are only caused by certain tubes…" he claimed. As to the nature of this "little difference" that distinguished dangerous tubes from safe ones, Westbury couldn't say. Nonetheless, he was not alone in his

[181] Heber Robarts, "Roentgen Society of the United States," *The American X-Ray Journal*, Vol. 8, No. 1, January 1901, 828.
[182] Ibid., 828.
[183] Ibid., 828-9.
[184] Ibid., 828.

beliefs regarding the cause of X-ray burns. He reported that he held this theory "in common with several other observers of tube phenomena…."[185]

At least one radiologist believed that tissues produce waste in response to exposure to X-rays and that X-ray burns were a consequence of this waste building up. This was Rome Wagner of Chicago, and he described his view in a paper delivered at the third annual meeting of the American Roentgen Ray Society in December 1902. This paper was described by Pratt in the December edition of *AXJ*. Pratt wrote that, "Dr. R. V. Wagner, of Chicago, said that the x-ray emanates from the motion of the rarified air particles in the tube, and when that produces movement of the molecular structures in the tissues we produce a certain amount of waste. If more waste is produced than can be absorbed by the tissues it accumulates and acts as an irritant, setting up an inflammation which is called an x-ray burn."[186] Wagner's theory identified exposure to X-rays as the cause of X-ray burns. However, his theory did not recognize the cumulative nature of X-ray injuries. His theory implied that if enough time was allowed to elapse between exposures, exposure to X-rays would have no harmful consequences.

N. Stone Scott alleged that Elihu Thomson initially believed that ultraviolet light caused X-ray burns. In the August 1897 edition of *AXJ*, Scott wrote that, "Elihu Thomson advanced the theory that the burns were caused by ultra violet light: he has since proved to his own satisfaction, although not to the satisfaction of some others, the falsity of this hypothesis."[187] The cause of the confusion was probably the fact that Thomson believed X-rays came in a range of waves, and that the least energetic X-rays could be absorbed by the skin, just as ultraviolet radiation is absorbed by the skin. Some of Thomson's readers, such as Scott, evidently conflated his references to lower-energy X-rays with ultraviolet radiation. Thomson corrected Scott in the

[185] H. Westbury, "Observations on Crooke's Tubes, Etc.," *The American X-Ray Journal*, Vol. 8, No. 5, May 1901, 899.
[186] H. Preston Pratt, editor's synopsis of H. Preston Pratt, "The Technique of X-ray Therapy," *The American X-Ray Journal*, Vol. 11, No. 6, December 1902, 1263-4.
[187] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 58.

October edition.[188] However, the quotation indicates that others continued to subscribe to this view, though it was never actually advocated in the pages of *AXJ*.

Many radiologists were agnostic as to what caused the injuries that came to be known as X-ray burns but suspected it was not X-rays themselves. In August 1897, N. Stone Scott reported that a patient which he had exposed to X-rays developed an injury to their skin as a consequence of the exposure. The patient's hand had been severely injured in an accident, and Scott had taken several X-rays. Speculating as to the cause of the burn, he wrote, "…it is impossible to prove that the inflammation was not due to the x-ray. It has to be borne in mind, however, that these cases of scar tissue and consequent lowered vitality are especially prone to inflammatory reaction; and some other accident, possibly slight, which she either unconsciously or willfully overlooked, might easily have been the determining cause."[189]

Likewise, Captain W. P. Bannister of the United States Medical Department was unsure regarding the cause of X-ray burns, but concluded that X-rays were probably not the culprit. He reported his perspective in *Transactions of the Medical Society of the District of Columbia*, and an excerpt of this article appeared in the January 1898 edition of *AXJ*. Bannister wrote that "A constant and critical observation of the effect of the ray in this case for six months, forces me to the conclusion that the lesion is not due to the luminous x-ray *per se*, but to some other factor not yet isolated."[190]

CHAPTER 8: IDIOSYNCRASY

[188] Elihu Thomson, letter to editor, *The American X-Ray Journal*, Vol. 1, No. 4, October 1897, 99.
[189] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 60.
[190] W. P. Bannister, "X-Ray Traumatism," *The American X-Ray Journal*,Vol. 2, No. 1, January 1898, 155. This is an excerpt of an article from *Transactions of the Medical Society of the District of Columbia*.

"Do some patients have an idiosyncrasy for the ray?" wondered J. N. Scott in an August 1900 article. And again he asked, "Is there any class of individuals more susceptible to the socalled (sic) 'burns' than others?"[191] Scott was not alone in posing the question of idiosyncrasy, or individual variation in susceptibility to being injured as a consequence of exposure to X-rays. Commenters on X-ray burns frequently discussed the possibility that there was a significant degree of individual variation in susceptibility to X-ray burns. The notion of idiosyncrasy did not inherently posit a cause for the injuries. For those who subscribed to it, however, it could have important implications. For some, it suggested that, whatever their cause, X-ray burns were anomalous developments that did not merit prolonged consideration. For others, it facilitated, even more dangerously, the notion that some people were immune from X-ray burns. These X-ray workers did not merely take ineffective precautions—they did not take any.

Some rejected the significance of idiosyncrasy in regard to susceptibility to develop X-ray burns. In September 1903, *AXJ* reported on an article by a Dr. Thomas Groover that had appeared in the *Virginia Semi-Monthly* in March. "He has not found any individual idiosyncrasy regarding x-ray dermatitis and believes such cases to be rare," reported Pratt.[192] Similarly, though Robert Gregg advised establishing the susceptibility of different patients to X-ray burns, his concern was their current state of health. He either did not believe that anyone possessed an inherent predisposition to develop X-ray burns, or he did not believe such predispositions were significant enough to warrant precautions. In a paper delivered to the American Electro-Medical Society in December 1903 and printed in the January edition of *AXJ*, he wrote, "we should endeavor to know the susceptibility of each and every case. Here a knowledge as to the constitutional condition of the patient is a great aid. A lessened vitality on part of the tissues and

[191] J. N. Scott, "X-Ray Burns," *The American X-Ray Journal*, Vol. 7, No. 2, August 1900, 758.
[192] H. Preston Pratt, "X-Ray Treatment of Epithelioma," *The American X-Ray Journal*, Vol. 13, No. 3, September 1903, 274.

the body as a whole predisposes to a much quicker decomposition, with a lessened reaction to the same." However, "Idiosyncrasies are not to be considered. Healthy tissue resists the action much more strongly and longer than diseased, owing to its greater anabolic or assimilative power."[193]

While Drs. Groover and Gregg rejected the notion, or at least the significance, of idiosyncrasy, many, perhaps most, early radiologists, answered Scott's questions in the affirmative. For E.A. Florentine, it seemed obvious that different people would respond differently to exposure to X-rays. People respond differently to virtually everything else, so why not X-rays? As he put it: "The resistant effect of the skin to the burning rays of the sun varies to the greatest degrees in different individuals; if this be true, why not then the resistant effects of the skin to the burning effects of the x-ray vary in the same extent in individuals, to the degree of no effect at all to a mild or even most dangerous 'burn.' Furthermore if idiosyncrasies are true of almost all chemical and physical agents why should we draw the line at certain unexpected results that sometimes follow the use of the x-rays?"[194]

Others agreed. For instance, in October 1900, Mihran Kassabian wrote, "I am of the opinion that idiosyncracies (sic) exist..." regarding susceptibility to develop X-ray burns.[195] L. A. Pierce wrote that a railroad surgeon had testified at his trial that he believed that X-ray burns were attributable to "the peculiar condition of the salts of the body in some subjects…."[196] In August 1903, Pratt informed readers of an article by Dr. Carl Beck in the *Medical Record*. Pratt wrote, "Dr. Carl Beck in the *Medical Record*, Jan. 31, 1903, considers the idiosyncrasy of the

[193] Robert S. Gregg, "X-Ray Burns," *The American X-Ray Journal*, Vol. 14, No. 1, January 1904, 12.
[194] E. A. Florentine, "A Review of Cases of X-ray 'Burns,'" *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 850.
[195] Mihran Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 785.
[196] L. A. Pierce, "Case of Tissue Injury by X-Ray and Result of Prosecution in Court," *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 857.

patient an important factor in x-ray burns."[197] Also in August 1903, an article from the *Canada Lancet* was excerpted in *AXJ*. The author claimed that "Idiosyncracy (sic) to the ray is very great."[198] And in August 1904 W. S. Newcomet warned of "that person who has a frightful susceptibility to unpleasant effects."[199]

The concept of idiosyncratic variation as to susceptibility to X-ray burns offered an explanation of the relative rareness of the phenomenon. As previously described, many early radiologists went months or years without developing an X-ray burn or inflicting one on a patient. "…[M]any people are exposed to x-ray demonstration and but very few suffer ill consequences" noted Mihran Kassabian.[200] As S. H. Monell put it in February 1898, "Probably a million x-ray pictures have been taken altogether; probably a thousand experimenters are now daily exposing themselves to x-rays; yet despite these facts, practically no one suffers."[201] When early radiologists did inflict an X-ray burn on a patient, it was always an exception. Most patients never developed an X-ray burn. For many early radiologists, it seemed that different patients responded differently to similar conditions and durations of exposure. The idea that patients varied in susceptibility to develop burns helped explain this apparent discrepancy.

Radiologists who believed that there existed idiosyncratic variation regarding susceptibility to develop X-ray burns drew different lessons as to the implications of such variation. For some, the possibility that some patients were highly susceptible to developing burns motivated enhanced caution. An article from the *Canada Lancet*, excerpted in *AXJ* in August 1903 advised that "Conservatism is essential until the personal peculiarity is well

[197] H. Preston Pratt, "Protection Against Roentgen Ray Dermatitis," *The American X-Ray Journal*, Vol. 13, No. 2, August 1903, 240.
[198] "Rules for the Use of the X-Ray." *The American X-Ray Journal*, Vol. 13, No. 2, August 1903, 243. This is an excerpt of an article from the *Canada Lancet*.
[199] W. S. Newcomet, "Pathological Changes in Tissue Under the Influence of the X-Ray," *The American X-Ray Journal*, Vol. 15, No. 2, August 1904, 246.
[200] Mihran Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 785.
[201] S. H. Monell, "Burns and Technique in X-ray Work," *The American X-Ray Journal*, Vol. 2, No.2, February 1898, 164. It should be noted that Monell was not addressing the idea of idiosyncrasy in susceptibility to X-ray burns.

known."[202] In discussing the use of X-rays in the treatment of cancer, Carl Beck proposed exposing patients to X-rays incrementally and observing whether or not burns developed. If they did not, it was safe to proceed with treatment. Pratt described Beck's advice to *AXJ* readers: "He advises a first exposure of five minutes with a soft tube and a moderate light, followed after one week by a second, and after another week by a third ten-minute exposure with the tube five inches distant. If no injurious reaction occurs after the third exposure x-ray treatment may be safely applied."[203] As mentioned, Newcomet wrote of "that person who has a frightful susceptibility to unpleasant effects." Regarding such patients, Newcomet advised "always being on guard."[204]

Implicit in this advice was the notion that precautions could be reduced once it was determined that the patient lacked a predisposition to burn. If those who developed burns were uniquely predisposed to burn, then those who did not burn must have lacked this predisposition. The cautions necessary for the former were not necessary in regard to the latter. In other words, for each of these radiologists, the operator was to increase the degree of exposure once a patient was deemed to lack a purported idiosyncratic predisposition to burn.

A few radiologists took the notion of a broad range of idiosyncratic susceptibility to X-ray burns even further. If variation existed regarding susceptibility to burn in response to exposure to X-rays, and some patients belonged to the lower limit of this spectrum, being very inclined to burn, what about those at the upper limit? Informed by the notion of significant idiosyncratic variation regarding susceptibility to burn, some radiologists drew the dangerous conclusion that there existed people who were inherently immune to the injurious effects of X-

[202] "Rules for the Use of the X-Ray." *The American X-Ray Journal*, Vol. 13, No. 2, August 1903, 243. This is an excerpt of an article from the *Canada Lancet*.
[203] H. Preston Pratt, "Protection Against Roentgen Ray Dermatitis," *The American X-Ray Journal*, Vol. 13, No. 2, August 1903, 240.
[204] W. S. Newcomet, "Pathological Changes in Tissue Under the Influence of the X-Ray," *The American X-Ray Journal*, Vol. 15, No. 2, August 1904, 246.

rays. For such people, no level of exposure was thought to pose a risk. Commenting on this phenomenon in 1904, John Pitkin wrote, "During a long period of increasing susceptibility the operator may imagine himself an x-ray immune, as if by some special dispensation he, like Shadrach, Meshack and Abednego, can walk in the fiery furnace (of the x-ray field) and not be burned."[205]

The experience of an operator who subscribed to this view was described in *AXJ* in August 1903. The case was described in an article excerpted from the *Journal of the American Medical Association*. It described the case of a man named Wiesner who "engaged in the manufacture of Roentgen tubes for years." Wiesner experienced constant exposure, but for most of that time had not experienced any injuries. Because of this, he had "considered himself immune to their action." By August 1903, his exposure, against which he had seen no reason to take precautions, had led to an "extensive and intense Roentgen ulceration."[206]

CHAPTER 9: PROTECTION

The previous chapters have demonstrated that early radiologists subscribed to a wide array of beliefs regarding the causes of X-ray burns. Some believed that X-ray burns were caused

[205] John T. Pitkin, "Dangers to the X-Ray Operator," *The American X-Ray Journal*, Vol. 14, No. 2, February 1904, 44.
[206] "Roentgen Dermatitis," *The American X-Ray Journal*, Vol. 13, No. 2, August 1903, 240. This is an excerpt from the *Journal of the American Medical Association*.

by the electrical field surrounding the X-ray tube. Others believed that they were caused by microscopic particles of the X-ray apparatus or microbes. Still others believed that X-ray burns were caused by ozone, flaws in X-ray tubes, nitrous acid, etc.

This heterogeneity of beliefs regarding the causes of X-ray burns resulted in a heterogeneity of protective measures taken against them. This chapter reviews some of those protective measures. Recognizing the diversity of protective measures adopted by early U.S. radiologists helps explain why so many of them experienced X-ray burns and why so many subsequently developed cancer.

Grounded Aluminum Screens

Early radiologists who believed that X-ray burns were caused by inadvertent electrolysis frequently proposed that a grounded aluminum screen be placed between the patient and the X-ray tube. Such a shield would carry any electric current to the ground and prevent it from reaching the patient. However, at least one early radiologist who believed X-rays caused X-ray burns also advocated the use of a grounded aluminum shield to protect from X-ray burns.

Grounded aluminum screens were advocated in *AXJ* between February 1898 and January 1901. At least 6 radiologists whose views appeared in *AXJ* advocated the use of a grounded aluminum shield to protect from X-ray burns. This included Heber Robarts, Charles Leonard, John Pitkin, and Alfred Prentice. An author by the name of Balthazard whose article in a different journal was summarized in *AXJ* also advocated the use of grounded aluminum screens, as did a Dr. Cunningham, who expressed his views in a discussion at a conference reported on in *AXJ*.

Balthazard's article was reported on by Robarts in February 1898. This was the first item in *AXJ* in which an author (Balthazard) proposed the use of a grounded aluminum screen to protect from X-ray burns. Robarts's report is a single sentence in length and simply noted that Balthazard had never produced an X-ray burn while using such a screen. Robarts wrote: "A short article, in which he endeavors to prove that the physiological actions of these rays is much less important than that of the electric radiations which accompany them; in all experiments with x-rays the electric radiations should be excluded by a screen of aluminum."

The second item in *AXJ* in which a grounded aluminum screen was proposed as a means of protecting against X-ray burns appeared in July 1898. The article was by editor Heber Robarts. Robarts was reporting on a meeting of the Section on Ophthalmology of the College of Physicians of Philadelphia that was held on March 15, 1898. Among the topics discussed by the attendees were the most effective methods of locating foreign objects in eyes. Midway through the article, Robarts explains that X-ray burns are not serious, they are due to inadvertent electrolysis, and that a grounded aluminum shield offers protection against them. He wrote, "The x-ray 'burn' is not due to the x-ray, but to the static electric charge induced in the tissues by the high potential induction field surrounding the tube. It is never serious, and may be prevented by introducing a 'grounded' aluminum conductor as a shield between the tube and patient."[207]

John Pitkin also advocated the use of a grounded aluminum screen. He expressed his views in a September 1898 article. He explained that advances in technology had rendered generators more prone to induce electrolysis. This was because they were capable of greater amperage. He wrote "With the modern static machines capable of developing a pressure of several millions of volts, the employment of additional spark gaps increases the electrical dissemination, raises the resistance, develops amperage, increases the electrification of the

[207] Heber Robarts, "Localization of Foreign Bodies in the Eye," *The American X-Ray Journal*, Vol. 3, No. 1, July 1898, 345.

patient and thereby adds to the danger." Because of this, grounded aluminum screens were essential for protection against X-ray burns. He wrote, "*Employment of* the metallic grounded screen…as a protective measure is of extreme importance."[208]

In the same edition of *AJX* in which Pitkin advocated the use of a grounded aluminum screen, Alfred Prentice also advocated its use. This was the same article where he described his experiments with guinea pigs, mentioned previously. "In all cases where exposure is required at a distance less than twelve inches from the tube," he wrote, "an aluminum screen, electrically grounded, should be placed between the tube and the exposed part."[209]

Charles Leonard also advocated the use of a grounded aluminum screen to prevent X-ray burns. He expressed his views in an article in November 1898. Regarding grounded aluminum screens, Leonard explained that "By the interposition of such a screen between the patient and the tube the static charge of electricity is collected in it and conducted to earth, while as it is penetrable to the Roentgen rays the fluoroscopic or skiagraphic efficiency is not altered." In fact, "Since the first few cases were accidentally produced, the employment of an aluminum screen attached to a grounding wire, has prevented further injury."[210]

Among those early radiologists who advocated the use of a grounded aluminum screen to prevent X-ray burns was Mihran Kassabian. "The interposition of an aluminum sheet connected to the earth through the gas pipe or other like means of conduction, is a good method," he wrote. Kassabian's reasoning in favor of this protective measure was unique because he did not believe that X-ray burns were caused by electrical currents. He believed that the injuries that came to be called X-ray burns were caused by X-rays. However, Kassabian recognized that X-rays came in

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[208] John T. Pitkin, "Injurious Effects of the Roentgen Rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 387. Pitkin claimed that Tesla also advocated the use of grounded aluminum screens.
[209] Alfred C. Prentice, "The Cause of the Effects Produced by Exposure to the Roentgen Rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 395.
[210] Charles Lester Leonard, "Roentgen Ray Dermatitis," *The American X-Ray Journal*, Vol. 3, No. 5, November 1898, 455.

a spectrum of wavelengths. Like Elihu Thomson, he believed that X-rays of the lower wavelength of the X-ray spectrum were more likely to cause the injuries that came to be called X-ray burns. Kassabian believed that a grounded aluminum screen was capable of preventing the passage of X-rays of the lower wavelength range. He referred to this harmful range of X-rays as "the chemical rays." Explaining how the interposition of a grounded aluminum screen offered protection against X-ray burns, Kassabian wrote, "This will, according to the absorption theory, absorb the chemical rays of the x-rays."[211] Unfortunately, he doesn't explain the purpose of grounding such a screen. In other words, he doesn't tell us why a non-grounded aluminum screen could not prevent the passage of "the chemical rays" as effectively as a grounded one.

The last item in *AXJ* in which the use of a grounded aluminum screen was advocated as a protective measure against X-ray burns appeared in January 1901. This was a report on a meeting of the Roentgen Society of the United States that took place in December 1900. This article reported that Dr. Cunningham advocated the use of a grounded aluminum screen. "Never saw any x-ray burns so long as screens were used," Robarts reported.[212]

Asepsis and X-ray Burns

Between 1898 and 1901, several radiologists expressed the view that X-ray burns could be prevented with aseptic measures. At least 3 items appeared in *AXJ* that advocated asepsis as a means of preventing X-ray burns. The first appeared in August 1898, the second in September 1898, and the third in April 1901. The first was written by Julius Mount Bleyer. The second was a summary of the views of N. A. Clive written by Heber Robarts, and the third was an article by

[211] Mihran Kassabian, "X-Ray as an Irritant," *The American X-Ray Journal*, Vol. 7, No. 4, October 1900, 786.
[212] Heber Robarts, "Roentgen Society of the United States," *The American X-Ray Journal*, Vol. 8, No. 1, January 1901, 829.

H. Preston Pratt. In two subsequent items, appearing in November and December 1902, Pratt advocated aseptic measures. However, by this time Pratt appears to have abandoned the view that X-ray burns were caused by microbes. He continued to advocate asepsis in order to prevent additional infections that burns might facilitate. In a sixth item, L. A. Pierce notes his own use of aseptic measures. This was a February 1901 article. Finally, in a seventh item, Robert Gregg advocated asepsis. Gregg did not regard microorganisms as responsible for X-ray burns, and he advocated asepsis as a preventative for "secondary infections," the position that Pratt appears to have arrived at by the end of the following year. Gregg's article appeared in January 1904.

As we've seen, Julius Mount Bleyer did not regard the injuries that came to be known as X-ray burns as burns, and he did not believe they were directly caused by X-rays. As we've also seen, his reasoning is difficult to follow, but his conclusion was clear. Bleyer regarded X-ray burns as caused by bacteria, and he was the first to advocate aseptic measures as a preventative to X-ray burns in the pages of *AXJ*. The article in which he did so appeared in the August 1898 edition of the journal. "All parts to be either photographed or examined by means of these x-rays," he wrote,

> should have all clothing removed therefrom, and washed with an antiseptic solution, or so prepared as if a surgical operation is to be performed. Also, a room which is free from infectious materials as possible, should always be made ready, or especially appointed for the purpose. Those are the cardinal rules and must not be deviated therefrom in order to avoid a dangerous inoculation or poisoning.[213]

[213] Julius Mount Bleyer, "The X-rays and Their Safe Application. Destruction of X-ray and Other Infections by Electro-Sterilization," *The American X-Ray Journal*, Vol. 3, No. 2, August 1898, 380.

N. A. Clive agreed. He wrote an article for the London journal *Health* on the subject. In the September 1898 edition of *AXJ*, Robarts summarized Clive's views. In Robarts's words, Clive believed that "with properly enforced surgical cleanliness of the member to be treated with the x-ray, we would never cause the troublesome dermatitis so often complained of in its employment." Indeed, Clive believed "that at some time in the future it will be considered unscientific to apply the ray through an unclean skin…."[214]

Dr. L.A. Pierce of Long Beach, California noted his own use of sterilization in an article in February 1901. In recounting the first time that he inflicted an X-ray burn on a patient, he wrote that he covered the portions of the body exposed to X-rays with a sterilized towel. "While no protection such as aluminium plates or any intervening metalic (sic) substance was used, I did carefully cover his face and shoulder with clean sterilized towls (sic)."[215] It is not entirely clear if Pierce believed that this would prevent an X-ray burn. However, it seems likely that he believed it would. He wrote of his use of sterilization as evidence that he was operating his equipment responsibly and could not therefore be held responsible for his patient having developed an X-ray burn.

Asepsis was advocated as a means of preventing X-ray burns for a third time in *AXJ* by H. Preston Pratt in an April 1901 article in which he wrote "All of the x-ray burns produced, so far as I am able to learn, are due to the lack of proper antiseptic measures."[216] Pratt advocated asepsis in *AXJ* on two additional occasions, but his statements on these occasions suggest that by November 1902, Pratt had abandoned the belief that X-ray burns were caused by microbes. He continued to advocate asepsis not as a means of preventing X-ray burns, but as a means of

[214] Heber Robarts, "Dermatitis, &c., from X-rays," *The American X-Ray Journal*, Vol. 3, No. 3, September 1898, 416. This is a summary an article by N. A. Clive that appeared in the London journal *Health*.
[215] L. A. Pierce, "Case of Tissue Injury by X-Ray and Result of Prosecution in Court," *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 857.
[216] H. Preston Pratt, "The Value of the X-Ray as a Therapeutic Agent," *The American X-Ray Journal*, Vol. 10, No. 1, April 1902, 1030.

preventing infections that might accompany the burn. For instance, in November 1902 the journal published a letter inquiring about the occurrence of X-ray burns when treating rectal cancer. Pratt does not propose applying X-rays under aseptic conditions. He writes that once a burn appears, "stop treatment a few days, and use mild antiseptic dressing to prevent infections."[217] In December he advised, "Before exposing render the part antiseptic."[218] On this occasion, he doesn't explain why he advocates asepsis. In light of his November statement, he was likely advising asepsis in order to prevent infections that might be indirectly facilitated by an X-ray burn.

The final advocacy of asepsis in relation to X-ray burns in *AXJ* occurred in January 1904. This was in an article by Robert Gregg. Gregg shared Pratt's later view that X-ray burns are not caused by microbes but that asepsis is nonetheless advisable in order to prevent infections that would be facilitated by an X-ray burn. Gregg advised that "While under treatment of x-rays it is essential that the parts be properly protected by borated gauze, or some other antiseptic protective agent." The failure to do so was "often the cause of secondary infection."[219]

Other Types of Screens

Pratt recommended screens of celluloid, though he does not appear to have believed such screens offered protection against X-ray burns, but rather that they offered protection against infections that X-ray burns could facilitate. Such screens would prevent microbes from reaching the patient, he reasoned. In December 1902 he advised "…interpose a celluloid screen…"

[217] H. Preston Pratt, response to E. A. L., *The American X-Ray Journal*, Vol. 11, No. 5, November 1902, 1189.
[218] H. Preston Pratt, editor's synopsis of H. Preston Pratt, "The Technique of X-ray Therapy," a paper delivered the third annual meeting of the American Roentgen Ray Society, *The American X-Ray Journal*, Vol. 11, No. 6, December 1902, 1263.
[219] Robert S. Gregg, "X-Ray Burns," *The American X-Ray Journal*, Vol. 14, No. 1, January 1904, 13.

between the tube and the patient.[220] In the following year he reported, "To protect the parts I am using a protecting screen, with celluloid interposed between the tube and the patient to prevent microbes and other impurities from being driven into the body, which is the cause of so many septic burns."[221]

Some radiologists adopted an any-of-the-above approach to screens, all of which, they believed, offered some degree of protection against X-ray burns. In February 1901, E. A. Florentine wrote that "In all methods of protection suggested, shields are advocated to intervene between the active tube and part to be exposed. This list covers sheet metals, rubber cloth, oiled silks, grounded screens and many others. All of these apparently have to some extent a protective effect regardless of the fact that 'burns' have been produced through all and every safety appliance yet brought upon the market. But as I said before, all of these have a somewhat protective effect."[222] And in January 1904, John Pitkin wrote that "…the danger decreases with…Interposition of substances, clothing, screens of copper plate, iron, tin, zinc, aluminum, plate glass, etc…."[223]

Distance

"There can be no doubt that deep burns have been produced, but from all reports which I have seen, the cause could be traced to the proximity of the tube to patient, or lengthy exposure,"

[220] H. Preston Pratt, editor's synopsis of H. Preston Pratt, "The Technique of X-ray Therapy," *The American X-Ray Journal*, Vol. 11, No. 6, December 1902, 1263
[221] H. Preston Pratt, "X-Ray and Its Adjunct Treatment," a paper presented at the May 30, 1903 meeting of the Chicago Electro-Medical Society, *The American X-Ray Journal*, Vol. 12, No. 6, June 1903, 170.
[222] E. A. Florentine, "A Review of Cases of X-ray 'Burns,'" *The American X-Ray Journal*, Vol. 8, No. 2, February 1901, 849.
[223] John T. Pitkin, "Dangers to the X-Ray Operator," *The American X-Ray Journal*, Vol. 14, No. 1, January 1904, 11.

wrote J. T. Dunn in March 1900.[224] Many early radiologists agreed that the longer a patient or operator was exposed to X-rays, and the closer they were to the X-ray tube, the greater the likelihood that they would develop an X-ray burn. However, radiologists disagreed as to why increasing the distance between the tube and the patient diminished the likelihood of an X-ray burn.

For N. Stone Scott, distance provided protection because the closer one was to the tube, the more concentrated were the X-rays to which one was exposed. As one withdrew further from the tube, the beam of X-rays spread out, striking a broader area, and therefore striking any particular area with diminished concentration. Incidentally, though N. Stone Scott never took a position on the cause of X-ray burns in the pages of *AXJ*, his explanation of why distance offered protection implied that the X-rays themselves were responsible.

Robarts agreed that distance offered protection, but for different reasons. Robarts attributed X-ray burns to electrical fields, and he believed that greater distance from the tube afforded protection by making it less likely that the electrical field surrounding the tube could reach the patient. In June 1898 he wrote that "the electrical discharge is confined in close proximity to the tube, probably at no greater distance than 15 inches." Technological advances rendered it unnecessary to place patients within a short distance of the X-ray tube, and therefore, "…there should never be such a thing as burns…."[225]

[224] J. T. Dunn, "Exhibition of Skiagraphs: Report of Cases," *The American X-Ray Journal*, Vol. 6, No. 3, March 1900, 735. Reprinted from *The Louisville Monthly Journal of Medicine and Surgery*. Originally read before the Kentucky State Medical Society in 1899.
[225] Heber Robarts, editor's note, *The American X-Ray Journal*, Vol. 2, No. 6, June 1898, 286.

CONCLUSION: X-RAYS BURN

By 1904, theories of X-ray burns that attributed them to something other than exposure to X-rays disappeared from *AXJ*. Radiologists began to take for granted that X-rays were directly responsible for the injuries they and their patients experienced as a consequence of exposure to X-rays. In John Pitkin's 1904 series of articles in *AXJ* on X-ray burns, he described them as "the action of the rays of Roentgen upon the operator…."[226] Gregg's article in January of the same year also took for granted that X-ray burns were caused by X-rays.[227]

[226] John T. Pitkin, "Dangers to the X-Ray Operator," *The American X-Ray Journal*, Vol. 14, No. 2, February, 1904, 44.
[227] Robert S. Gregg, "X-Ray Burns," *The American X-Ray Journal*, Vol. 14, No. 1, January 1904, 12-13.

Even more striking is the change in attitudes toward X-ray burns. The dismissive attitude of Robarts, Pratt, and others toward the significance of X-ray burns disappeared. The author of a *London Electrical Review* article that was reprinted in *AXJ* who was agnostic on the cause of X-ray burns described the issue of X-ray burns as a "burning question," writing, "It is evident that whoever undertakes the treatment of any morbid condition by x-rays, undertakes a serious responsibility….Especially must there be a complete understanding, perhaps even expressed in writing, that the patient is aware of the nature of the treatment, and is willing to accept its attendant risks or necessities."[228] As described in chapter two, Pratt argued for placing restrictions on who could use X-rays for medical purposes in 1903, citing the risk of X-ray burns.[229] "If obliged to enter the field for any purpose," cautioned Pitkin in his series of articles in 1904, "remain as far away from the excited tube, work in the outer confines as much as possible, do what is required, then return to a position of safety immediately."[230]

Though the process by which this change took place was not described in *AXJ*, it appears that as alternative explanations lost credibility, X-rays became identified as the culprit by a process of elimination. The theory that electrical fields was responsible had ceased to be advocated in *AXJ* by 1900. Regarding the theory that microbes were responsible for X-ray burns, while Pratt had previously subscribed to this view, by November 1902, as we've seen, he was advocating asepsis as necessary to prevent secondary injuries, but not X-ray burns. Pratt, in other words, abandoned the idea that X-ray burns were caused by microbes by the end of 1902. Like other theories, the notion simply disappeared from the journal's pages.

In retrospect, it is striking that the first reports of X-ray burns attributed the burns to the direct effects of exposure to X-rays. "It is worthy of note that in these early reports on skin

[228] Author not identified, "The Medico-Legal Aspect of X-Rays," *The American X-Ray Journal*, Vol. 14, No. 6, June 1904, 186. Reprinted from *London Electrical Review*.
[229] H. P. Pratt, "Dangers of X-Rays," *The American X-Ray Journal*, Vol. 13, No. 1, July 1903, 202.
[230] John T. Pitkin, "Dangers to the X-Ray Operator," *The American X-Ray Journal*, Vol. 14, No. 3, March, 1904, 80.

manifestations practically all were attributed to the roentgen rays, and though disagreements and arguments followed later, the original authors were correct in their unfounded assumptions."[231] Portman notes that these initial attributions of burns to the direct effects of exposure to X-rays were "unfounded assumptions." To call them *un*founded is an overstatement. All attributions of causation are based on correlation. These first reports attributed the skin injuries to exposure to X-rays because the most salient, obvious factor common to them all was that they were preceded by exposure to X-rays. Nonetheless, correlation, as the saying goes, isn't causation. Correlation is necessary but insufficient to establish causation, and so it was reasonable to contemplate alternative explanations in the absence of experiments that ruled them out. Surprisingly, just such experiments had been conducted by the beginning of 1897. Moreover, readers of *AXJ* would have been aware of these experiments.

Elihu Thomson was an electrician and inventor based in Lynn, Massachusetts who worked for General Electric. He was among those nineteenth-century electricians whose work on alternating current motors was dramatically eclipsed by Tesla's AC motor design, which became the basis of all large-scale electricity generation.[232] Nonetheless, Thomson was a prolific inventor, and he was the first person in the United States to be awarded a patent for an X-ray tube design.[233] "Among the non-medical group" of contributors to the field of radiology, wrote William A. Evans in 1933, "Elihu Thomson was by far the greatest contributor…."[234]

"…from the first I discarded all theories as to the cause of x-ray burns for the one which was the most obvious to me, namely, that the injuries were caused by the rays themselves…"

[231] Portman, in Glasser (1933), 213.
[232] W. Bernard Carlson, *Tesla: Inventor of the Electrical Age* (Princeton, New Jersey: Princeton University Press,2013), 106-7.
[233] Audrey B. Davis, "Medical Technology," in Trevor I. Williams (ed.), *A History of Technology, Vol. III, The Twentieth Century c.1900 to c.1950, Part III* (Oxford: Oxford University Press, 1978), 1331. Davis writes that the design was not in fact original.
[234] William A. Evans, "American Pioneers in Radiology," in Glasser (1933), 33.

wrote Thomson in an article in *AXJ* in October 1897.[235] Thomson had conducted experiments into X-ray burns, one of which ruled out the then-popular theory that electrical fields were responsible for the burns incurred following exposure to X-rays. In this experiment, Thomson subjected his finger to X-rays. Part of his finger was left bare, and the other part of his finger was covered with aluminum foil. Both parts of his finger were burned. Because electricity, but not X-rays, would have been blocked from reaching his finger by the aluminum, electrical fields could not have been the cause of the burn.[236]

Thomson's experiments were widely known of. More than one contributor to *AXJ* mentioned them, and Thomson himself made three contributions to *AXJ*. Unfortunately, his views and experiments were also widely misunderstood. For instance, as previously discussed, N. Stone Scott, in his August 1897 article, wrote "Elihu Thompson (sic) advanced the theory that the burns were caused by ultra violet light…."[237] In his October 1897 article, Thomson responded:

> Dr. N. Stone Scott has undoubtedly done a great service in putting the results of his inquiries into the causes of x-ray injuries into such form as to be available to the general reader through the means of your valuable journal.
>
> There are some remarks which he makes, however, which I must take exception to: for example, on page 58, he states that I advanced the theory that the burns are

[235] Elihu Thomson, letter to the editor, *The American X-Ray Journal*, Vol. 1, No. 4, October 1987, 99.
[236] Elihu Thomson, "Roentgen Ray Burns," *The American X-Ray Journal*, Vol. 3, No. 5, November 1898, 452.
[237] N. Stone Scott, "X-ray Injuries," *The American X-Ray Journal*, Vol. 1, No. 3, August 1897, 58.

caused by ultra-violet light. I am not aware of ever having advanced such a theory….[238]

Thomson explained that he believed X-ray burns were directly caused by exposure to X-rays. In November 1898, Thomson complained in *AXJ* that his views continued to be misunderstood, and he reiterated his views in greater detail.

> So much difference of opinion has been manifested by various writers who have considered the now rare injuries produced in x-ray experimentation, that it seems desirable that a clear expression of the writer's experience and opinion on this subject should be made. This is particularly the case since, in a number of cases, opinions and conclusions have been attributed to him which are not in his judgment, tenable in view of the facts.
>
> The writer's further experiments tend to confirm him in the opinion which he expressed when his first experiments were published, namely: That the burns are produced chiefly by those rays of the x-ray order which are most readily absorbed by the flesh.[239]

To his consternation, when Thomson received his copy of this edition of *AXJ*, he found that his front-page article was immediately followed by an article by surgeon Charles Leonard of

[238] Elihu Thomson, letter to the editor, *The American X-Ray Journal*, Vol. 1, No. 4, October 1987, 99.
[239] Elihu Thomson, "Roentgen Ray Burns," *The American X-Ray Journal*, Vol. 3, No. 5, November 1898, 451.

Pennsylvania in which Leonard argued that X-ray burns were caused by exposure to electrical fields. In Thomson's third and final contribution to *AXJ* in January 1899, he wrote,

> I notice that in the November number of THE X-RAY JOURNAL immediately following my article on X-Ray Burns, there is a paper by Dr. Chas. Lester Leonard practically on the same subject.
>
> He endeavors to show that electro-static charges or effects are the true cause of the dermatitis and not Roentgen rays. In doing this, however, he misinterprets very ordinary electrical phenomena and conditions. Had he interpreted correctly the results he alludes to, his conclusions must have been the opposite of those which he takes so much pains to maintain.[240]

Thomson's experiments were mentioned a final time in *AXJ* in January 1901 in a transcription of the minutes of the inaugural meeting of the Roentgen Society of the United States, held at Grand Central Palace in New York City in December 1900. It was there that Dr. Cunningham was reported to have stated "That Prof. Thomson's experiments, as well as others, showed that when the skin was near an x-ray tube currents were present and when a properly grounded screen was placed across, the currents disappeared. Never saw any x-ray burns so long as screens were used."[241] In other words, Dr. Cunningham believed that Thomson had *not* been burned on the portion of his finger that was covered with aluminum and that his experiments supported the claim that electrical fields were responsible for X-ray burns. By this time,

[240] Elihu Thomson, "Roentgen Ray Dermatitis," *The American X-Ray Journal*, Vol. 4, No. 1, January 1899, 494.
[241] Heber Robarts, "Roentgen Society of the United States," *The American X-Ray Journal*, Vol. 8, No. 1, January 1901, 828-9.

Thomson had written three articles for *AXJ*, two of which were in part responses to misrepresentations of his experiments and views. This time, no correction was offered.

What happened between 1896 and 1904 that led so many early U.S. radiologists to not only consider the possibility that X-ray burns were caused by electrical fields, dust particles, microbes, nitrous oxide, imperfections in vacuum tubes, etc., but to assert with certainty that these were the causes? I propose two factors that I believe contributed to this development. The first is the human mind's propensity for what Michael Shermer calls paternicity, by which people not only discern real patterns from meaningful data, but imagine false patterns in meaningless data. The second factor, which helps explain the direction in which this patternicity nudged early U.S. radiologists is what I will call a vocational bias.

The Meaningless Data of the First Reports of X-ray Burns

Factors that likely played a major role in contributing to the confusion that reigned among early radiologists regarding the cause of X-ray burns was their rareness and the lack of systematic collection of data. Most patients never developed an X-ray burn. While Emil Grubbe developed a burn as early as January 1896, Robarts and others were declaring in 1897 and beyond that they had been using X-rays for months and had not produced such injuries. It was three years into his career as a radiologist that J. N.

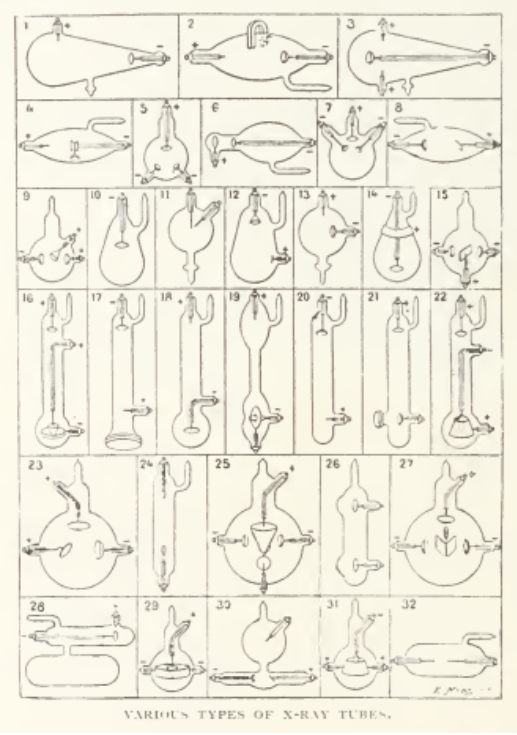

Figure 2: An illustration the variety vacuum tubes used to produce X-ray by early radiologists. American X-Ray Journal Vol. 2 page 22.

Scott first encountered an X-ray burn.[242] In retrospect, X-rays burns seem to have appeared randomly. Of course, this is not the case. The striking variation in the frequency with which early radiologists' experienced burns was a product of the variation in equipment and technique among early radiologists. The first radiologists used different types of machines, with different degrees of vacuum. And they exposed their patients for different durations of time, and at varying distances and angles, with different protective measures. Figure 1, for instance, illustrates the great variation that prevailed regarding the design of the vacuum tube used by early radiologists in the production X-rays. Furthermore, early radiologists had little means of assessing the quantity of radiation to which they exposed themselves and their patients. "Those who have watched an x-ray tube in operation and noticed how the vacuum will change from time to time will wonder how any constant result can be obtained…" noted Newcomet in 1904.[243]

Strikingly, what appears at first to us as the randomness of the incidence of X-ray burns was not experienced as randomness by early radiologists. J. N. Scott's January 1901 article is singular, or virtually so, in admitting bafflement. Whether caused by electrical fields, particles of dust, or microbes; whether they could be dismissed as the product of the improper technique of the "tyro," one thing early radiologists rarely said of X-ray burns—none said it in quite these words—was that their incidence was too random to be explained, the data too anecdotal and unsystematically collected for a conclusion to be reached.

The significance of this fact as a clue to explaining why early radiologists took so long to acknowledge that X-rays burn is that it suggests the relevance of what Michael Shermer describes as patternicity. Shermer argues that we form beliefs for reasons independent of

[242] J. N. Scott, "X-Ray Burns," *The American X-Ray Journal*, Vol. 7, No. 2, August 1900, 757.
[243] W. S. Newcomet, "Pathological Changes in Tissue Under the Influence of the X-Ray," *The American X-Ray Journal*, Vol. 15, No. 2, August 1904, 246.

evidence and then proceed to develop arguments in favor of them. "*Beliefs come first, explanations for beliefs follow*," he writes:

> Once beliefs are formed, the brain begins to look for and find confirmatory evidence in support of those beliefs, which adds an emotional boost of further confidence in the beliefs and thereby accelerates the process of reinforcing them, and round and round the process goes in a positive feedback loop of belief confirmation. (5)

Furthermore, Shermer notes, scientists are not immune from this process.

> Belief reversals happen more often in science, but not at all as frequently as we might expect from the idealized visage of the exalted 'scientific method' where only the facts count. The reason for this is that scientists are people too, no less subject to the whims of emotion and the pull of cognitive biases to shape and reinforce beliefs." (6)

In assessing the poor data and anecdotal accounts of X-ray burns that were available, early radiologists perceived patterns. Some imagined that X-ray burns only occurred in the absence of aluminum shields. Others perceived the incidence of X-ray burns to comport with the theory that they were actually microbial infections. Knowing that exposure to X-rays is directly responsible for X-ray burns, we can deduce that these patterns were not real, and that early radiologists were perceiving patterns that were either not real or were not meaningful.

Given the human proclivity for perceiving false patterns, it isn't surprising that early radiologists subscribed to a variety of beliefs regarding X-ray burns. X-ray burns were, after all, a new phenomenon. But it still remains to explain why early radiologists subscribed to the particular views that they held, as opposed to other ones. In particular, why did so few contributors to *AXJ* advocate the theory that X-ray burns were caused by X-rays? Why were some false patterns more appealing than others? And why were real patterns—for instance, the fact that X-ray burns only occurred after exposure to X-rays—neglected?

Vocational Bias

As we've seen, Thomson had already conducted an experiment that strongly suggested that electrical fields were not responsible for causing X-ray burns. However, even in the absence of such experiments, why wouldn't exposure to X-rays have been the first possibility entertained? Given that all X-ray burns occurred subsequent to exposure to X-rays, X-rays, it might be expected, would have been the prime suspect. So why were early radiologists so inclined to suspect anything other than X-rays as being responsible for X-ray burns?

Thomson's critique of Leonard may offer a clue, at least regarding the propensity to identify electricity as the alleged cause. As fascinated and informed as many early radiologists were with electricity, their expertise was with the human body, not electricity. "He endeavors to show that electro-static charges or effects are the true cause of the dermatitis and not Roentgen rays," wrote Thomson of Leonard. In the process, Leonard, "misinterprets very ordinary electrical phenomena and conditions."[244]

[244] Elihu Thomson, "Roentgen Ray Dermatitis," *The American X-Ray Journal*, Vol. 4, No. 1, January 1899, 494.

Thomson or Tesla, neither of whom subscribed to the view that electricity was the cause of X-ray burns, were experts regarding electricity. Both would have been very familiar with the dangers that electricity posed. However, having worked intimately with electricity for decades and never experienced precisely the injuries early radiologists and their patients were reporting, they also recognized that the injuries that came to be known as X-ray burns were not among the dangers posed by electricity.

Interestingly, while Thomson quickly recognized that X-ray burns were not caused by electrical fields, it was the physicians' predictions that proved more prescient regarding the future medical applications of X-rays. For instance, in April 1896 Thomson conducted a public presentation on X-rays that was reported on in the *Boston Daily Globe*. Just as Emil Grubbe and others were demonstrating the therapeutic potential of X-rays to treat cancer, Thomson, the article notes, did not believe X-rays "had any curative effect on disease."[245] In addition, the article noted that "He ridiculed the idea that it would ever be possible to photograph the brain by this process."[246] The capacity to produce radiographic images of the brain was a long way off in 1896. However, this did not prevent Heber Robarts from displaying a very different attitude toward the potential applications of X-rays to neuroscience.

In 1897, Robarts attempted to produce a radiograph of the brain of death row inmate Arthur Duestrow. Robarts, accompanied by his fourteen-year-old son, who served as his assistant, attempted to produce a radiograph of Duestrow's brain in order to provide evidence of his insanity and potentially rescue him from execution. Robarts was unsuccessful, but advances in technique and equipment would eventually make such radiographs possible, not to mention lend credibility to the notion that such images could reveal neurological abnormalities that would

[245] No attribution. "Prof Elihu Thomson on the X-Ray." *Boston Daily Globe (1872-1922)*. April 23, 1896. ProQuest Historical Newspapers: The Boston Globe pg. 3.
[246] Ibid.

rescue inmates from the death penalty.[247] "What a glorious achievement in behalf of humanity will be recorded when the x-ray is the medium of determining with scientific precision the extent and character of that disease which dethrones reason and makes life a curse. Heaven speed the time of its arrival," wrote Charles Johnson, the former lieutenant governor of Missouri who had accompanied Robarts to the prison.[248]

These differences in outlook between Thomson and Tesla, on the one hand, and Robarts and his colleagues on the other suggest that there were biases of perspective embedded in the vocation of physician or radiologist that led to a *dis*inclination to suspect X-rays of harm and an *in*clination to suspect that they had additional virtues as a tool of medicine. Both groups (electricians and radiologists) rejected the notion that the technology that defined their profession was responsible for the injuries.

So why did so many early radiologists believe that X-ray burns were caused by something other than X-rays? Because the data available on X-ray burns was too limited and imperfect to overcome the emotional and cognitive biases of their vocation. For much of the period before 1900, many radiologists did not have personal experience with burns. Those burns that did occur took place under widely varying circumstances. This left the vocational biases of early radiologists, such as an aversion to believing that the device around which they were forging a new discipline was inherently harmful, unchecked. Early radiologists were therefore drawn to other plausible explanations, which had their own appeal in the historical context of the turn of the twentieth century. For instance, electricity remained something of a mystery, and was legitimately dangerous, and microbes were being revealed to be responsible for a large proportion of human suffering. Additionally, the rareness of X-ray burns initially permitted early

[247] See Adrian Raine, *The Anatomy of Violence: The Biological Roots of Crime*, New York: Random House, 2013. Raine's expert testimony led to one defendant being sentenced to life instead of death.
[248] Charles P. Johnson, "THE X-RAY IN THE CASE OF ARTHUR DUESTROW," *The American X-Ray Journal*, Vol. 1, No. 1, May 1897, 10. Johnson is incorrectly identified as an ex-governor of Missouri by *AXJ*. Johnson served as Duestrow's lawyer.

radiologists to categorize them as anomalies (idiosyncrasy) or attribute them to irresponsible use of X-ray apparatus.

"We Are Not Imitators"

This paper has demonstrated that early U.S. radiologists subscribed to more than half a dozen theories of the cause of X-ray burns. It has also demonstrated that early U.S. radiologists adopted a variety of protective practices depending on which theory they subscribed to. Some of these practices, such as minimizing exposure times, provided a degree of protection. Others, such as asepsis, did not. These beliefs therefore had profound implications for radiologists, their patients, and the history of radiology, and this paper is the first to have thoroughly documented these views and identified their implications.

Recognizing this diversity, this heterogeneity, of beliefs and practices supports the claim that early U.S. radiologists incurred the risk of X-ray burns to themselves and their patients unwittingly. In Percy Brown's 1936 *American Martyrs to Science Through the Roentgen Rays*, he portrayed early U.S. radiologists as knowingly incurring the risk of injury because of their commitment to science and medicine. He noted that some people questioned their status as "martyrs," arguing that this term wasn't applicable because they did not recognize the risks they were incurring. Brown responded by trying to argue otherwise, writing, "On the contrary, this momentary period of complete nescience as to the deleterious qualities of the roentgen-rays was soon over. Within a period of ninety days after Rontgen's *Preliminary Communication*,

suspicion was aroused in the minds of many investigators that x-rays, or something evolved in the production of x-rays might have some ill effect on living tissues exposed to them."[249]

This paper has demonstrated that early U.S. radiologists did recognize the risks they were incurring. So why did Brown resist this conclusion? Because he was describing the sacrifices of his colleagues, and his purpose was to portray them in the best possible light. Portraying them as displaying recklessness borne of devotion to mankind was more appealing than portraying them as displaying recklessness borne of erroneous beliefs. Brown sought to counter those who questioned the bravery and heroism of the "martyrs" because, in doing so, such commentators questioned their very status as martyrs.

This paper has argued that early radiologists held false beliefs—a condition not generally regarded as laudable. However, Brown's aversion to this conclusion was unnecessary. While early U.S. radiologists did not recognize the risks they were incurring, they also did not proceed recklessly. This paper has demonstrated that early radiologists attempted to proceed responsibly. They adopted the protective measures that to them seemed most prudent and carried on a public dialogue with their colleagues in which they urged them to adopt similar measures.

Moreover, early radiologists were engaged in something fundamentally new. Kevles perhaps overstates the case when she writes, "The X-ray was the first technology to come with a built-in time bomb. The shock of this realization tore at the fabric of faith in all technology—and that was perhaps the biggest change the X-ray made in twentieth-century sensibilities."[250] Nonetheless, X-rays were fundamentally different than the medical technologies that preceded them, such as the stethoscope. X-rays utilized a newly identified phenomenon, and they emerged from the laboratory of a physicist to be deployed in the offices of physicians almost instantly.

[249] Percy Brown, *American Martyrs to Science Through the Roentgen Rays* (Springfield, Illinois: Charles C Thomas Pub Ltd., 1936), 6.
[250] Kevles, 4.

Radiologists were treading entirely new ground in the relationship between medicine and technology. As the cover of the inaugural edition of Robarts's journal declared, it was dedicated to the "practical application" of a "new science." Describing himself and his colleagues, Robarts noted, "We are not imitators."[251]

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Heber Robarts founded the journal in May 1897. He served as editor through April 1902. In the following edition—that of May 1902—Charles Renner took over as editor. He filled this position until July 1902. From the August 1902 edition through the period under consideration, H. P. Pratt served as "managing editor." The official editor, Hall, was unable to fulfill his duties during this period.

The authorship of some items in *AXJ* is unclear. Sometimes an item was reprinted from another source without providing the name of the author of the original. Other times, the *AXJ* editor seems to have summarized news from another source. I used my best judgment as to whether or not an item was a reprint or a summary, but it was not always entirely clear.

[251] Heber Robarts, "ANNOUNCEMENT," *The American X-Ray Journal*, Vol. 1, No. 1, May 1897, 1.

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