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A century of medical imaging

The last few years of the 19th century saw great advances in the understanding of the principles of basic physics. Tesla was exploring electricity and magnetism in his adopted United States, Becquerel and the Curies were investigating radioactivity in Paris, Thomson discovered the electron and in November 1895, Wilhelm Roentgen, working in Wurzburg, discovered X-rays using equipment that was already widely available in many of the research laboratories.

'Chance favours the prepared mind' is usually associated with Sir Alexander Fleming and the discovery of penicillin, but it is equally true in this situation. Using a vacuum tube invented by Sir William Crookes to study the properties of electric currents, Roentgen noticed that when his tube was switched on, a nearby barium platinocyanide screen fluoresced—a reaction that was only prevented by putting dense material between the tube and the chemicals. At least one other investigator had experienced this without realising its significance—he had already sent back several batches of photographic paper that were darkened, believing that they had been fogged during production.

Roentgen realised that he was demonstrating the existence of 'a new kind of ray' which rapidly became known as X-rays, though in many parts of the world they are still referred to as 'Roentgen rays'. Assessing their properties, he realised they would allow doctors to 'see through' patients, so revolutionising the investigation of medical problems. The picture of the bones and ring of Mrs Roentgen's left hand travelled the world and became the hallmark of this major innovation. As the technique for production of X-rays was already widespread and Roentgen refused to patent the idea for personal gain, the benefits spread rapidly between the medical institutions of Western Europe and North America. The importance of the demonstration of fractures, stones and foreign bodies such as bullets was quickly appreciated. The *Archives of Clinical Skiagraphy*, the first radiological journal, was established in London in April 1896 and in 1897 the X-ray Society, subsequently renamed the Roentgen Ray Society, was also established in London. Roentgen was awarded the first Nobel Prize in Physics in 1901. The age of medical imaging had arrived and physicians were no longer limited to what could be inspected, palpated, percussed or auscultated.

The limitations of X-rays however soon became apparent. A three dimensional object was rendered flat into two dimensions; long exposures with equipment that would make a modern safety officer's hair stand on end (and often literally did!) raised safety questions for both doctor and patient. There was also the realisation that tissue damage from radiation (both X-rays and radioactivity) was a major hazard although this effect was rapidly and successfully harnessed as radiotherapy for the treatment of tumours. Unfortunately early workers fell prey to these side effects and early investigators had a ten-fold mortality compared with their peers. Another major problem was the lack of soft tissue differentiation.

The aim of medical imaging is to find a technique that can contrast different tissues to demonstrate anatomy or to distinguish pathological from normal tissues so that disease can be identified. X-ray images are produced by differential absorption of the rays by the various atomic weights in the atoms of the tissues through which the beam passes. The conspicuity between tissues of very different density is excellent—the high absorption of bones contrasts with soft tissues, and soft tissues contrast with aerated lung so that skeletal X-rays and chest X-rays are very effective. However, as soft tissues are predominantly composed of water they all tend to produce a rather similar grey shadowing. Even the use of computers such as in CT has not fully overcome this physical limitation. Consequently, over the years, contrast agents have been developed that can be ingested or injected into various body compartments and systems to delineate the function of the different organs with an impressive degree of safety. Catheters and needles have also been developed that allow access through minute portals to all parts of the body.

Wartime led to the emergence of the specialist radiologist and the equipment became more refined and safe. It was portable, more compact and also more powerful. As the exposure times became shorter and electronic sophistication improved, the phenomenon of fluorescence was re-examined and exploited in fluoroscopy, or real-time, low dose imaging. This technique is now perfected in the highly sophisticated digital subtraction angiography equipment commonplace in all modern departments.

Meanwhile, parallel discoveries were being used to explore different methods for imaging medical problems. Roentgen's early images stimulated Henry Becquerel to explore radioactivity and the Curies isolated radium a few months later. From an understanding of this process and the discovery of artificial radioactivity, the huge fields of nuclear medicine and of radiotherapy have arisen.

War was again a stimulus for another completely different imaging technique that does not require ionising radiation. 'Sonar', developed for anti-submarine warfare, was used by Donald in Scotland in the sixties for demonstrating the foetus in pregnant mothers. This safe 'radar' map using high frequency sound waves (ultrasound) that reflect off different parts of body tissues has evolved from primitive contrast pictures to modern real-time colour scans showing perfusion and three-dimensional representations.

The most recently developed technique, magnetic resonance imaging (MRI), promises to be the most useful of the new modalities whose potential has barely been appreciated. It has excellent soft tissue discrimination that is unaffected by bone, is apparently safe, can produce images in any plane and in three dimensions and can be used without contrast agents to obtain images of the vascular system, dynamic flow patterns of eg CSF, and functional movement of intra-cellular and extra-cellular fluids. MR spectroscopy can demonstrate cellular metabolic activity. The combination of the techniques of MRI and magneto-encephalographic recording (MEG)—measuring the minute magnetic field changes in living tissues that accompany the electrical activity as, in effect, a 'magnetic EEG'—that is now known as magnetic source imaging (MSI) is on the threshold of taking medical imaging away from the predominantly anatomy based concepts into true functional imaging.

It is interesting that as Roentgen has his centenary and the emphasis is changing from radiation to magnetic fields, his contemporary, Tesla, whose discoveries were significantly responsible for the rapid propagation of X-ray technology, is remembered in the unit of magnetic field strength of medical imaging equipment.

The management of spinal injuries utilises all these techniques and each has its place. Plain X-rays with which Roentgen would have been completely familiar are still the basis of imaging. However, remembering the definition of a fracture as 'a soft tissue injury in which the radiological marker is a broken bone' (surely a definition most apposite in spinal injury) the importance of the newer techniques, especially MRI, is apparent as they allow unprecedented evaluation of these soft tissue components.

Wilhelm Roentgen's discoveries unleashed a whole new era in medical diagnosis and treatment. After 100 years, his discoveries are still being refined and used but they have also acted as the catalyst for the development of many other techniques. This stimulation shows no signs of abatement as we move from the era of anatomical imaging into that of functional imaging.

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Suggested further reading

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