

## EARLY CLINICAL USE OF THE X-RAY

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### ABSTRACT

Western medicine has long been dominated by a faith in the value of science and a belief in the power of technology. I study the history of how technology came to be seen as useful by focusing on one of the most dramatic new tools ever discovered: the X-ray machine. I use a statistically valid sampling of case records from 1900–1925 at the Pennsylvania Hospital to ask why and when physicians at these hospitals came to see X-rays as useful for patient care. Soon after the X-ray's 1895 invention there was seemingly worldwide agreement that it could be used to diagnose common conditions such as fractures and foreign bodies. However, it was only several decades later, after the underlying structure of the hospital changed due to importation of technologies from business, that X-ray images became seen as part of routine patient care.

### INTRODUCTION

If one considers what has happened to clinical practice in the United States over the past century, arguably no change has been more consequential than the widespread introduction of science and technology. The dominance of scientific thinking and technological intervention are evident in almost every part of health and health care. And of the many dramatic innovations we have seen over the past century, perhaps none has had a more ubiquitous impact than the use of imaging technology (1,2). We need think only of the quotidian use of the X-ray, the computer assisted tomography scan, the magnetic resonance image, the positron-emission tomography scan, and others. Not only do such imaging technologies color almost every aspect of patient care, the pictures they produce are usually viewed as trustworthy evidence, determinative findings in instances of clinical ambiguity. A significant portion of the rapidly increasing money spent on health care in the United States is spent on imaging technologies, and the tools are used

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at a much higher rate in the United States than in other industrialized countries (3).

If one wants to ask how and why medical technology has come to play such a dominant role in US medicine, the introduction of the X-ray machine makes an especially propitious case study. Unlike some innovations in medical thought and practice that were created as the result of a sustained series of experimental interventions, or even discoveries that came about as the result of a rapid series of incremental changes, the invention of the X-ray machine came at the moment when a physicist named William Conrad Röntgen, working in a small provincial German village, took a picture of his wife's hand. To do so he used rays that pierced the skin and revealed shadows of the bone beneath. These were rays about which Röntgen knew little, and thus he called them "X" rays. He sent the image of his wife's hand around the world on Christmas Day 1895 (4).

It is difficult to overestimate the widespread impact of this singular event (5). The sudden ability to see within the human body had a tremendous impact on almost every segment of society. Within the first year after its invention the X-ray was the subject of some 49 books and more than 1,000 articles (at a time when there were far fewer journals than we have today) (6). Because the equipment necessary to make an X-ray machine was cheap and the device was easy to use, X-ray machines were soon found in numerous locations, both medical and non-medical (7).

Within the medical world, X-ray images were initially attempted for many disparate conditions. While some parts of the body (such as the brain) were difficult to visualize with the new tool, numerous observers noted the ease with which foreign bodies (such as swallowed coins) could be located with new machine. Fractures, too, were amazingly easy to identify with the new rays. By 1900, only 5 years after its invention, the use of the X-ray machine was widely described as being essential for clinical care, especially for making a diagnosis of foreign bodies and fractures (8).

As appealing as "great moments in medicine" stories such as this may be, to understand the actual history of the uptake of the X-ray machine for clinical care is not nearly so simple. If we want to analyze the initial use of the technology, how it was actually applied to patient care, one useful place to start could be in hospitals. Hospitals at the end of the 19<sup>th</sup> century and the start of the 20<sup>th</sup> century were rapidly growing in number and size, increasing in structural complexity, and starting to be seen as clinically relevant not only as a last resort for the worthy poor but also as places where middle-class patients might want to come for health care (9).

Moreover, looking at patient care in hospitals eliminates one potential confounder in a study of early use of the X-ray, and that is the issue of transportation. The United States was a mostly rural country without many automobiles or paved roads. Many patients with a broken leg would find it difficult to make their way to an X-ray machine. Once admitted to a hospital, however, if that hospital had an X-ray machine, they did not need to travel to obtain the test. Moreover, hospitals that saved their patient records from the period (as hospitals that see themselves as being historic are wont to do), allow researchers to track utilization of the new technology using statistically valid, systematic sampling of those records.

### NEW TOOLS IN OLD HOSPITALS

This presentation is based largely on work performed using the case records of the Pennsylvania Hospital, the nation's oldest hospital, and one that takes its history very seriously (10). Similar to many other institutions, in the excitement that followed Röntgen's discovery, the hospital purchased an X-ray machine in 1897. To study how often and for what purpose the X-ray was clinically used, a systematic sample of 400 case records was obtained for each of the years 1900, 1909, 1920, and 1925 (Table 1). A comparable set of data were obtained from the New York Hospital, which revealed similar findings, but are not presented in the interests of time.

Using Table 1, if we first consider the overall use of the X-ray for all patients, it was used only rarely in 1900, and for fewer than 10% of patients in 1909. By 1925 about a quarter of all patients admitted

TABLE 1.  
*Use of the X-ray at Pennsylvania Hospital as a Percentage of Patients  
Having an X-ray Taken\**

Year	All Patients	Excluding Patients Admitted With Diseases of the Tonsils	Patients With Fractures Only
1900	1.31 (0.426-3.02)	1.33 (0.434-3.08)	8.7 (1.01-28.0)
1909	6.97 (4.68-9.91)	8.19 (5.51-11.6)	50 (26.0-74.0)
1920	16.78 (13.4-20.6)	22.02 (17.7-26.8)	100 (76.8-100)
1925	25.25 (21.0-29.8)	32.54 (27.2-38.2)	85.7 (57.1-98.2)

\*95% confidence intervals in parentheses.  
From Howell (16) with permission.

to the hospital had some sort of an X-ray examination performed. One can start to refine the analysis a bit by excluding patients admitted for removal of their tonsils and/or adenoids. Tonsillectomies and adenoidectomies were becoming quite popular. They were based on the widespread theory of "focal infection," the idea that microbes growing in pockets such as provided by the tonsils and adenoids could result in systemic bodily illness, and that the only way to effect cure was to remove the offending organisms and the organ that harbored their presence. These patients who needed removal of their tonsils and/or adenoids were admitted only overnight, and generally were not seen as having any reason to have an X-ray image taken. Removing them from the analysis gives another, perhaps more realistic idea of the overall use of X-rays in the more seriously ill patients admitted to the Pennsylvania Hospital, but does not change the overall impression.

The third column in Table 1 shows patients who were given a diagnosis of a fractured bone. This column is perhaps the most telling. Not only were fractures seen as a key diagnosis, easily visualizable with an X-ray image, fractures were a common problem. This was especially true on the rapidly industrializing Eastern Seaboard. Young men might become injured working on the Philadelphia docks; others might find themselves running afoul of the trolley cars or falling from the apartment buildings. For patients suspected of having a broken bone, using an X-ray mattered to both physician and patient. It was a less painful method of diagnosis for the patient than the traditional use of manual manipulation of the suspected broken bone, and potentially a more precise and modern technique for the physician. Moreover, fractures were relatively easy to detect with an X-ray, and by 1900 they were widely described as being best diagnosed with the new tool.

The Pennsylvania Hospital had purchased an X-ray machine in 1897, and had even assigned someone to be in charge of the machine. Yet despite the widespread attention paid to this exciting new tool in the medical literature, it was only rarely used to diagnose fractures in the Pennsylvania Hospital 1900. Even in 1909, use was far less than the medical literature would suggest was proper. Why? Rather than ask why the X-ray was so little used in 1900 and 1909, it might be more productive to ask what happened that led to the increased X-ray use by the close of the first quarter of the 20<sup>th</sup> century.

One major change was in who was designated to operate the machine. From 1897 to 1909 the X-ray machine was run by the chief medical resident, a position created in 1897, whose duties included being in charge of a variety of other equipment (as well as other responsibilities). In 1910 and 1911 the former chief resident stayed on for a year to run the

X-ray machine. The first promptly declared the old equipment obsolete and insisted on the purchase of new equipment.

But the year 1912 marked a qualitative shift in the operation of the X-ray machine. In that year responsibility shifted to David Bowen, who would devote his career to using the X-ray machine. He was thus an early form of a specialist in that he decided to limit his medical practice (in this case to use of a new machine). He was someone who would come to be known as a radiologist (or sometimes a Röntgenologist, in honor of the machine's inventor). He had his own department; he had space assigned to the department; from 1919 on he had an assistant. Bowen also was able to keep a percentage of the fees generated from paying patients. Such patients were a small but growing minority of hospitalized patients over this period. Bowen thus had reasons both professional and personal to encourage use of this new technology.

Another important change over this period was a new way of conceptualizing the meaning of scientific medicine in general and of a scientific hospital in particular. Hospitals marked themselves as being modern in part by recording information in patient records using a systematic approach. This involved the use of new organizational methods such as the graph or the memo and new tools such as the typewriter. Scientific record-keeping was something seen as significant enough to be featured in hospital annual reports. All of these record-keeping innovations became more widely evident in case records between 1900 and 1925. Results of laboratory tests — including not only the X-ray, but also older tests such as urine analysis and newer ones such as the electrocardiogram — started to be recorded in standardized ways that systematically included specific data elements. Omitting one part of the data thus became obvious. Tests were also recorded on specific forms that by their very existence reified a separate department, run by people with specialized knowledge about the use of the test. All of these changes marked the introduction of medical technology into America's oldest hospital and all facilitated (and encouraged) use of a variety of technologies, including the X-ray machine.

### **X-RAY DISCUSSION AT ACCA: DANGER AND DISCORD**

The X-ray machine did not escape the attention of members of the American Clinical and Climatological Association. At the 15<sup>th</sup> Annual Meeting in 1898, along with a talk on the "Climatology of Nudity," members heard a presentation by Francis H. Williams on "Some of the Medical Uses of the Röntgen Light." Williams opined that the new tool had

passed from being a new fad and was now a central element of clinical care. He also thought that there was no need for any fear associated with use of the X-ray (11). Afterwards, 22 members of the Association climbed to the 6,293-foot summit of Mt. Washington, where they enjoyed dinner.

Unfortunately, it soon became apparent that Williams was wrong, along with most other early adopters. The X-ray tube could, in fact, be quite dangerous not only for patients, but also for those physicians who were early users of the machine. Early X-ray users would test to see if the tube was putting out an adequate amount of X-ray by looking for a glow in their hand when put in front of the beam, a method of testing that would soon reveal itself to have deleterious consequences (12). Recent historical work has suggested that these early radiologists knew about the dangers involved more than they let on. They pushed ahead nonetheless into what they saw as a brave new world, and did so in a way that valorized the suffering that they doubtless experienced (13,14).

### LESSONS FROM THE PAST

This early history of the X-ray machine demonstrates that to understand the medical use of a machine, even one that from today's perspective seems to have such obvious utility, one must study more than simply the medical applications of the device. One must study how that machine is used within a specific social, political, and economic system. The technology to be considered is not only a machine; it is also the system within which that machine is used. In the case of the X-ray machine that would include the organizational structure of the institution, the people designated to run the machine, and the forms on which such use was recorded. Even though the published medical literature would suggest that the case for using X-rays to diagnose fractured bones was firmly established by 1900, it was not a regular part of patient care for decades to come. What was required for it to become a part of routine patient care included changes in the type of person who was running the machine, changes in the payment mechanism, and changes in the ways that data were conceptualized.

New diagnostic capabilities came at a cost. Use of the machine did have unintended consequences for early adopters. Some of those consequences were a direct result of early radiographers trying to accommodate to a new and unfamiliar world.

We now live in a world that is filled with technology, both medical and non-medical. It has been observed that "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it" (15).

Imaging technology has become so routine that it is easy to forget that it has a history. Knowing that, history may give us insight as we introduce even more new technology into the practice of clinical medicine.

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Some of this presentation is based on work originally published in *Technology in the Hospital*, where more detail may be found on the sampling methodologies as well as the findings from the New York Hospital (16).

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## DISCUSSION

**Schreiner, Los Altos:** Joel, that was very fascinating. The implication of a lot of what you said is that there was an independent push towards the use of X-rays based on the institutionalization of both the technology and the people administering that technology. From a medical history standpoint this is a very interesting disease to study because fractures were an extremely familiar event in 19<sup>th</sup> century and earlier America, a very common consequence of a vigorous and challenging outdoor life. If what you are saying is correct, that the use of X-rays was not necessarily driven solely by medical need, would the implication be that in the early days, when most doctors knew perfectly well how to treat a simple fracture, that the efficacy of the treatment was not proportional to the increase in X-rays? In other words, is there any way of gleaning from these hospital records whether or not the 10% of patients who were getting X-rays in the early days were having them taken for legitimate diagnostic issues? Or was it purely a sort of a self-replicating technology, in that the treatment outcomes wouldn't go up in proportion to the use of X-rays? The diagnostic procedure would thus be confirmatory rather than actually critical to the diagnosis. I am just wondering whether you have a sense that outcomes improved. Did the 10% figure actually represent the legitimate question of whether the physician was dealing with a complex fracture, and whether or not it needed to be treated with the cast versus a surgical intervention? Do you see any evidence that taking an X-ray image impacted outcomes to the same extent that it was taken up as a technology?

**Howell, Ann Arbor:** Yes, I not only have a sense, I also have data, which is even better. You ask good questions. First of all, as you suggest, people already knew how to diagnose fractures before the X-ray was invented. The problem was that the diagnostic procedure was fairly painful for the patient. If you grasp one piece of the bone here and one piece of the bone there, and you can move the two pieces independently, then there is probably a break in the bone. This isn't very pleasant procedure for the patient. The X-ray could theoretically reduce the need for such a procedure. But being able to use the X-ray also relied on another kind of technology, which was transportation. One of the advantages of working in the hospital was that everybody and everything was already there, including physicians, patients, and diagnostic technology. The problem was that most people who broke their bones weren't in hospitals and weren't near hospitals. Moreover, the early X-ray machine wasn't portable. So manual diagnostic techniques were all that many physicians had to use. However, hospitals become central for medical care just as the X-ray was being invented. This was during an industrial age on the Eastern Seaboard. Railroads were expanding, workers were unloading ships on the docks, and lots of people were breaking their bones and being taken to the hospital. To answer your specific question, I looked not only at the use of the X-ray to diagnose fractures, but also at the lag time between admission to the hospital and taking an X-ray. Early after the X-ray's invention there was a mean lag of 10 or 12 days between admission to the hospital and getting an X-ray taken. That being the case, we can infer that the diagnosis and treatment decision was made on admission, not on the basis of the X-ray image, which was taken later not to make a diagnosis or to guide therapy. Basically, the physicians got a new tool and they just wanted to see what the fracture looked like. By 1925, the median lag time was well under a day. Physicians were actually using the X-ray to make a diagnosis. Now, did it make a difference in terms of treatment? That's a much harder question to answer.

**Markovitz, Ann Arbor:** Joel that was a very fascinating talk. I was first of all fascinated to discover that once upon a time diagnostic radiology was a macho field.

It's changed. I wanted to ask you specifically, how did patients react to X-rays. The very name sounds very imposing. Were they worried about the effects? How did that go?

**Howell, Ann Arbor:** You bet they were worried. They were worried with good reason. They were worried because electricity in hospitals (and elsewhere) was new. People were still trying to work out whether to use DC or AC current, were still trying to agree on the voltage to use. There was a lot of electricity, there were a lot of loose wires, and patients and occasionally physicians would get electrocuted in hospitals. So yes, they were extremely worried. Offline I can show you a wonderful painting from 1926 showing a man getting an X-ray who looks extremely scared. [John Sloan (1871–1951), *X-rays*, 1926.]

**Hook, Birmingham:** I really enjoyed your talk. I wondered about radiology and cathode ray tubes outside of medicine and how their use was affected by medicine.

**Howell, Ann Arbor:** That's a great question. As I mentioned in the talk, cathode ray tubes were easy to make and use. Anybody who had a little bit of money could make themselves a cathode ray tube and take pictures. One of the most interesting aspects of the history is how X-rays became medical. They weren't always medical. Early in the 20<sup>th</sup> century lay entrepreneurs would set up stands to take X-rays at the opera house. People would set up stands on the street. People had their X-ray pictures taken to give to their beloved as if it were the most beautiful picture they had ever had. In *Magic Mountain*, Hans Castorp holds up his beloved's X-ray image of her chest and says "How often did I hold it, how often pressed it to my lips." Many people (outside of the novel) who bought X-rays didn't buy a medical X-ray; it wasn't being taken by physicians. Instead, it was being taken by photographers. One of the interesting changes is how the field of taking an X-ray picture becomes medical. That change is associated with the claim that the radiologist is not a photographer, taking the picture for the patient to take home or give to someone else. Rather, the radiologist claims that they are a consultant. When making this claim, some use the specific example of physicians who do a blood count. If you come to me as a hematologist and I do a blood count, they say, I am not going to give you the smear. In a similar way, what you are buying from me as a radiologist is my expert opinion about what the X-ray shows, not the actual physical image itself. In this way the X-ray works its way into the medical world. The X-ray machine is obviously used outside of medicine for a variety of applications.

**Goodenberger, St. Louis:** Something you said stimulated a memory in me. When I was a kid you could walk into a shoe store and put on your shoes and put your foot under a fluoroscope and see your toes wiggle. Were there other commercial uses of this in the general public that you are aware of?

**Howell, Ann Arbor:** That comes at the tail end of what I was talking about — the non-medical use of the X-ray machine. I remember doing the same thing. It was a lot of fun.