SINCE 1895, ORTHOPAEDIC SURGERY RELIES ON XRAY IMAGING : A HISTORICAL OVERVIEW FROM DISCOVERY TO COMPUTED TOMOGRAPHY

R. VAN TIGGELEN

The first application of xray techniques to human beings was made in Germany by Wilhelm Conrad Röntgen in November 1895. From this first use, different groups became interested in creating and improving the technical devices.

Focusing on Germany, in honour of the centenary of the awarding of the first Nobel Prize in Physics to Röntgen in 1901, we present some of the milestones in xray imaging, from the first pioneer's approach on glass plates, cathode xray tubes, fluoroscopy, earlier communications leading to xray films and screens, rotating xray tubes, tomography and CT, classic textbooks, radioprotection aspects, as well as some contributions in radiological techniques and orthopedic pathology.

Keywords : xray history ; orthopaedic surgery history.
Mots-clés : histoire des rayons X ; histoire de la chirurgie orthopédique.

INTRODUCTION

The first application of xray techniques to human beings was made in Germany by the physicist Wilhelm Conrad Röntgen (1845-1923), in November and December 1895. Focusing on Germany, in honour of the centenary of the awarding of the first Nobel Prize in Physics to Röntgen in 1901, we present some of the milestones in orthopaedic radiology (fig. 1).

THE BEGINNING IN GERMANY

Although the radiographs taken with röntgen rays did not overly impress the members attending

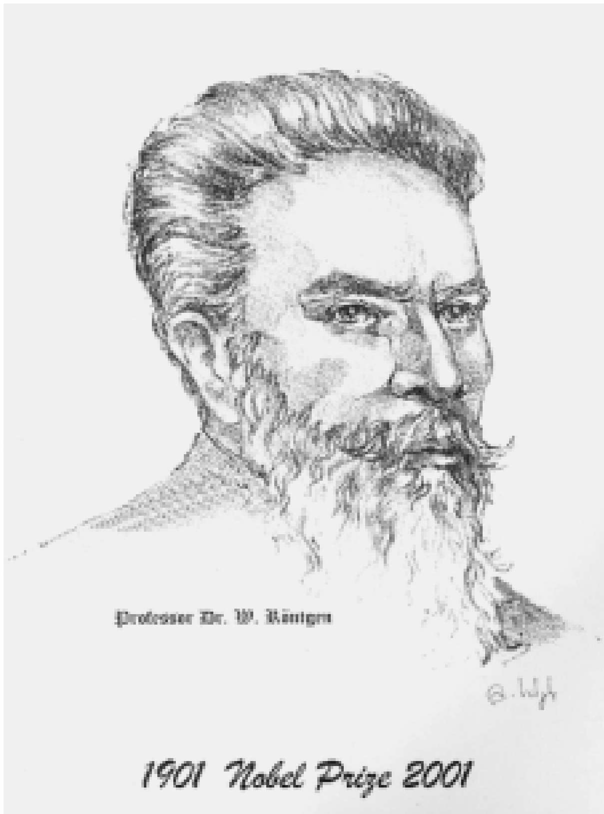


Fig. 1. — Centennial lithography made by Anne Velghe in 1995 for the Belgian Museum of Radiology.

Correspondance and reprints : R. Van Tiggelen, Belgian Museum of Radiology, Military Hospital Queen Astrid, Bruynstreet 2, 1120 Brussels.

the 50 year convention of the Society of Physics (president Wilhelm von Bezold, 1837-1907) in Berlin on January 4, 1896, the neuropsychiatrist and röntgen pioneer from Berlin, Moritz Jastrowitz (1839-1912), who had seen a reprint with Röntgen's radiograph of his wife's hand, immediately understood the significance of the discovery (15).

As early as January 1896, he talked about xrays before the "*Verein für innere Medicin*" in Berlin. The medical journal "*Deutsche medicinische Wochenschrift*" of January 30, 1896 (fig. 2) printed two lectures by M. Jastrowitz, given on January 6 and 20, 1896 on "*Die Roentgen'schen Experimente mit Kathodenstrahlen und ihre diagnostische Verwerthung"*, with a reproduced radiograph of a hand with a glass splinter near the joint of the middle finger from a 4-year-old patient. This radiograph was probably taken on January 12, 1896, by Paul Spies, chief physicist of a manufacturing plant (*Urania-Werke*).

The report stated that the discovery of xrays was one of the most important of its time. Initially, it was uniquely a physical phenomenon but the report stated : "This aspect is obviously important for medicine. The surgery could take advantage of it in producing bone images of a living person. Fractures, dislocations, ballooning and foreign bodies will be well distinguishable ; I draw your attention to the sharp contours of the finger joints, appearing bright on the photograph ; we will be able to look into the joints. It is also possible that we will be able to look inside the body, into the abdominal cavities, if the radiation will pass the walls, and detect some changes, perhaps denser tumors, which are less translucent for xrays".

Max Levy-Dorn (1863-1929) opened in October 1896 the first roentgenologic laboratory in Berlin. In 1906, he was appointed physician-in-charge of the roentgenologic ward of the "*Rudolf-Virchow-Krankenhaus*" (23).

Later, perhaps the most famous German roentgen pioneer Heinrich Ernst Albers-Schönberg (1865-1921), opened a private institute with a phthisiologist Gustav Georg Deycke (1865-1940) in Hamburg, in 1897. Earlier, he was a gynaecologist but he became the first physician in Germany certified in roentgenology. He was cofounder of the "*Fortschritte auf der Gebiete der Röntgenstrahlen*" (*FoRö*) in 1897. In 1905, he opened the Institute of Roentgenology at the "*Allgemein Krankenhaus S*t. *Georg*".

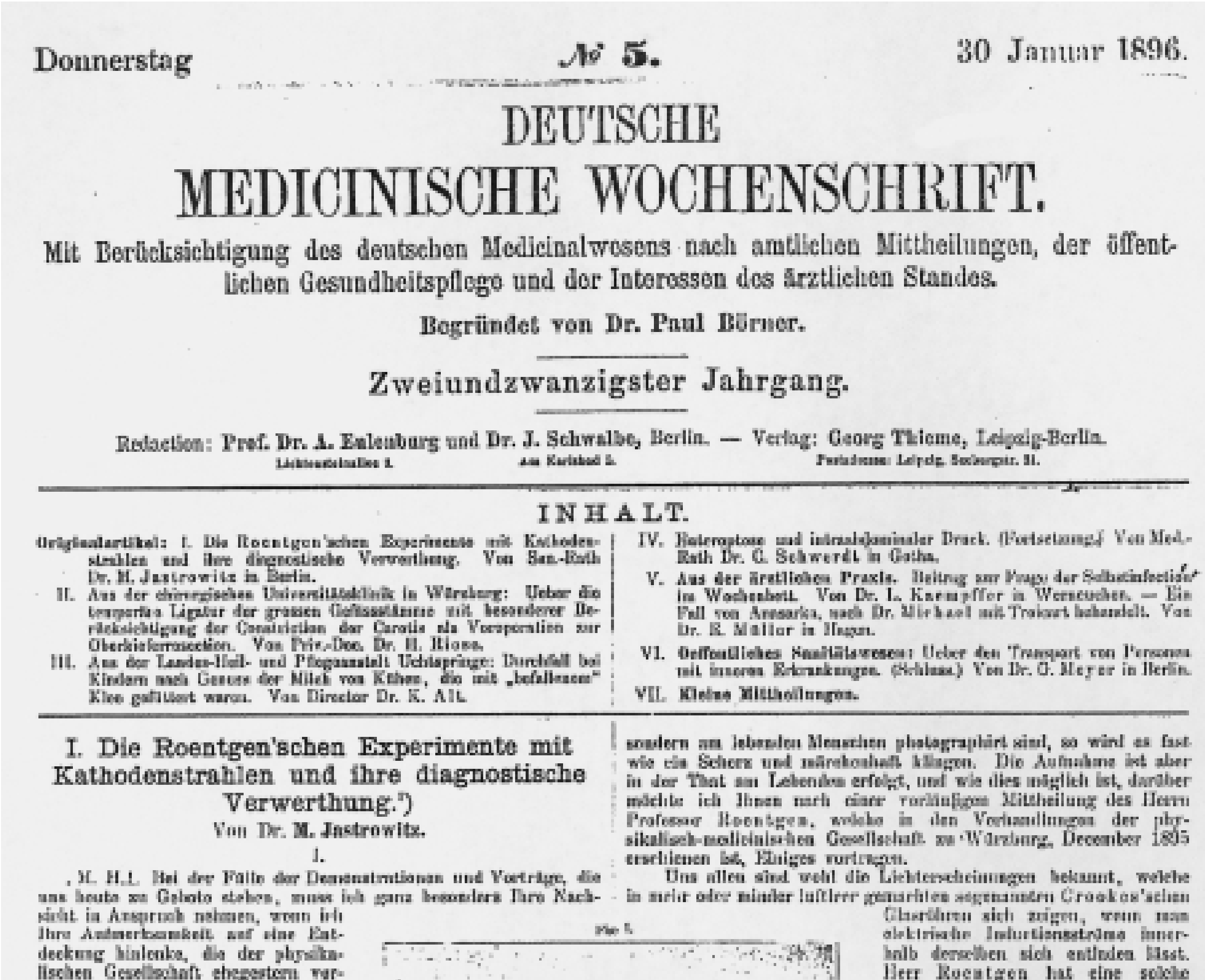
Hermann Gocht (1869-1938) was assistant in the surgery department of the "*Allgemein Krankenhaus Hamburg-Eppendorf*". He established an institute of roentgenology (first xray image on March 20, 1896) with the surgeon Hermann Kuemmel (1852-1937) in the same hospital (23).

FIRST TECHNIQUES TO IMPROVE SKELETAL IMAGES, … AND THE FIRST UNDESIRABLE EFFECTS OF RADIATION

Two major technological developments occurred during the early months of 1896. First, there was the xray tube designed in 1896 by Sir Herbert Jackson (1863-1936), a British radiophysicist. A small platinum disk placed at an angle in the center of a Crookes tube coupled with a curved cathode to focus the cathode rays on a small spot on the target was immediately adopted. This tube design made sharp focused radiography possible.

Prior to 1910, the best known German tube was manufactured by *Emil Gundelach in Gehlberg* (Thüringen) (fig. 4). The *Müller GmbH* produced tubes until after World War I. The German giant in the electromedical field is now the *Siemens-Reiniger-Werke Aktiengesellschaft* (*SRW* or *SiReWA*) in Erlangen. *SRW* resulted from the merging of the electromedical section of *Siemens and Halske* (Berlin), *Reiniger*, *Gebbert and Schall* (Erlangen) (fig. 5), *Veifa-Werke* (Frankfurt-Main), and *Phönix Röhrenwerk* (Rudolstadt/Thüringen). In 1925 they created a common sales outlet, the *Siemens-Reininger-Veifa GmbH*. The consolidation was finalized in 1932.

Secondly, there was the fluorescent screen, a critical item in Röntgen's discovery of the xray, which was proposed and was shown to shorten the exposure time and improve the image.In January 1896, Michael Pupin (1858-1935), an American physicist and röntgen pioneer, was the first to use fluorescence to reinforce the exposure of a medical radiograph (11, 22). In the "*Deutsche Medicinische*



Donnerstag № 5. 30 Januar 1896.

DEUTSCHE
MEDICINISCHE WOCHENSCHRIFT.

Mit Berücksichtigung des deutschen Medicinalwesens nach amtlichen Mittheilungen, der öffentlichen Gesundheitspflege und der Interessen des ärztlichen Standes.

Begründet von Dr. Paul Börner.

Zweiundzwanzigster Jahrgang.

Redaction: Prof. Dr. A. Eulenburg und Dr. J. Schwalbe, Berlin. — Verlag: Georg Thieme, Leipzig-Berlin.

INHALT.

Originalartikel: I. Die Roentgen'schen Experimente mit Kathodenstrahlen und ihre diagnostische Verwerthung. Von San.-Rath Dr. M. Jastrowitz in Berlin. — II. Aus der chirurgischen Universitätsklinik in Würzburg: Ueber die temporäre Ligatur der grossen Gefässstämme mit besonderer Berücksichtigung der Constriction der Carotis als Voroperation zur Oberkieferresection. Von Priv.-Doc. Dr. H. Riese. — III. Aus der Landes-Heil- und Pflegeanstalt Uchtspringe: Durchfall bei Kindern nach Genuss der Milch von Kühen, die mit „befallenem" Klee gefüttert waren. Von Director Dr. K. Alt. — IV. Enteroptose und intraabdominaler Druck. (Fortsetzung.) Von Med.-Rath Dr. C. Schwerdt in Gotha. — V. Aus der ärztlichen Praxis. Beitrag zur Frage der Selbstinfection im Wochenbett. Von Dr. L. Kaempffer in Wernsuchen. — Ein Fall von Anasarka, nach Dr. Michael mit Troicart behandelt. Von Dr. R. Müller in Hagen. — VI. Oeffentliches Sanitätswesen: Ueber den Transport von Personen mit inneren Erkrankungen. (Schluss.) Von Dr. G. Meyer in Berlin. — VII. Kleine Mittheilungen.

I. Die Roentgen'schen Experimente mit Kathodenstrahlen und ihre diagnostische Verwerthung.[1])

Von Dr. M. Jastrowitz.

I.

, M. H.! Bei der Fülle der Demonstrationen und Vorträge, die uns heute zu Gebote stehen, muss ich ganz besonders Ihre Nachsicht in Anspruch nehmen, wenn ich Ihre Aufmerksamkeit auf eine Entdeckung hinlenke, die der physikalischen Gesellschaft ehegestern vorgelegt worden ist. Dieselbe scheint bedeutsam auch für die Medicin zu sein. Ich glaube, dass die Natur dieser geradezu wunderbaren Entdeckung es rechtfertigen wird, wenn ich hier gleichsam als Referat erstatte, was zur Zeit darüber bekannt gegeben worden ist. Die Uebermittelung der neuen Entdeckung verdanke ich der Freundlichkeit des Assistenten an der Sternwarte Herrn Professor E. Goldstein, welcher Ihnen wohl durch seine Arbeiten über Kathodenstrahlung in luftleer gemachten Glasröhren bekannt ist. Der Entdecker ist Herr Professor Roentgen in Würzburg.

Ich will zunächst mit einer kurzen Demonstration beginnen: Sie sehen auf dieser Photographie das knöcherne Gerüst einer menschlichen Hand, Mittelhandknochen, nebst Phalangen. Bei scharfem Hinblicken gewahrt man eine feine helle Contour die Knöchel der Finger umziehen, welche Contour derjenigen der Weichtheile entspricht; ein Finger ist mit einem Ringe versehen, welcher noch dunkler als die Fingerknochen erscheint. Der Ring schwebt über dem Knochen der betreffenden Phalanx gleichsam wie der Ring über dem Saturn (Fig. 1). Wenn ich Ihnen sage, dass diese Knochen nicht von einem Skelett, sondern am lebenden Menschen photographirt sind, so wird es fast wie ein Scherz und märchenhaft klingen. Die Aufnahme ist aber in der That am Lebenden erfolgt, und wie dies möglich ist, darüber möchte ich Ihnen nach einer vorläufigen Mittheilung des Herrn Professor Roentgen, welche in den Verhandlungen der physikalisch-medicinischen Gesellschaft zu Würzburg, December 1895 erschienen ist, Einiges vortragen.

Uns allen sind wohl die Lichterscheinungen bekannt, welche in mehr oder minder luftleer gemachten sogenannten Crookes'schen Glasröhren sich zeigen, wenn man elektrische Inductionsströme innerhalb derselben sich entladen lässt. Herr Roentgen hat eine solche Röhre, durch welche die Entladungen einer Ruhmkorff'schen Maschine gingen, mit einem dunklen Carton bedeckt, und da er seine Untersuchungen im dunklen Zimmer anstellte, war von den Lichterscheinungen nichts zu bemerken. Allein auf einer mit Bariumplatincyanür bestrichenen Platte, wie solche die Physiker zur Erkennung der für das menschliche Auge unsichtbaren Strahlen gebrauchen, gewahrte er jedesmal bei der Entladung einen Lichtschimmer, ein fluorescirendes Aufleuchten, welches von der Kathodenstrahlung innerhalb der Glasröhre ausging. Diese Lichterscheinung erstreckte sich bis auf zwei Meter Entfernung. Es lag nahe, die Natur dieser Lichterscheinung in Bezug auf ihre Fähigkeit, Substanzen verschiedener Art zu durchdringen, zu untersuchen. Da sie durch den dunklen Carton hindurchgegangen war, so fragte es sich, ob sie auch andere Materien zu passiren imstande sei. Roentgen hat verschiedene Stoffe daraufhin geprüft. Er theilt mit, dass diese Strahlung selbst durch ein Buch von tausend Seiten hindurchging und sich an der prüfenden Platte durch Fluoresciren verrieth, ebenfalls durch mehrfache Lagen mehrere Centimeter dicker Guttapercha. Auch durch tannene Bretter bis 3 cm Dicke ging sie hindurch. Bei den Versuchen mit Metallen stellte sich heraus, dass die Passirfähigkeit des Lichtes ihre Grenzen

Fig. 1.

Nach dem Roentgen'schen Verfahren aufgenommen von P. Spies in Berlin.

[1]) Vorgetragen im Verein f. innere Medicin am 6. und 20. Januar 1896.

Fig. 2. — Front page of the "*Deutsches medicinische Wochenschrift*" of January 30, 1896

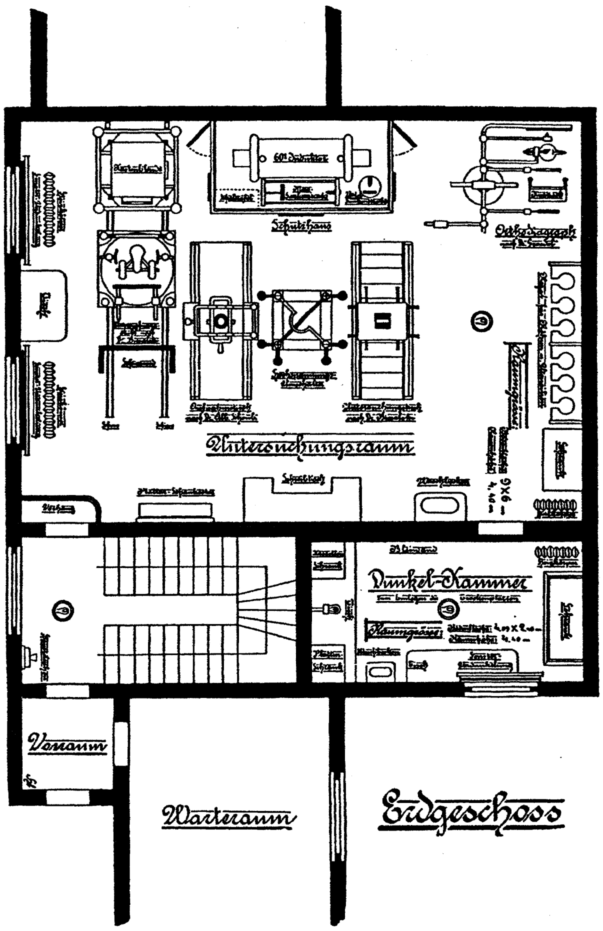


Fig. 3. — General plan of the radiology department of the "*Städtischen Krankenhaus am Urban*" Berlin, 1908 (*FoRö*, band XII, 136).

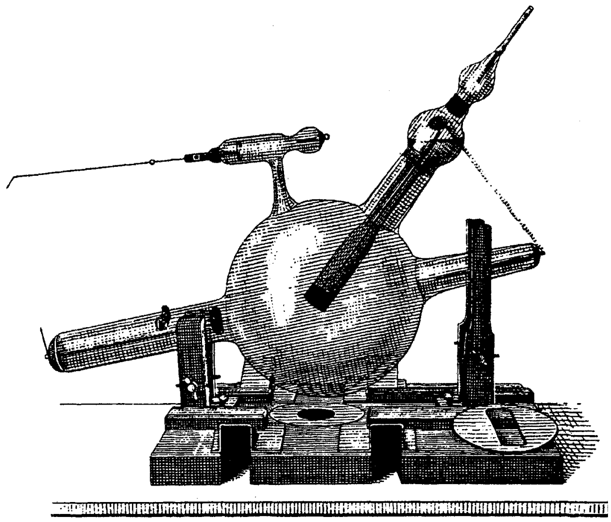


Fig. 4. — Illustration showing an early xray tube (*Albers-Schönberg, H. Technische Neuerungen. FoRö,* July 1904, 137-149).

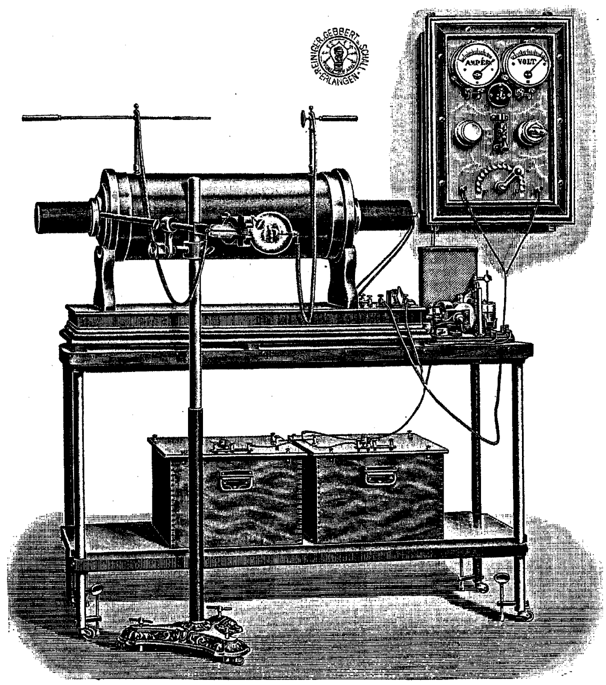


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Fig. 5. — Xray equipment manufactured by *Reiniger, Gebbert* and *Schall* in 1898 (Belgian Museum of Radiology).

Wochenschrift" of April 9, 1896, B. Schäfer, a physician from Charlottenburg described the utilization of a barium-platinocyanide screen manufactured by "*Kahlbaum*" in Berlin (*Kahlbaum* merged later with *Schering)* (24).

Thomas Edison (1847-1931), American inventor and pioneer röntgen experimenter, had determined that calcium tungstate was the most suitable material for making fluorescent screens (14). Adapting this idea, the German Gehler soon began manufacturing intensifying screens using calcium tungstate. Under the name "*Gehler-Folie*", large quantities were exported to radiologists throughout the world.

In the early days of radiology, only fluoroscopy was performed for the detection of fractures and the assessment of subsequent therapy. The musculoskeletal tissues have thus been instrumental in revealing the risk associated with radiation. Often these tissues have manifested the undesirable effects associated with occupational exposure to radiation.

Within the first months after the discovery of the xray and coinciding with enthusiastic experimentation and application, some investigators noted skin changes due to the effects of too much exposure.These changes were most evident in the hand because the radiographer commonly used his own hand to gauge the penetrating power of the tube.

In Germany, the first radiation burn of a hand was reported in the "*Deutsche medicinische Wochenschrift*" on July 9, 1896. The description originates from O. Leppin, an engineer who used his left hand as the test object for tube testing (18).

In general, the early investigators were not afraid of the xrays because they could neither see, hear, smell, nor feel them. Moreover, any effects were delayed and were often attributed to some other cause. Nevertheless, long and repeated exposure resulted in much damage to the hands and even in many deaths of young men. There were many martyrs to radiology in those early days. In 1936 the "*Deutsche Röntgen Gesellschaft*", upon the suggestion of Hans Meyer (1877-1964), a radiotherapist from Bremen, erected a monument to the xray and radium martyrs of all nations. The monument stands near the radiology department of the "*Allgemein Krankenhaus S[t].Georg*" in Hamburg, the hospital of Heinrich Albers-Schönberg, the celebrated xray pioneer who died from radiation injuries in 1921. Inscribed on the column (fig. 6) are the names of xray and radium workers of many nationalities (71 Germans) who died before 1936, as well as the following inscription (19) :

"*Den Röntgenologen und Radiologen aller Nationen, Ärzten, Physikern, Chemikern, Technikern, Laboranten und Krankenschwestern, welche ihr Leben zum Opfer brachten im Kampfe gegen die Krankheiten ihrer Mitmenschen. Sie waren heldenmütige Wegbereiter für eine erfolgreiche und gefahrlose Anwendung der Röntgenstrahlen und des Radiums in der Heilkunde.*

Unsterblich ist des Toten Tatenruhm.

Die Deutsche Röntgen Gesellschaft".

Fig. 6. — Monument to X-ray and radium martyrs in Hamburg (Courtesy of Philips Medical System).

In the "*Deutsches Röntgen-Museum*" you can find the amputated hand of Professor Paul Krause (1871-1934) exhibited as a testament for future generations.

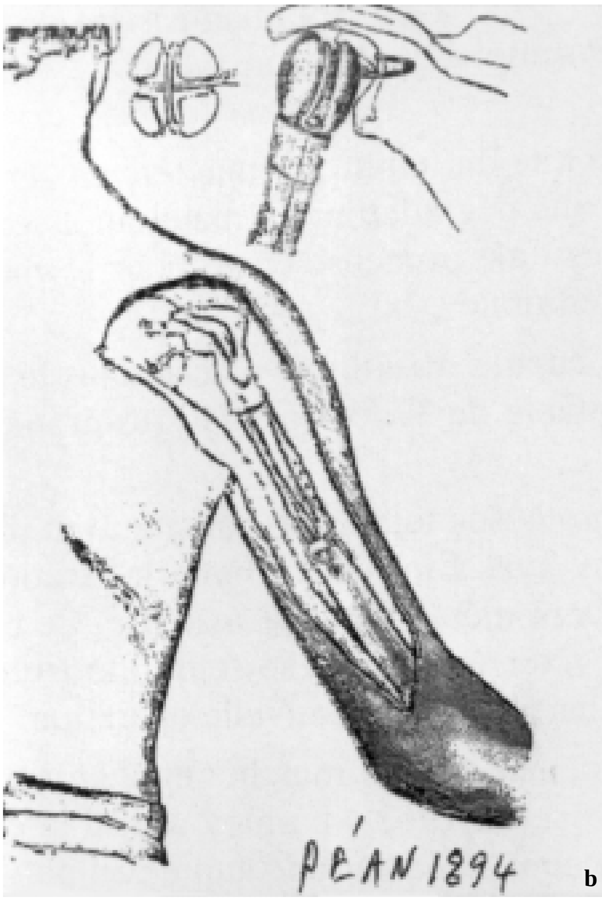

Fig. 7. — Radiogram and drawing presented in Paris on June 23, 1896, showing a shoulder prosthesis that Péan implanted in 1894. (Histoire des Sciences Médicales 2000, XXXIV, 1, p. 6).

RADIOLOGY'S FIRST CONTRIBUTION TO ORTHOPAEDIC SURGERY

The earliest and most obvious clinical application of the xray was for detection and characterization of fractures and dislocations. Several reports described clinically unsuspected fractures, especially near joints, that could only be demonstrated radiographically.

A major advantage of radiology was that it could be performed through an ordinary plaster cast without the need to remove a splint. This technique also significantly altered the concept of fracture healing. Improper setting of a fracture could lead to deformity and secondary joint disease.

During the meeting of the "*Berliner medicinische Gesellschaft*" on February 5, 1896, Frans König (1832-1910), "*Direktor der Chirurgisches Klinik der Charité in Berlin*", reported a case of a 46-year-old female patient with a neoplasm in the tibia (16). Following the amputation, he compared the operative specimen with the radiogram. Reading the xray shadows, he concluded that the tibia was destroyed, not by an infection, but by to a neoplasm (17).

In 1899/1900, Lorenz Sudeck (1866-1938) recognized "*akuten, entzündlichen Knochenatrophie*", hyperemia caused by an injury and accompanied by pain and bone changes (26). Probably the first xray of an endoprothesis was made in the spring of 1896 on a patient operated by Jules Péan (1830-1898) in Paris (fig. 7) (20).The first radiography of a metallic osteosynthesis appeared in the beginning of the 20th century (Albin Lambotte, (1866-1955), in Belgium ; Vitorio Putti, (1880-1940) in Italy).

Before WWI, some surgeons, such as Sir Robert Jones (1855-1933) of Great Britain and Lorenz Böhler (1885-1973) of Austria, began to specialize in traumatic bone surgery.

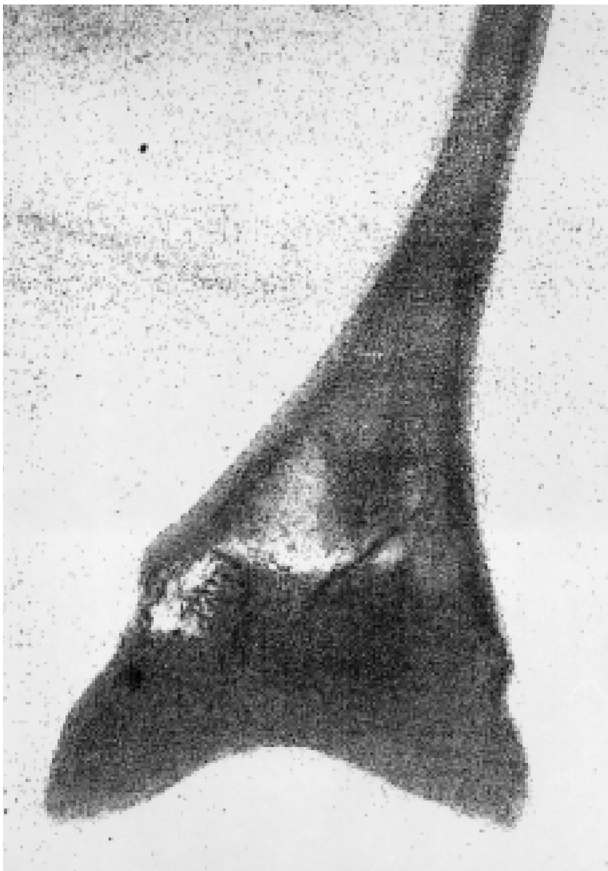

Fig. 8. — Radiogram of femoral osteomyelitis presented in Paris by P. Oudin in January 1896 (G. Pallardy *et al.* 1989, 114).

When the classic article on xray diagnosis of osteomyelitis was published in 1918 by Frederich Baetjer (1874-1933) (1), a Baltimore radiologist, a similar case (20) had already been described in 1896 by the Parisians Paul Oudin (1851-1923) and Barthélemy Toussaint (1852-1906) (fig. 8).

With an image providing a permanent record of the fracture, the need for more exact diagnosis and anatomic reduction became apparent. The first medical malpractice case in which an xray image was admitted as evidence occurred in England in the summer of 1896. This case alleged failure to diagnose a cuboid fracture (13).

In Germany, Max Immelmann (1864-1923), who had created a private xray department "*Medicomechanisches Institut mit Röntgenlaboratorium*" in Berlin (1896) and had given the first educational program for medicotechnical assistants (MTA) (20), wrote what is assumed to be the first article on the medicolegal topics : *Über die Bedeutung der Röntgenstrahlen für den ärztlichen Sachverständigen* (14), in the "*Zeitung Medizinalbeamte*" (1901). Subsequently, the threat of legal action was a potent stimulus for adopting routine radiography in the diagnosis and treatment of fractures.

CONTRIBUTIONS FROM CONFLICTS

War has been a regular stimulus to rapid advancements in many technologies, with ultimate transfer of the improved technology to the improvement of civilian services once the war was over. This has been particularly true for radiology, even during its earliest years.

Soon after the discovery of the xray, military organizations realized the potential contributions of xray images to the treatment of musculoskeletal injuries. For example, the "*Kriegsministerium*" assigned Otto von Schjerning (1853-1921), a military physician, röntgen pioneer, and father of the German Medical Military Corps, and Fritz Kranzfelder (1858-1907), a ballistic expert, to evaluate the surgical usefulness of the röntgen method. Their carefully worded, but otherwise promising report was published in April 2, 1896 in the "*Deutsche medicinische Wochenschrift*" (25).

They found the xray valuable for locating foreign bodies and treating fractures. This was reported in the medical literature and influenced physicians' attitudes and patient care. They emphasized the value of xrays ; facilities should be made available for the medical unit closest to the action so that wounds and fractures would be properly evaluated and treated. This further influenced the management of musculoskeletal trauma.

These early military experiences with xray diagnosis led to abrupt changes in the methods of treating injuries. Foreign body localization was rapidly perfected and the use of probes abandoned. With the number, size, and distribution of foreign bodies and fracture fragments accurately determined, surgery became directed and more successful. Unnecessary surgery was recognized and avoided. Once these principles were learned in the military, they quickly spread to civilian practices to the benefit of many.

The grid was introduced just before World War I ; it was discovered in 1913, by the Berliner radiologist Gustav Bucky (1880-1963) (5, 6).

At the begining of the war, radiology was far from a mature specialty. The war effort required more trained radiologists and technologists than existed. It also demanded standardized, simple, reliable, and safe equipment. Thus, the war stimulated organized training programs, development of portable xray units, and replacement of glass plates with film.

The development of Coolidge's hot-cathode tube (7, 8), (William David Coolidge, American physicist, 1873-1975), especially the fine focus type cooled by water, was introduced in Europe by the American medical services during WW I, and the movable grid, created by Hollis Potter (1880-1964), a Chicago radiologist, made striking refinements possible in diagnosis, especially in deeper and heavier skeletal structures.

Another very important advance was the discovery of conventional tomography (27). Even the earliest pioneers recognized a major shortcoming of radiography : the method superimposed the shadows of all structures in the path of the xrays, and this often obscured the locations of interest. They knew the xray pictures were two-dimensional representations of three-dimensional objects, and they partially overcame the problem by obtaining images in various projections, just as we do today. However, a method was needed to create images of the skeleton and other organs without overlapping the structures. This concept, body-section tomography, was also discovered during WW I.

In 1916, the French dermatologist André Bocage (1892-1953) was drafted for the war and, being tired of the daily measurements, proposed a revolutionary method : tomography (2, 27). He may well be considered to be the founder of this new radiological technique. The tomograph is a machine that can make a radiological cross-section of an organ at any given depth. Bocage did not file his patent until 1922.

Several pioneer tomographers, including Germans (Gustav Grossman (11, 12, 27), 1878-1957, former director of *Siemens-Reiniger-Veifa GmbH*, *Siemens-Halske* and *Sanitas* ; Ernst Pohl (21, 27) , 1878-1912), contributed immensely.

The generalization of this method did not occur until the late 1930's and lasted through the 1970's, which is considered to be the golden age of famous tomographers.

Until the First World War radiographic images were made on photographic plates. It is easy to imagine how easily these plates could break, especially in the mobile radiological units. The photographic cellulose film that had long been used for dental radiology replaced these plates. In 1924, the American Eastman Kodak Company became the pioneer of radiographic filming. This new vision was generalized. The German industries (Agfa, Ansco, Cawo, Schleussner) contributed to the expansion of the film, which is still being used today (9, 10).

In 1929, Albert Bouwers (3) (4), a Dutch xray engineer, improved these tubes by using the revolving anode, which is also still used today. The xray tubes now had better heat resistance and duration.

World War II again required major educational and equipment procurement efforts. Combat musculoskeletal radiology had become routine. Radiology, now a mature specialty, made major contributions to advances for military and civilian populations.

Fluoroscopy was used in operating rooms from the beginning. The introduction, in 1928, of the spectacular head surgical fluoroscopy by the "*Kryptoskop*" manufactured by H. Patzer, a German manufacturer in *Hermsdorf-Thüringen*, was a further step.

However the first real image intensifier (fig. 9) (Westinghouse USA, marketed for the first time in 1952) (9) in Germany was the famous unit BV20 for surgical fluoroscopy, designed by *C.H.F. Müller* (later Philips) in 1956 (23). The equipment consists of the Z-shaped support, the single-tank transformer and tube with attached cone, and on the other arm of the U an image intensifier with vidicon tube. The television monitor could be pushed around on its own casters. When television pick-up and monitoring was available, one could dispense with many of the sterility problems connected with

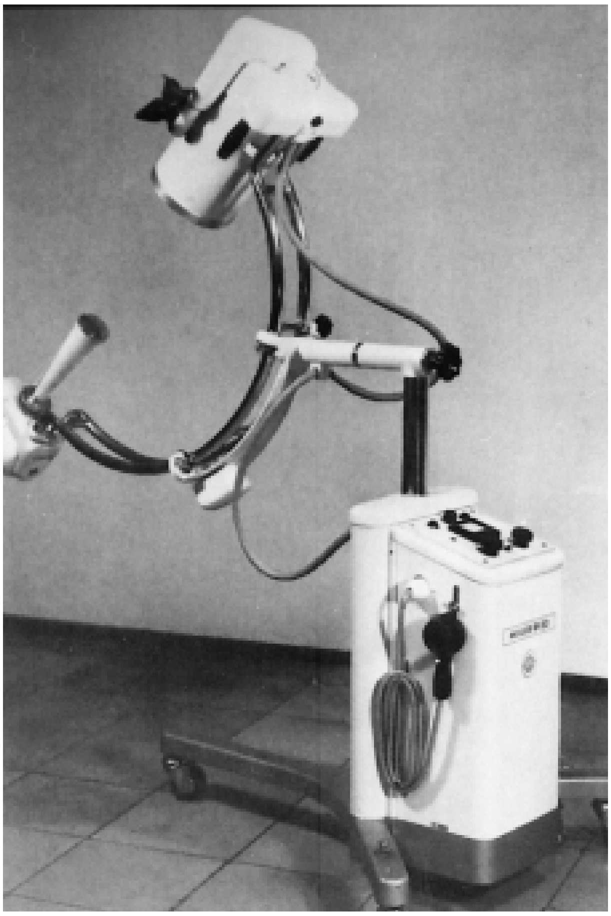

Fig. 9. — Probably the first image intensifier (BV 20) for surgical fluoroscopy designed by C. H. F. Müller in 1956.

looking into the eyepiece or mirror of an image intensifier. Moreover, everybody in attendance could see what was going on.

Another innovation from the US was the introduction of the automatic film processor by Pako. The first prototype was built in 1942. World War II delayed the "civilian" applications of the film machine, but it was very successfully employed in this country by the Armed Forces and a few private industries (9).

However the most important technological progress was made with the use of computers for decoding crypted military messages from the German and Japanese armed forces. This quickly resulted in numerous applications in both military and civilian domains. Hence the axial computer-assisted tomography was achieved, based on the principles of tomography discovered in the First World War and the power of the computers developed in the Second World War. This computer-assisted tomography was constructed in 1972 by an English team of researchers led by Godfrey Hounsfield (1919 -), who was awarded the Nobel price for medicine in 1979 (fig. 10).

CT provided body sections in the third dimension, a perspective always missing from conventional radiography, and CT also eliminated the problem of structures obscuring each other. As such, during the 1970's CT almost totally replaced mechanical body-section imaging. For musculoskeletal conditions, CT facilitated the treatment of fractures in complex anatomic regions such as the pelvis. It also revolutionized the characterization and staging of bone tumors.

Finally, other nonionizing medical imaging techniques were discovered and are, daily, used for orthopaedic application ; namely ultrasonography by the late 1950's and magnetic resonance since 1973. But … this is another history.

EDUCATION IN ORTHOPAEDIC RADIOLOGY

In the begining, textbooks of radiology relating to the musculoskeletal system were published for physicians who were bold enough to employ the xray in their practices and required a central source of fundamental information. Such books provided considerable technical information and practical hints about positioning. They examined the broad spectrum of potential applications of the xray, from the obvious fracture work through more experimental applications such as in the chest and heart. Radiation therapy received equal if not greater consideration compared with diagnostic radiology. However, with regard to diagnosis, musculoskeletal conditions were the most prominently considered clinical problems throughout these books. For example "*Das Lehrbuch der Röntgen-untersuchung zum Gebrauche für Mediziner*", by H. Gocht in 1898, was considered to be the first in Germany.

Fig. 10. — Probably the first EMI CT scanner in continental Europe. It was used in the radiology department of Professor R. Collard (Charleroi, Belgium) in 1975 and is now located in the Belgian Museum of Radiology.

To keep up with the rapid development of technology and specialization and to exchange experience, associations where founded shortly after the discovery of xrays. The Roentgen Society was founded in England on June 3, 1897, and locally in Berlin, on March 18, 1898, the "*Röntgen Vereinigung*", which helped to form the "*Deutsche Röntgen Gesellschaft*" on May 2, 1905 during their convention. The founders of the German Roentgen Society were : H.E. Albers-Schönberg, Hamburg ; W. Cowl, Berlin ; R. Eberlein, Berlin ; H. Gocht, Halle ; R. Grashey, Munich ; M. Immelmann, Berlin ; A. Köhler, Wiesbaden ; H. Rieder, München and B. Walter, Hamburg. As early as 1900, the first International Congress of Radiology was held in Paris by A. Béclère (10).

At this time the first national radiologic journal started. In Germany, the famous "*FoRö*" (fig. 11), founded in September 1897, by Albers-Schönberg with his office partner and friend G. Deycke, must be mentioned. In 1921, after the death of Albers-Schönberg, Rudolf Grashey (1876-1950) took over the editorship of the "*FoRö*".

Most of the early advances in skeletal radiology occurred in Europe, especially in Germany. Special mention should be made of the publication in 1903 of Albers-Schönberg, "*Die Röntgentechnik. Lerhbuch für Ärtze und Studierende*" and those from Rudolf Grashey with his "*Atlas typischer Röntgenbilder von normalen Menschen*", published in 1905. A major force was Alban Köhler, who published his first monograph on bone in 1910 : "*Lexikon der Grenzen des Normalen und der Anfänge des Pathologischen im Röntgenbilde*". After "*G.* Thieme-Verlag" had published Alban Köhler's work up to the eighth edition, Emil Alfred

Fortschritte

auf dem Gebiete der

Röntgenstrahlen

Unter Mitwirkung von

Prof. Dr. v. **Bramann** in Halle, Prof. Dr. v. **Bruns** in Tübingen, Geh. Med.-Rat Prof. Dr. **Curschmann** in Leipzig, Geh. Med.-Rat Prof. Dr. **Czerny** in Heidelberg, Prof. Dr. **Forster** in Bern, Prof. Dr. **Grunmach** in Berlin, Prof. Dr. **Henschen** in Upsala, Prof. Dr. **Hoffa** in Würzburg, Prof. Dr. **Kölliker** in Leipzig, Prof. Dr. **Krause** in Altona, Oberarzt Dr. **Kümmell** in Hamburg, Prof. Dr. **Lenhartz** in Hamburg, Prof. Dr. **Lennander** in Upsala, Prof. Dr. **Oberst** in Halle, Geh. Med.-Rat Prof. Dr. **Riedel** in Jena, Prof. Dr. **Rumpf** in Hamburg, Geh. Med.-Rat Prof. Dr. **Schede** in Bonn, Prof. Dr. **F. Schultze** in Bonn, Oberarzt Dr. **Sick** in Hamburg, Geh. Reg.-Rat Prof. Dr. **Slaby** in Charlottenburg, Generaloberarzt Dr. **Schjerning** in Berlin, Generaloberarzt Dr. **Stechow** in Berlin, Prof. Dr. **Voller** in Hamburg und Prof. Dr. **J. Wolff** in Berlin

herausgegeben von

Dr. med. Deycke in Constantinopel und **Dr. med. Albers-Schönberg** in Hamburg

Erster Band

Hamburg

Lucas Gräfe & Sillem

1897—1898

Fig. 11. — Cover of the first issue of the German radiologic journal, founded in 1897

Zimmer (1871-1935), a French radiologist, continued this up to the twelfth edition and restricted its contents to the skeleton. It was written in German and translated into English, French, Italian and Spanish.

Since the "*interbellum*" period, the textbook development evolved into the publishing of specialized books dealing with many details of musculoskeletal tissues. It was followed by larger, more codified compilations of musculoskeletal conditions, for example those edited in 1928 by Hans Rudolf Schinz (1891-1966), a Swiss radiologist *et al.* : "*Lehrbuch der Röntgen-Diagnostik mit besonderer Berüchsichtigung der Chirurgie*".

These textbooks clearly established the subspecialty of musculoskeletal radiology. They were meant for radiologists, either those in training or those in full-time practice. These books were monumental efforts in their time and commanded great respect for their authors.

Education in a subspecialty is attained not only from books but also from specialty training programs, local and national educational efforts and societies. Until recently, training programs typically included the study of musculoskeletal radiology in a general radiological rotation. In the middle decades of the 20th century, an increasing number of experts in musculoskeletal radiology became recognized. They provided more specialized training in musculoskeletal radiology for a few programs.

Musculoskeletal radiology is well represented by a subspecialty society, the International Skeletal Society, that was launched in 1970 and has met annually since 1972.

CONCLUSION

The development of modern orthopedics would clearly have been impossible without the benefits of Röntgen's ray and subsequent imaging techniques and education.

"Was ist das Schwerste vom allem ?
Was dir das Leichteste dünket :
Mit den Augen zu sehen,
Was vor den Augen dir liegt"
Goethe

REFERENCES

1. Baetjer F. H. Osteomyelitis. Am. J. Radiol., 1919, 6, 259-263.
2. Bocage A. E. M. Procédé et dispositif de radiographie sur plaque en mouvement. Brevet français. N° 534 464, 1922.
3. Bouwers A. X-ray tube. US Patent 1, 893. 759, issued January 10, 1933.
4. Bouwers A. Self-protecting tubes and their influence on the development of X-ray technique. Radiology, 1929, 13, 191-196.
5. Bucky G. A grating diaphragm to cut off secondary rays from the object. Arch. Roentgen Ray, 1913, 18, 6-9.
6. Bucky G. Method of an apparatus for projecting Röntgen images. US Patent 1, 164. 987, issued December 21, 1915.
7. Coolidge W. D. A powerful Roentgen ray tube with a pure electron discharge. Phys. Rev. Ser., 1913, 2, 409-430.
8. Coolidge W. D. Vacuum tube. US Patent 1, 203. 495, issued October 31 1916.
9. Eisenberg R. L. Radiology. An Illustrated History. Mosby Year Book, 1992.
10. Grigg E. R. N. The trail of the invisible light : From X-Strahlen to radio(bio)logy. Springfield, III,Thomas, 1965.
11. Grossman G. Tomographie I. Fortschr. Röntgenstr., 1935, 51, 61-80.
12. Grossman G. Tomographie II. Fortschr. Röntgenstr., 1935, 51, 191-208.
13. Heuck F. H. W., Macherauch E. Forschung mit Röntgenstrahlen. Bilanz eines Jahrhunderts (1895-1995), Springer, 1995.
14. Immelmann M. Über die Bedeutung der Röntgenstrahlen für den ärtzlichen Sachverständigen. Z. Medizinalbeamte, 1901, 14, 147-150.
15. Jastrowitz M. Die Roentgen'schen Experimente mit Kathodenstrahlen und ihre diagnostische Verwerthung. Dtsch. Med. Wschr., 1896, 22, 5, 65-67.
16. König F. Die Bedeutung der Durchleuchtung (Röntgen) für die Diagnose der Knochenkrankenheiten. Dtsch. Med. Wschr ., 1896, : 22, 113.
17. König F. Demonstration eines Präparates nebst einer mit Röntgenstrahlen aufgenommen Photographie. Berl. Klin. Wschr. , 1896, 568.
18. Leppin O. Aus kleine Mitteilungen. Wirkung der Röntgenstrahlen auf die Haut. Dtsch. Med. Wschr., 1896, 28, 454.
19. Molineus W., Holthusen H., Meyer H. Ehrenbuch der Radiologen aller Nationen. 3 erweiterte Auflage, Blackwell Wissenschaft Berlin, 1992.
20. Pallardy G., Pallardy M. J., Wackenheim A. Histoire illustrée de la radiologie. Dacosta, Paris, 1989.
21. Pohl E. Verfahren und Vorrichtung zur röntgenographischen Wiedergabe eines Körperschnittes und Ausschluß der davor und dahinter liegenden Teile. Dtsch. Patentstr. 544 4200, 1927.
22. Pupin M. From immigrant to inventor. New York, Scribner's, 1923.

23. Rosenbusch G., Oudkerk M., Ammann E. Radiology in medical diagnostics. Evolution of X-ray applications 1895-1995. Blackwell Science, 1995.
24. Schäffer B. Zur direkten Betrachtung innerer Körperteile mittels Röntgenscher Strahlen. Dtsch. Med. Wschr., 1896 , 2, 240, (9 April).
25. Schjerning von O., Kranzfelder F. Über die von der Medizinalabteilung des Kriegsministeriums angestellten Versuche zur Festellung der Verwertbarkeit. Röntgenscher Strahlen für die medizinisch-chirurgischen Zwecke. Dtsch. Med. Wschr., 1896, 22, 211, (2 April).
26. Sudeck P. Zur Altersatrophie und Inaktivitätsatrophie der Knochen. Fortschr Röntgenstr., 1899/1900, 3, 201.
27. Webb S. From the watching of shadows. The origins of radiological tomography. Adam Hilger, Bristol and New York, 1990.

SAMENVATTING

R. VAN TIGGELEN. Sinds 1895 gebruikt orthopedische chirurgie xstraal beeldvorming. Een historisch overzicht vanaf de ontdekking tot de computer tomografie.

De eerste toepassing van X-stralen op de mens werd door de Duitser Wilhelm Conrad Röntgen zelf verricht (nov 1895).
Vanaf dan hebben verschillende firma's radiologische uitrusting vervaardigd en verbeterd. Ter herdenking van de uitreiking van de eerste Nobelprijs voor fysica (Röntgen, 1901) willen wij de belangrijkste radiologische mijlpalen (voornamelijk in Duitsland) overlopen. Wij zullen eerst het pionierswerk met glazen platen, cathode X-buizen en fluoroscopie bespreken, alsook hun eerste publicaties.
Daarna zullen wij spreken over het ontstaan van de radiologische filmen, de versterkingsschermen, de draaiende anode X-buis, de conventionele en computergestuurde tomografie en, tot slot over enkele belangrijke tekstboeken, radioprotectie en orthopedische pathologische problemen.

RÉSUMÉ

R. VAN TIGGELEN. Depuis 1895, l'orthopédie s'appuie sur l'imagerie médicale. Survol historique depuis la découverte du rayon X à la tomographie computérisée.

La première application des rayons X à l'homme fut faite, en Allemagne, par Wilhelm Conrad Röntgen (novembre 1895). Dès le début, différentes équipes réalisèrent et améliorèrent l'équipement.
En nous concentrant particulièrement sur l'Allemagne, à l'occasion du centenaire de l'attribution du premier prix Nobel de physique à Röntgen en 1901, nous survolerons les principales étapes de la radiologie en partant du travail des pionniers utilisant des plaques photographiques en verre, des tubes cathodiques, la fluoroscopie et de leurs premières publications pour arriver aux films radiologiques, aux écrans renforçateurs, aux tubes à anode rapide, à la tomographie conventionnelle et computée.
Ensuite nous aborderons quelques ouvrages radiologiques de référence, les problèmes posés par la radioprotection et quelques étapes marquantes dans la pathologie orthopédique.