One Hundred Years of Medical Radiology

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Diagnostic Radiology

The development of diagnostic imaging has been the result of a fruitful relationship between doctors, radiographers, physicists and equipment manufacturers. New apparatus has stimulated the introduction of new techniques and medical needs have in their turn stimulated new developments in equipment.

The Discovery

In 1895 Wilhelm Conrad Roentgen was the professor and head of the department of physics at the Julius-Maximillan University at Wurzburg in Germany. On the 8 November of that year, he was working with cathode rays using evacuated glass bulbs. Rontgen noted that when a current was passed across the bulb, a barium platinocyanide screen was seen to fluoresce. He at once realised the significance of this observation. Simultaneously he noted the effect of the new phenomena on photographic plates. On the 28th of December 1895, his manuscript "On a New Kind of Ray" outlining the essential features of X-rays was submitted to the Wurzburg Physical Medical Institute. The new discovery aroused considerable interest. The description of the ability to see through the body was greeted by many with considerable incredulity and early descriptions made pains to reassure the public that this was indeed a serious discovery by a respected scientist. Rontgen was awarded the first Nobel Prize for physics in 1901.

The apparatus used by Rontgen was readily available and the experiment could easily be repeated. In the initial apparatus designed by Sir William Crookes (1832-1919), the tube consists of a partially evacuated glass bulb with the anode in a side arm. The cathode rays (electrons) hit the end of the glass bulb which then acts as a large target emitting X-rays and resulting in a poor image. Crookes had experimented himself with the passage of current across such tubes. In the initial modification by Herbert Jackson of King’s College London to the simple tube the cathode became a dish which produced some focusing of the electrons and the anode was made of platinum and placed opposite the cathode. The Jackson focus tube produced a considerable improvement in image quality due to the reduction in size of the focal spot.

The apparatus was demonstrated in scientific and medical meetings and also in fun-fairs and popular lectures. The clinical use was appreciated immediately. In a case described in the British Medical Journal in early 1896, a cavalry subaltern had come off his horse suffering a severe injury to his elbow. Assessment was difficult, however a radiograph revealed simple dislocation with no fracture and this could be reduced with confidence.

Early Apparatus

The apparatus gradually improved and hospitals started to acquire the equipment. Many hospital X-ray departments were located in the cellars and basements and were often poorly ventilated and damp. The dampness made it difficult to work the apparatus and made it more difficult to pass the current across the glass tube. The first hour of the day was often spent in drying the apparatus. Even at the Royal London Hospital in 1897 there was no electric current in the hospital and the accumulator of Grove cells was taken out of the hospital by a porter to a nearby establishment to charge it. The equipment was usually mounted on a trolley with the accumulator on the lower level and the induction coil and contact breaker on the upper level. The tube was held in a wooden clamp and was a bare bulb with no protection for the operator. The trolley could then be taken around the hospital.

The New Photography

Many people were involved in what was called "The New Photography" including photographers and general practitioners. At King's College Hospital in London, two medical students were sent to use the new apparatus. After some time, a Doctor Mayou was put in charge of them since it was felt they were spending too much money on plates! Financial considerations were important even then. He was warned by the students not to expose his hands to the X-rays. The advice was ignored and soon he had X-ray dermatitis on every finger. At that time, it was not obvious at to why these injuries were occurring and some workers thought that they were caused by the developer or the high tension. It took some time to realise that it was the X-rays themselves that were causing the injuries.

Pioneers at the Royal London Hospital

At the Royal London Hospital experiments were undertaken by a physician, Dr Page and a surgeon, Mr Harold Barnard. The initial interest was centred around a registrars volunteered his services as a radiographer and the first radiograph of a needle in a foot was made early in 1896. Peripheral radiography was not a problem where the body part was thin. Radiography of the trunk was to prove technically more demanding and the shadows produced were much more difficult to interpret. Harnack had three assistants, Reginald Blackall, Ernest Wilson and Harold Suggars. Ernest Wilson joined in 1898 to help with the X-ray work and to perform clinical photography and developed signs of injury within a few months. By 1903 they all had radiation injuries. Wilson died of his injuries in 1911 and took a series of photographs of his hands showing progressive bony damage leading to malignancy. Harnack ultimately had both hands amputated. Suggars and Blackall worked for longer and helped to establish the College of Radiographers.

The absence of protection around the early X-ray tubes resulted in considerable injury to the operators. The problem was compounded by the common practice of looking at the operator's own hand with a fluorescent screen to test the apparatus. These dangers were gradually recognised and standards for exposure and protection were gradually introduced. It was following the shock at the death at the age of 42 in 1921 of Dr Ironside Bruce who was a radiologist at Charing Cross Hospital and the Hospital for Sick Children at Great Ormond Street in London that the British X-ray and Radium Protection Committee came into being. This group finally disbanded in 1952.

Ironside Bruce, Reginald Blackall and Ernest Wilson were among the 14 British names on the martyr's memorial in the grounds of St George's Hospital, Hamburg. The name of Ernest Harnack was added in the 1950s.

Plates and Film

The radiographs were initially made onto glass photographic plates which had to be placed into light tight cassettes or envelopes. The photographic plates were coated with emulsion on one side only. The emulsion had a habit of slipping off during developing and the job of a junior was to wax the edges of the plates to help to keep the emulsion in place. Film was introduced by Eastman in 1918, however film only came into general use from about 1923. It should be remembered that the image quality on glass was excellent and it took some time for film to replace the older technique. Unlike the glass plates, the film could be coated on two surfaces emulsion ("Dupli-Tized"). The base was made of celluloid nitrate and was highly inflammable. This high risk property was tragically shown in the infamous Cleveland Clinic fire when the X-ray film store caught fire and 129 people died. In 1924 Eastman introduced the cellulose acetate base as safety film. This innovation was more expensive and it was only the accidents with the previous film that forced its introduction.

Radiography

Most of the early X-ray work was performed by doctors and the departments were often combined with electro-therapeutic departments. However from about 1903, lay X-ray operators as they were then called were appointed to assist in the work. They had no special training and learnt on the job. Gradually more and more of these lay X-ray operators were appointed and training courses were set up. The culmination was in the formation of the Society of Radiographers in 1920.

The Development of New Tubes

The gas tubes were difficult to use and the skill of the operator lay in proper seasoning of the new tube and caring for it during use. It was only following the introduction of the Coolidge tube in 1913 that predictable results were obtained. In the Coolidge tube, the bulb could be completely evacuated and electrons were liberated from a heated spiral cathode. The results were far more uniform and it was possible to vary the current and voltage independently. In the early tubes, the high-tension cables were attached to the ends of the tube producing a considerable risk of electrocution. Sealed and electrically insulated "shock-proof" apparatus was gradually introduced from the 1930s. The self protected Metalix tube was designed by Bouwers of Philips in 1924 and this tube also incorporated the principal of line focus. Bouwers also designed the first rotating anode tube, the Rotalix, which was first marketed in 1929.

Diagnosis and Therapy

X-rays were used for therapy from the earliest times. Skin lesions were easily treated and gradually techniques evolved to treat deeper lesions. These techniques depended on the development of more powerful apparatus, the use of multiple therapy beams and in the use of radium. The doctors working in the X-ray department were involved in both therapy and diagnosis. It was only from the 1930s that doctors were appointed with specific interests in diagnosis or therapy.

Chest Radiography

The initial apparatus was of low power and therefore fluoroscopy was superior to radiography. In 1896 a chest plate on a girl aged 10 years taken at St Thomas's Hospital in London took 30 minutes to expose. The initial workers used fluoroscopy often with the hooded fluorescent screen. It was only with the development of higher powered apparatus with large induction coils and electrolytic interrupters that instantaneous radiograph could be developed. By 1905 better quality films could be obtained. A cultural change was also needed in physicians who initially found it hard to accept that an abnormality could exist when it was not clinically apparent and could only be demonstrated radiographically.

The first English book on Chest Radiography was published in 1905. The initial chest films were of rather poor quality however they were of diagnostic quality and for example enabled the drainage of a pneumothorax (collapsed lung) under X-ray control by John Fawcett at Guys Hospital in 1907. It is now difficult to imagine the management of chest disease without the benefit of chest radiography. Additional techniques were gradually introduced. Although earlier workers had used various contrast agents in the bronchial tree it was Sickard and Forestier in the early 1920s who injected mixture of iodine and poppy seed oil (lipiodol) into the lungs and enabled the production of good quality images of the airways (bronchography). The use of plain tomography to obtain sections of the body was invented in the 1930s by Bernard Ziedses des Plantes and popularised in the UK by Ernest Twining of Manchester. Plain tomography continues to this day although the introduction of computed tomography (CT) scanning has considerably reduced the number of applications.

The techniques used reflected the pathology encountered, bronchiectasis (dilated bronchi), tuberculosis, lung abscess and empyema (pleural abscess) being common in the early years of this century. Fluoroscopy was extensively used in the treatment of TB to assist in the diagnosis and in the performance of artificial pneumothorax and dedicated chest fluoroscopic apparatus was used in many chest clinics. In a similar way to the current use of screening mammography, the introduction of mobile miniature-film apparatus in the 1930s by Russell Reynolds and Watsons Ltd enabled the development of mass radiography for the early diagnosis of pulmonary tuberculosis (TB). Mass radiography became important when effective drug treatments for TB were introduced in the 1950s. The apparatus for miniature radiography has gradually been taken out of use and now only a few units survive.

The introduction of agents that could safely be injected into the circulation allowed the lung vessels to be demonstrated. More recently nuclear medicine, computed tomography (CT) scanning and magnetic resonance imaging (MRI) have been introduced. These techniques enable detailed anatomy to be demonstrated non-invasively. In CT scanning the information from a rotating X-ray tube rotating around the patient is processed to produce a cross section of the anatomy. Pulmonary secondary deposits from cancer were first demonstrated on CT by Louis Kreel in 1976. Nuclear medicine involves the administration of a radioactive compound. In 1955 there was the first use of a radioactive tracer in the lungs with the introduction of inhaled xenon-133 and external counting. In 1964 pulmonary blood flow was demonstrated with injected albumen particles labelled with iodine-131 and in 1975 Fanzio and Jones described the use of inhaled krypton-81M for lung ventilation scanning. The plain radiograph however, remains central and is being developed by the use of digital computed radiography and other techniques. Modern techniques enable the non-invasive investigation of conditions previously requiring complex and often surgical procedures. Percutaneous fine needle biopsy techniques have been introduced for pulmonary and pleural masses.

The Abdomen

The difficulty of visualising the abdominal organs is related to the thickness and density of the structures involved. As already indicated, radiography was difficult because of the low power of the apparatus used. Compression devices were used and because of the lack of contrast in the tissues contrast material had to be introduced. A major initial problem was the extent of new anatomical knowledge required and the identification of normal variants. The normal locations of abdominal organs in life is not obvious and earlier this century many operations to correct floating kidneys were performed. An early landmark was the publication by Kohler in 1910 of the first edition of his classic book on normal variants. To distinguish calcified lymph glands, gallstones, kidney and bladder stones and other shadows on an abdominal radiograph could be a major problem. In the renal tract Hurry Fenwick of the Royal London Hospital introduced ureteric catheters to identify the course of the ureters and retrograde studies with injected agents soon followed to demonstrate the kidneys. Intravascular (injectable) contrast agents were introduced in the 1930s and transformed the examination producing the intravenous urogram.

Liquid contrast was introduced into the stomach as the bismuth meal and later using the less toxic barium sulphate. The opaque meal to diagnose ulcers and cancers of the stomach and duodenum was developed in Vienna in 1904 by Reider and popularised in the UK by workers such as AE Barclay and Sebastian Gilbert Scott. Rectally administered the colon could be filled with bismuth or barium to assist in the diagnosis of large bowel disease such as cancer or diverticulosis.

The diagnosis of gallstones was difficult since most stones are not opaque to the X-rays. The lack of contrast of the unopacified biliary tract therefore was a difficulty until the development of iodine containing oral contrast agents introduced as the Graham test in 1924. Direct opacification of the biliary tree by large needle injection obstruction is now often done as a team effort between radiologist and endoscopist.

Image Intensification

In the 1950s came the development of the image intensifier and X-ray television. The initial systems produced a brightness gain of about 1000 and meant that the red goggles needed for dark adaptation when viewing a simple fluoroscopic screen could be dispensed with. The result was also that the operator looked at the television and not at the patient. The use of image intensification has stimulated the flowering of techniques in the last 20 years, including the associated development of catheters, needles and contrast media.

Recent Developments

Many new techniques have been introduced in recent years. The principles of CT scanning were first described by Godfrey Hounsfield and the first prototype EMI scanner was installed in 1972 at Atkinson Morley's Hospital. Work was progressing on Magnetic Resonance Imaging (MRI) in the 1970s and the first human image was obtained at Aberdeen in 1977. Nuclear Magnetic Resonance can be used to either to produce planar images of anatomy or as Magnetic Resonance Spectroscopy can provide biochemical information. Ultrasound started in the 1950s and gained popularity in the 1960s. "Real-time" ultrasound machines were introduced in the late1970s and ultrasound is now the most commonly used examination after plain radiographs. The use in the last 10 years of Doppler technology has enabled flow to be assessed as well as anatomy. These new techniques have displaced many of the older X-ray techniques and this process will continue.

In modern radiological practice it is not possible to consider techniques in isolation. An integrated approach is needed with the various techniques used as appropriate. Often it is better for a complex procedure to be used early in an investigation since a diagnosis may be reached quickly with minimal inconvenience and risk to the patient. In recent years the widespread use of percutaneous biopsy techniques and ultrasound and CT scanning have considerably reduced the need for exploratory surgery. There have been many changes in medicine which influence radiological practice and for example, the increasing use of endoscopy has considerably reduced the need for barium meals. The recent developments in diagnostic imaging have considerably facilitated the recent trend to investigate and treat patients as day cases or as outpatients with considerably less disruption to the patients life.

Until the 1980s the techniques needed to store reports and films had changed little since the 1920s. Modern technology is transforming departments with the introduction of computer management systems and digital image storage. This last technique will dramatically alter the use of images with studies being transferred via links between different institutions and offices. The last 100 years have produced many changes and the next 100 will be even more dramatic.

To stimulate the study and conservation of British radiological history, the Radiology History Committee was founded in 1987. The committee became a charitable trust in 1992. The UK R0ntgen Centenary Conference took place in Birmingham in June 1995.

For further information please contact the author.

Further Reading

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