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History of Radiology

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18.1 Introduction
Following initial astonishment when X-rays were discovered, they were soon used in clinical practice transforming our understanding of the body in health and disease. Following the period of the pioneers, there was a long period of classical radiology. The 1970s can be seen as a golden decade and modern radiology is giving an increasing understanding of disease processes and opportunities for novel interventions.

18.2 Wilhelm Conrad Röntgen and the Discovery of the New Rays
In the nineteenth century there was a great scientific interest in passing electrical currents across evacuated glass bulbs, partly initiated by the work of Michael Faraday. As Silvanus Thompson pointed out, in addition to the visible spectrum there are other waves that bring no sensation to our eyes and yet are light waves (Thompson 1897). Thompson knew that the spectrum extended invisibly in both directions, below the extreme red and beyond the extreme violet. It should therefore have come as no great surprise that new invisible rays were discovered by Wilhelm Conrad Röntgen in 1895; however, it took some time to realize that these rays were of a similar nature to visible light, but with a shorter wavelength. So, why were the X-rays not discovered before 1895? X-rays had certainly been produced by both William Crookes and ArthurGoodspeed, but neither had realized what they had accomplished. It was on November 8, 1895 that Röntgen noted that when a current was passed across an evacuated glass bulb a barium platinocyanide screen was seen to fluoresce (see Section I, Chapter 17 of this book). On December 28, 1895, Röntgen submitted his manuscript On a New Kind of Ray outlining the essential features of the new radiation to the Würzburg Physical Medical Institute (Röntgen 1896). The new discovery aroused both considerable interest and disbelief, and 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 (Guy and Thomas 1995). Röntgen only ever gave one public lecture on the discovery, which was on January 23, 1896 to the Physical-Medical Society. In his 1895 paper Röntgen wrote:

May not the new rays be due to longitudinal vibrations in the ether? I must admit that I have put more and more faith in this idea in the course of my research, and it now behoves me therefore to announce my suspicion, although I know well that this explanation requires further corroboration.

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Röntgen was awarded the first Nobel Prize for physics in 1901, and produced only three papers on what were to be called X-rays. In these three papers Röntgen gave a full account of the new rays, and little was added until the work of Max von Laue, who in May 1912 passed a fine pencil beam of X-rays through a copper sulfate crystal and recorded the diffraction pattern on a photographic plate. The pattern consisted of a large number of well-defined spots, which were arranged in intersecting circles around the central beam, demonstrating that X-rays were electromagnetic waves of short wavelength, and von Laue was justly awarded the Nobel Prize for Physics in 1914.

The discovery of X-rays, the new photography, caused great excitement in the popular press, as well as in the medical and scientific communities as the potential of the new discovery became apparent.

### 18.3 The First X-ray Department

Following the discovery of the X-rays in 1895, Röntgen sent copies of his paper with accompanying sample radiographs to scientists throughout the world, including the physicist Lord Kelvin in Glasgow, and Arthur Schuster in Manchester (Schuster 1932). Kelvin gave the paper to J. T. Bottomley, who then worked with a doctor John Macintyre. In January 1896 Macintyre lectured to Glasgow University on “The New Light—X-rays,” and by March of that year had obtained the consent of the managers of Glasgow Royal Infirmary to start an X-ray department, which was the first in the world. Macintyre made the first radiographic demonstration of a renal calculus, which was proven at surgery. In 1897 the first issue of the new journal *Archives of Clinical Skiagraphy* (the forerunner of the *British Journal of Radiology*) contained three papers by Macintyre. In 1897 Macintyre made his famous demonstration of the cine-radiological study of the frog’s leg to the Royal Society of London (Figure 18.1), and also corresponded with Röntgen who gave him an X-ray tube.

It was in 1897 that the famous New Electrical Pavilion opened at the Glasgow Royal Infirmary (Figure 18.2) (Macintyre 1903), and the rooms were fitted up with the most modern and up-to-date apparatus (Figure 18.3a,b). Electricity was supplied either
by the 250 V mains supply from Glasgow Corporation, or from the department’s own generator. Patients could either attend the department or could be examined in the wards or operating theatres, since these were all wired for electricity. The department provided both electrical (electro-therapeutic) and radiological services. The radiological services included plain film radiography, radiotherapy, foreign body localization, and stereoscopic radiography. In general the first X-ray departments arose from hospital electrical or photographic departments, and were broadly similar and provided radiography (Figure 18.4) and fluoroscopy (Figure 18.5). Note should be made of the absence of either radiation or electrical protection for the tube, operator, and patient.

It is very interesting to see how very contemporary the concerns of Macintyre, and the other pioneers, are. By 1903 Macintyre was already saying that the new building from 1897 was being fully utilized, and that the number of staff had been increased to examine the large number of cases. In 1897 the Electrical Pavilion had been built as large as possible, and by 1903 the demands upon it were far in excess of what could be accommodated. The department was staffed by two medical officers, an unqualified assistant, and a number of nurses. It is important to note that the role of the radiological nurse can be seen as crucial right back to the earliest days of radiology departments, and that nurses are not a recent addition to radiology.

By 1903 the Electrical Pavilion was taking 2000 radiographs each year and performing many fluoroscopic examinations. Macintyre himself felt that the most important addition to the hospital was the electrotherapeutic department. In 1903 Macintyre was also looking forward to the rebuilding of the hospital and was hoping, as many generations of radiologists were to do in subsequent years, for still greater facilities. This was to be a recurrent theme, and successive generations of radiologists have pressed for more resources.

18.4 William Morton

William J. Morton was an important early figure in radiology in the U.S. Morton had the splendid title of “Professor of Diseases of the Mind and Nervous System and Electro Therapeutics” at the New York Post Graduate Medical School and Hospital. His book The X-ray or Photography of the Invisible (Morton 1904) (Figure 18.6) was written in collaboration with Edwin Hammer, who was an electrical engineer. This book is important because it is the first book on radiology written by a physician, and Morton covers all areas of radiology known at the time with speculations about potential future uses for the new rays. Morton makes the very pertinent observation that:

In teaching the anatomy of the blood vessels the X Ray opens out a new and feasible method. The arteries and veins of dead bodies may be injected with a substance opaque to the X Ray, and thus their distributions may be more accurately followed than by any possible dissection. The feasibility of this method applies equally well to the study of other structures and organs of the dead body. To a certain extent, therefore, X Ray photography may replace both dissection and vivisection. And in the living body the location and size of a hollow organ, as for instance the stomach, may be ascertained by causing the subject to drink a harmless fluid, more or less opaque to the X-ray, or an effervescent mixture which will cause distension, and then taking the picture.
This passage is quoted in full because Morton’s words are so perceptive. In this very early book, written less than a year following the discovery, Morton is not only predicting later contrast gastrointestinal studies, but also the use of radiology in the equivalent of modern virtopsy (virtual autopsy). It is worth noting that pioneers so often realize the exact significance and importance of their observations, and those who come after then build on this solid foundation. Morton had immediately seen that the radiological examination of the body, either living or dead, could produce more information than could be found in either the operating theatre or the pathology department.

18.5 Early Image Interpretation: Skeletal Development and Variations

It might be thought that the interpretation of these early images would be straightforward. In reality nothing was further from the truth. This is illustrated in the life of Charles Thurstan Holland, who was a major figure in early radiology, and who was the President of the First International Congress of Radiology. Holland worked as a general medical practitioner in Liverpool from 1889, and following the discovery of X-rays he was approached by the pioneer orthopedic surgeon Robert Jones. As Holland recollected “In the beginning of 1896 Robert Jones visualized some of the possibilities of radiography in respect to his own work” (Holland 1937). His first radiograph was made on May 29, 1896 and was “My first X-ray. My own hand” (Figure 18.7). This involved a 2 min exposure using a 3 in. coil and five Grove cells. The total number of plates he took in 1896 was 261. Holland radiographed many conditions including foreign bodies, arthritis, fractures, a stillborn fetus (Figure 18.8), “mummy bird,” a fish to show bones, and a series of hands to demonstrate bone growth (Figure 18.9) (Holland 1923). While his apparatus may look very primitive today, the difficulties that he overcame and the skills that he showed cannot be overemphasized. As Holland recalled “There were no X-ray departments in any of the hospitals. There were no experts. There was no literature. No one knew anything about radiographs of the normal, to say nothing of the abnormal.” Writing in 1938, R. E. Roberts was able to say...
that “In spite of the inadequate apparatus which was available, and of the lengthy exposures required, some of Holland’s early radiographs of small parts compare very favourably with many of those seen nowadays, taken with much more costly equipment” (Burrows 1986).

On September 1, 1896, Holland was able to examine a full-term stillbirth (Figure 18.8). He was fascinated to see the bony ossifications, particularly of the hands and feet. He noted the absence of ossification of the epiphyses, and immediately realized the role that X-rays could have for anatomical studies and observing skeletal growth. He started collecting radiographs at different ages and in September 1896 showed them at the British Association meeting in Liverpool.

This work on bone age was developed by John Poland, a surgeon from the Miller Hospital in Greenwich. In his bone age atlas (Poland 1898), Poland pointed out that the actual development of the ossification centers differed quite considerably from that which had been previously described (Figure 18.10). Poland had a particular interest in epiphyseal anatomy, and considerable effort was being made in the late nineteenth and early twentieth Century to understand the anatomy of the developing epiphyses and its radiographic appearances. Eugene Corson, a surgeon from Savannah, Georgia, U.S. wrote to Poland on November 21, 1900, admiring his book The Traumatic Separation of the Epiphyses and enclosing some reprints, including one from the November 1900 Annals of Surgery on
"A Skiagraphic Study of the Normal Membral Epiphyses at the Thirteenth Year." Corson had written that "The X-ray will prove to be a valuable aid in the study of many points of normal anatomy," and that "The bone relationships in joints, the various joint movements, and the different steps in bone development can all be studied in a striking way by the X-ray." It was the clarity of radiography that so very much impressed Colson (Figure 18.11), who commented that "the discovery of Röntgen, a discovery which makes possible and easy and an absolutely correct diagnosis where previously uncertainty and error outweighed definite knowledge."

Indeed accurate information on normal child and skeletal development would be essential following the establishment of well-baby clinics, school health programs, and the routine health examination of children that were to be developed in the first half of the twentieth century. It was in 1921 that T Wingate Todd, from Cleveland, Ohio, U.S. began his studies of human growth and development (Todd 1937). In 1931, three-month-old children were introduced into the program and children up to the age of 14 years were introduced into the study until the summer of 1941. Todd published his Atlas of Skeletal Maturation (Hand) in 1937. This groundbreaking book used data from the study group and also children from public (i.e., state run) schools and various social agencies, and Todd found measurable differences between these two groups. In 1950 William Walter Greulich and D. Idell Pyle, who were both anatomists from Stanford, published Radiographic Atlas of Skeletal Development of the Hand and Wrist, with a second edition appearing in 1959 (Greulich and Pyle 1959). This book is a classic and remains the standard over 60 years later.

18.6 Anomalies and Variations

As described, on December 4, 1896 Holland had radiographed a 7-month fetus and various congenital deformities were shown clearly (Figure 18.8) (Holland 1923). Variations from the normal, either as congenital abnormalities or normal variants, were only poorly understood at that time, and indeed the majority of normal variations were unknown before X-rays were introduced, and it was largely due to the work of Alban Köhler of Wiesbaden that variations were first described.

Köhler was a founder member of the German Röntgen Society and president in 1912. The Lexikon der Grenzen der Normalen und der Anfänge des Pathologischen im Röntgenbilde was first...
published in 1910 (Köhler 1910) and went through a number of German editions and received the highest Röntgen award in Germany, the Rieder Gold Medal. The book was enormously influential and an immediate classic. Instead of reproducing radiographs the book was illustrated using line drawings (Figure 18.12). It was translated into English in 1931 appearing as Röntgenology, The borderlands of the normal and early pathological in the Skiagram with a second edition appearing in 1935 (Köhler 1931, 1935).

The work of Köhler was continued by Theodore Keats from Charlottesville, Virginia, U.S. His Atlas of Normal Roentgen Variants That May Simulate Disease first appeared in 1973 and is currently in its 9th edition. It is a modern classic and its presence in most, if not all radiology departments, is a witness to its value (Keats 1992). As each new imaging technique develops, normal and abnormal appearances need to be learned afresh. The lesson learnt was that if we do not understand the normal then we cannot recognize the pathological. If normal variations are mistaken for pathology, then this leads to inappropriate interventions and surgery for non-existent conditions such as dropped organs (visceroptosis) and floating kidneys. We enter the realm of fantasy surgery for made-up diseases with radiologists compounding the problems.

18.7 The Cryptoscope and Fluoroscopy

When Röntgen discovered X-rays in 1895, he observed their effect on photographic glass and on fluorescent salts. These fluorescent effects could be observed by holding a coated screen in front of an object. It was Thomas Edison who had the idea of placing a tapering box over the screen with the opening covered by some soft dark material to fit the face closely and to exclude light (Figure 18.13). An object placed in front of the screen will then be shown clearly using X-rays, and this hooded box or cryptoscope was particularly valuable for looking at the chest and thicker parts of the body, particularly in the early days of low-powered apparatus (Thomas and Banerjee 2013). With a strongly active X-ray tube the cryptoscope would enable the operator to see the bones in the hands clearly when standing even 10–12 feet away from the tube. As can be seen in the image from 1896 (Figure 18.14), the danger of the cryptoscope in the early years was related to the lack of protection around the X-ray tube, the lack of protection for the operator, and the habit of the early radiologists to use their own hand as a test object to check the adequate functioning of their apparatus. While Edison did not develop any injuries his assistant Clarence Dally was not so lucky. Dally developed severe changes in his hands related to the use of the cryptoscope, and sadly he died in 1904 as a radiology martyr after prolonged suffering, and Edison stopped working on X-rays because he thought they were too dangerous.

In spite of the dangers, the cryptoscope remained in use for many decades into at least the 1950s. Presumably, this was partly related to its ease of use. The figure (Figure 18.15) shows an
An advertisement from the British Journal of Radiology in 1942 advertising the Victor handheld cryptoscope.
advertisement from the *British Journal of Radiology* in 1942 advertising the Victor handheld cryptoscope.

### 18.8 Early Uroradiology and Clinico-Radiological Correlation

The changing role of our imaging techniques is quite interesting. Traditionally, our radiological techniques were used to confirm a clinical diagnosis, and since the technique was often quite invasive it was only applied when there was a reasonable chance of the examination being positive. So, for example, in the diagnosis of ureteric calculus, the technique in the late nineteenth century as used by Edwin Hurry Fenwick (Fenwick 1908), a urologist and pioneer of cystoscopy, was as follows: the surgeon performed a cystoscopy and a ureteric bougie with wax on its tip was passed up the ureter. If the wax was scratched when removed this was evidence of the presence of a stone. This was not a technique to be undertaken lightly, nor was it particularly accurate. Following the discovery of X-rays, Hurry Fenwick was an enthusiastic supporter of the new technique. A radio-opaque ureteric bougie was passed in to the ureter and a radiograph was made. The position of an opacity in relation to the ureter could be determined with confidence and a phlebolith distinguished from a ureteric calculus (Figure 18.16). Hurry Fenwick commented on the distressing situation with the failure of operative surgery when a kidney was opened and damaged to remove a stone when it was no longer in the kidney and was now in the ureter. Hurry Fenwick estimated that this happened in about 30% of cases when the X-ray expert was not called upon to help in the diagnosis. The X-ray expert (radiologist) can “guide the urinary surgeon (urologist) with a precision unattainable before the introduction of the (X-ray) method is without cavil.” Hurry Fenwick was writing in 1908 when the techniques used were still quite primitive and before the introduction of retrograde or intravenous pyelography.

He was one of the first to practice clinical-radiological-pathological correlation (Figure 18.17), correlating the clinical findings with the radiography and then with the operative findings.

**FIGURE 18.16** Early radiograph by Hurry Fenwick from the London Hospital showing left ureteric catheter and the calcification shown not to be ureteric.

One of the problems of modern radiology is that with the increasing availability of techniques, the level of indication for a given procedure has dropped. So a CT scan of the head is now used as part of a confusion screen, and even a short time ago a CT head scan was difficult to request without specific indications. A traditional invasive technique such as a lumbar myelogram or radiculogram would only be used if the likelihood of finding an abnormality was quite high since the examination was unpleasant and entailed risks. Part of the problem is that the significance of radiological findings is more difficult to determine as the threshold for investigation falls. So with a high clinical probability of an abnormality, the utility of MRI scanning in the lumbar spine is good and there is a high chance of finding abnormalities that may be surgically treated. As scanning is now used for more general causes of back pain, the clinical significance of the findings is more difficult to assess.

18.9 The Coolidge Tube

The early X-ray tubes were gas or ion tubes. The cathode was a simple cup and their working depended on the ionization of the gas inside the glass bulb. Although they worked well, their function was unpredictable and the radiographer needed to know the tube and how a particular tube functioned in use. The function of the tube varied with its use and before use the tube needed to be seasoned.

In 1906 William Coolidge discovered how to make molybdenum and tungsten ductile—this was a major discovery. Prior to this, these metals were seen as being unworkable because they were far too brittle. The ductile tungsten could be made into good lamp filaments replacing the earlier carbon filaments. When working with X-ray tubes, Coolidge found a particular tube that worked well when the cathode became heated (Anon 1919, Miller 1963, Liebhafsky 1974). Coolidge worked with Irving Langmuir who was studying electron emissions from hot tungsten filaments. It was found that even in the highest vacuum the electron emission was stable and reproducible. It occurred to Coolidge that this could be adapted for use in the X-ray tube. In his notebook of December 12, 1913 Coolidge wrote that “I L (Langmuir) tells me that in his study of the Edison Effect, current from the hot cathode is greater with vacuum of 0.01 or 0.02 micron than at higher pressure (except in case of argon). I will try this at once in an X-ray tube in which I can heat the cathode.”

The first new tube (Figure 18.18) was used by the well-known U.S. radiologist Lewis Gregory Cole of New York and was demonstrated at a dinner in a New York hotel on December 27, 1913. The new tube was enclosed in an open-topped lead glass bowl. Up to this point the X-ray generators had a capacity considered as the threshold for investigation falls. So with a high clinical probability of an abnormality, the utility of MRI scanning in the lumbar spine is good and there is a high chance of finding abnormalities that may be surgically treated. As scanning is now used for more general causes of back pain, the clinical significance of the findings is more difficult to assess.

![FIGURE 18.18 The Coolidge or vacuum tube.](image)

18.10 The Potter–Bucky Diaphragm

In the history of invention, two discoveries may be synergistic, with neither as good without the other. Coolidge developed a new way of making an X-ray tube, and Gustav Bucky invented a different way of making the X-ray image, and these discoveries combined helped to define and perfect classical radiography.

It had been realized early on that scattered radiation resulted in blurring of the radiographic image. In 1903, Otto Pasche from Switzerland had suggested trying to block the secondary rays by using a slit-like device between the patient and the X-ray tube (Moehringer 1964). However, it was not until 1913 that Bucky, a German radiologist, designed a honeycombed and grid-like diaphragm that he placed between the patient and the X-ray plate (Holbeach 1921). This metal lattice had individual cells which allowed the primary X-rays from the focal spot of the X-ray tube to pass directly through to the film. Secondary scattered radiation was blocked by the filtering effect of the metal strips. The major disadvantage was that the grid was visualized on the X-ray plate and obscured some of the findings.
Bucky came up with a possible solution, which was to move his grid and therefore the shadows of the strips would no longer be visible. It is interesting that quite independently in 1917 Eugene Caldwell from New York had the same idea of moving the grid to remove the shadows. A third investigator, Hollis Potter from Chicago, was unaware of the previous publications and presented his ideas at meetings of the American Roentgen Ray Society (ARRS) in 1915. Potter described a diaphragm which he adapted for fluoroscopy and which consisted of a rotating circular disc with radiating strips to absorb the scatter.

These early grids with the criss-cross pattern were neither successful nor popular. However, Potter understood that a moving wire did not cast a shadow on an X-ray plate, and so he realized that this would also happen if a lead strip which moved uniformly across the beam were used. Potter created a series of parallel strips and although this should only have absorbed a portion of the scattered radiation, Potter found that not only was the total amount absorbed similar to that of the criss-cross Bucky grid, but that it was also much easier to manufacture (Figure 18.19).

This new device was marketed as the Potter–Bucky Diaphragm and was announced in February 1917 at the ARRS. Potter demonstrated the use of this apparatus to show the lumbar spine, hips and pelvis, and renal calculi. It is famously recorded that at one meeting after Potter had shown his work, one radiologist was so surprised by the quality of the images that he accused Potter of touching up the negatives!

There was a certain delay in making the apparatus commercially available because of discussions about the priority of the discovery. However, in 1921 the Potter–Bucky diaphragm was finally marketed and was immediately accepted by the radiological profession. While the image of the pelvis from 1921 is excellent, it should be noted that the exposure time was 12 seconds (Figure 18.20).

**FIGURE 18.19** (a and b) The principles of the Potter–Bucky interception of scattered rays by a grid, and using a Coolidge tube. (Adapted from Holbeach, C. H. 1921. *Journal of the Röntgen Society*, 17, 179–181.)

**FIGURE 18.20** A normal pelvis from 1921 using the Potter–Bucky diaphragm and a Coolidge tube using a 12 sec exposure. (Adapted from Holbeach, C. H. 1921. *Journal of the Röntgen Society*, 17, 179–181.)
One effect of the new grid was to hasten the demise of X-ray photographic glass plates since using the new Potter–Bucky diaphragm larger films could be used with limited effects from scatter and the consequent blurring. Scatter was more the problem with larger than smaller films and traditionally radiologists were restricted to smaller plates. The smaller the plate and therefore the volume irradiated the less scatter was generated. The reason that a cone had been introduced over the X-ray tube was to reduce the irradiated volume and therefore the scatter.

18.11 Victims or Martyrs? The Radiological Radiation Victims

Following the use of X-rays, it became apparent that many were being injured. The exact cause of harmful effects was related to three factors. They were ionizing radiation, electrical injuries with pre-shockproof apparatus, and chemical processing. There had been an awareness of the harmful effects of ionizing radiation from the earliest days, and within three months of Röntgen’s first paper there had been reports appearing in the literature of the harmful effects of ionizing radiation. However, it took some time to introduce effective guidelines and recommendations. In June 1915, the Röntgen Society, which was a forerunner of the British Institute of Radiology (BIR), held a meeting to discuss protective guidelines for those involved in X-ray work. The meeting was opened by the pioneering medical physicist Professor Sydney Russ. A single sheet entitled “Recommendations for the Protection of X-ray Operators” was issued in November 1915 and this was the first British code of practice. Many radiographers had been recruited during the First World War, and Sidney Russ was concerned that many of the novices could suffer injuries. Matters were brought to a head in March 1920 when Dr. William Ironside Bruce of Charing Cross Hospital died of radiation-induced aplastic anemia (Figure 18.21).

A letter appeared in The Times of London on March 29, 1921 by the British radiologist Robert Knox who was trying to calm the current public anxiety over the medical use of radiation. So as an example, when the radiographer Kathleen Clara Clark entered the profession in the early 1920s her family tried strongly to dissuade her from entering such a dangerous profession. Knox announced the appointment of a standing committee, which subsequently became the British X-ray and Radium Protection Committee, and the major figure behind this was Sydney Russ who had been appointed to the Joel Chair of Medical Physics at the Middlesex Hospital. Russ remained joint secretary for the whole period of the life of the committee. The committee in its 31 years of existence showed itself to be of great scientific and economic benefit: it was hugely influential and was the model for other such groups.

18.12 The Martyrs’ Memorial in Hamburg

There is a monument to the X-ray and radium martyrs of all nations located in the grounds of St. George’s Hospital in Hamburg, Germany (Thomas and Banerjee 2013). Heinrich Albers-Schönberg was a German pioneer who worked at this hospital, and who had died of radiation injuries in 1921. The monument was set up in 1936 by the German Röntgen Society following the recommendation of Hans Meyer of Bremen. The
initial column records 169 deaths before 1936, and additional names were added in the mid 1950s (Burrows 1986).

A poignant example of the injuries sustained is seen in a wristwatch presented to Corporal Edward Wallwork Royal Army Medical Corps who was a radiographer working at the King George Military Hospital in London during the First World War (Figure 18.22a,b). All three radiologists who made the presentation died of radiation-induced disease, and all three are recorded on the Radiological Martyrs’ Memorial in Hamburg. The wristwatch is a poignant reminder of the sufferings and risks of the pioneering generation of radiographers and radiologists.

It was inscribed:

Presented, To Corporal E. Wallwork RAMC, By Doctors Ironside Bruce, Stanley Melville and, Harrison Orton as a token of appreciation of his work in the X Ray Department of the King George Hospital 1915–1919.

As J. H. Gardiner said in his presidential address to the Röntgen Society in 1916: “The most active and earnest of our workers were the worst victims” (Gardiner 1916). Ernest Wilson a radiographer from the Royal London Hospital, who died in 1911, said that he was not a martyr to science, but a victim since a martyr knows what to expect (Scott 1910).

The inscription on the Martyrs Memorial reads:

To the Röentgenologists and Radiologists of all Nations.
Doctors, Physicists, Chemists, Technical Workers, Laboratory Workers and Hospital Sisters who gave their lives in the struggle against the diseases of mankind.
They were heroic leaders in the development of the successful and safe use of X-rays and radium in medicine. Immortal is the glory of the work of the dead.

18.13 Classical Radiology

By the 1920s radiology was passing from the early stage of the pioneers and classical radiology was being established. Now, are historical changes the result of the action of individuals of genius and destiny, or are there are social and cultural trends and would the discoveries and developments have happened anyway because the time was right? However I think it’s not a question of either/or but rather of both/and. We have individuals of genius working within a historical stream.

Modern medical imaging has replaced many of the older classical radiological techniques and these are now disappearing from our memories. These older techniques often involved considerable technical skills from both radiologists and radiographers, and many years were spent in the perfection of skills.

Examples of older techniques include bronchography, and retroperitoneal air studies.

In bronchography the bronchial tree was opacified with an opaque medium using a variety of techniques. The examination was unpleasant for the patient and there was therefore a high threshold of referral for performing the examination. The first experimental bronchogram was performed by Karl Springer from Prague in 1906. Over the years, many contrast agents were used including colloidal silver and bismuth. In the classical technique, iodized oil was used, commonly introduced by tracheal injection. Contrast agents could also be introduced using a catheter (Figure 18.23), bronchoscope, or dripped over the back of the tongue.
In retroperitoneal air studies the tissues around the kidney is outlined by gas (Thomas and Banerjee 2013). Paul Rosenstein from Berlin and Humberto Carelli from Buenos Aires described the technique independently in 1921. A 10 cm needle was used to make a retroperitoneal injection. Rosenstein injected 600 ml of oxygen and Carelli about 200–400 ml of carbon dioxide. The examination was introduced in the days before the intravenous urogram to show the kidney. Rosenstein emphasized that it was “important that the radiologist became independent of the clinician for these pictures.” Rosenstein said that this technique was of value in various conditions including determining the presence of one or both kidneys and looking for displacements of the kidneys. This would diagnose the “floating kidney” which was thought to be a cause of symptoms as a part of visceroptosis. In later years the technique was combined with tomography to show the adrenal gland. The examination illustrated was performed in 1943, and in this case the gas was injected directly into the retroperitoneum with a long needle (Figure 18.24).

18.14 Angiography

Clinical angiography developed from post-mortem angiography with the first procedure being performed in January 1896 by the physicist Edward Haschek and his medical friend Dr. T. O. Lidenthal who injected a calcium carbonate emulsion (Teichmann’s mixture) into the severed arm from a cadaver (Doby 1976). The arteriogram exposure was for 57 min, which is not unreasonable when one remembers the low power of the apparatus that was then available. This procedure was performed in Vienna, and the radiograph can be seen at the Museum in the Josephinum. Sigismund Exner was professor of physics at the University of Vienna and was a friend of Röntgen, and had received a personally dedicated copy of the first communication and a collection of radiographs.

The angiographic work in Vienna was soon followed by work of the group in Sheffield in England (Anon 1896). Professor Hicks, who was the Principal of Firth College in Sheffield, and Dr. Addison, achieved both a renal and a hand arteriogram (Anon 1896). The delicate branching pattern of the arteries in the kidney and hand were shown in a similar manner to those that have been demonstrated in Vienna a few weeks earlier.

18.15 H.C. Orrin and His Atlas

The first X-ray atlas of the arteries of the body was written by H. C. Orrin, and was published in 1920 (Orrin 1920) as *The X-ray Atlas of the Systemic Arteries of the Body*. The book is illustrated with beautiful radiographs (Figures 18.25a,b and 18.26). The book was designed to be used by students of anatomy, surgical anatomy, and operative surgery. It was intended to provide a series of natural illustrations of the systemic arteries in continuity, and precisely as they exist *in situ* in the undissected body. The aims of the book were therefore purely anatomical in nature. Orrin wrote in his introduction that:

> No matter how well dissection is performed, complete continuity of the vessels; their exact relationship to bones; their finest terminal branches; the series of anastomosis into which they enter are seldom if ever accurately displayed or intelligently appreciated by dissection alone.

Orrin therefore echoed the earlier words of Morton. The atlas was accompanied by a full set of stereoscopic radiographs (Figure 18.27), “which provide the only possible means of accurately rendering visible the points and details specified.” It is interesting that in 1920 Orrin recognized the value of what is now 3D angiography.

It was thanks to the work of Portuguese radiologists that the goal of practical angiography in the living was fully realized (Veiga-Pries and Grainger 1982). The leader of this Portuguese team was Egas Moniz, who was the Professor of Neurology in Lisbon. Moniz was physically severely handicapped by topaceous gout and was therefore unable to make any vascular injections himself; however, he meticulously planned his research project on the localization of cerebral tumors. He was dissatisfied with the recently developed technique of ventriculography, which he found could make a correct diagnosis in less than a third of patients. Moniz had been aware of the pioneer work of the Frenchmen Jean Sicard and Jacques Forestier in early angiography. After his initially efforts to opacify the brain failed, he started performing intra-arterial injections. He had
FIGURE 18.25  Injected vessels of the upper half of fetus. (a) Vessels of upper half of fetus and (b) vessels of lower half of fetus. (Adapted from Orrin, H. C. 1920. The X-ray Atlas of the Systemic Arteries of the Body. Baillère, Tindall and Cox, London.)

surmised that if he could concentrate radiopaque material in the brain then the brain itself would be visible on radiographs, and knowing that bromides were used as sedatives, since they accumulated in the brain they might show up on radiographs. Moniz gave large amounts of bromides orally but showed nothing. He then tried injecting bromide into a carotid artery but apart from giving the patient a headache he again showed nothing. Next he thought of opacifying the brain by intravenous or parenteral administration of a variety of agents, giving large doses of lithium bromide and strontium bromide. After these techniques failed he tried using intra-arterial injections using an iodide salt. Iodine was chosen because its atomic weight is higher than bromine's. After many difficulties, he was successful using a 25% solution of sodium iodide with bilateral carotid artery cut downs. His successful patient, on June 28, 1927, was the ninth in his series, a young man with a pituitary tumor. Moniz (1931) shows the head positioned for angiography (Figure 18.28), and angiogram (Figure 18.29).

In 1929 Moniz’s surgical colleague Reynaldo dos Santos, Professor of Surgery in Lisbon, introduced percutaneous Trans

lumbar aortography (TLA) by direct aortic puncture with injection of a sodium iodide solution. Dos Santos et al. (1932) described the technique (Figure 18.30). The radiograph (Figure 18.31) shows abnormal vascularity in a sigmoid tumor; also note the stationary grid lines. Trans-lumbar aortography remained a standard for vascular imaging until the 1980s. Other members of Moniz’s team were equally innovative and successfully introduced pulmonary angiography (by Lopa de Carvalho and Almeida Lima), lymphography (by Hernani Monteiro), phlebography (by João Cid des Santos, the son of Reynaldo) and portal venography (by Sousa Pereira). The Portuguese School therefore introduced many aspects of clinical angiography in the 1930–1950 period,

FIGURE 18.28 The head positioned for cerebral angiography. (Adapted from Moniz, E. 1931. Diagnostic des Tumeurs Cérébrales et épreuve de l’Éncephalographie Artérielle. Masson et Cie, Éditeurs, Paris.)

FIGURE 18.29 Cerebral angiogram (arterial phase). (Adapted from Moniz, E. 1931. Diagnostic des Tumeurs Cérébrales et épreuve de l’Éncephalographie Artérielle. Masson et Cie, Éditeurs, Paris.)

FIGURE 18.30 Technique illustrating lumbar aortography. (Adapted from Dos Santos, R., A. C. Lamas, and J. P. Caldas. 1932. Artériograîhie des Membres et de l’Aorte Abdominale. Masson et Cie, Éditeurs, Paris.)

FIGURE 18.31 Lumbar aortogram for sigmoid tumor showing abnormal vascularity. The needle is visible in the upper abdominal aorta, and stationary grid lines are clearly visible. (Adapted from Dos Santos, R., A. C. Lamas, and J. P. Caldas. 1932. Artériograîhie des Membres et de l’Aorte Abdominale. Masson et Cie, Éditeurs, Paris.)
but the international adoption of their techniques was severely delayed by the Second World War.

Trans lumbar arteriography was replaced by catheter angiography from either the femoral or brachial/radial route. The use of a catheter began in 1929 when Werner Forssmann introduced a well-oiled ureteral catheter via an antecubital vein into his own right atrium (Doby 1976). It was in 1931 that Moniz, de Carvalho, and Almeida Lima using the Forssmann method demonstrated the pulmonary vasculature with an injection of sodium iodide (Moniz and de Carvalho 1932). The next major development related to the method of delivery of contrast medium into vessels and the heart chambers was achieved by Sven Seldinger in 1956, working at the Karolinska Clinic in Stockholm. He introduced the needle-guide wire-catheter replacement technique that permits selective catheterization and injection of most vessels from a simple puncture. This technique is now routine for many procedures requiring catheter access.

Now diagnostic angiography has been superseded by non-invasive imaging such as Doppler ultrasound, and CT and MR angiography. Angiography is now reserved for access for interventional procedures.

### 18.16 Charles Dotter and the Origins of Interventional Radiology

The development of interventional radiology depended on a number of factors. These include modern image intensification so that radiologists were no longer working in the dark, modern contrast media that were neither non-toxic nor painful, and the technology to produce wires, catheters and balloons.

It was on January 16, 1964 that Charles Dotter performed the first ever percutaneous transluminal angioplasty (PTA) (Thomas et al. 2005). In the early years of radiology the purpose of vascular catheterization was diagnosis; however, following the work of Charles Dotter catheterization increasingly came a prelude to intravascular intervention. At that time our ability to diagnose vascular disease was far greater than our ability to treat.

Dotter’s first patient was a bedridden 82-year-old woman with peripheral vascular disease and a pulseless and ulcerated foot. Dotter performed diagnostic angiography and an atheromatous obstruction of the superficial femoral artery was demonstrated. All seemed hopeless and the surgeon had recommended amputation, but the patient had refused surgery. Dotter performed a percutaneous trans femoral catheter dilatation, and he recorded that this was done with little pain and was without difficulty. When the dilating catheter was removed good pulses were palpable for the first time in the lower leg and foot. Subsequent angiography revealed that the stenosis was no longer present. There was immediate diminution in pain, discoloration and coldness of the foot, and during the week after the procedure there was rapid healing of the skin changes, including the ulceration of the lower leg. A follow-up angiogram was performed on February 6, 1964 at 3-weeks post-procedure and the lumen remained patent. At 8 months the patient was mobile, the ulceration was gone, the gangrenous toes had separated and the sites were healed. The patient’s pain disappeared and she was able to walk until she died three years later.

Dotter wrote that “Despite the frequency and importance of arteriosclerotic obstruction, current methods of therapy leave much to be desired. Nonsurgical measures, however helpful they may be, provide the patient little more than an opportunity to live with his disease” (Dotter and Judkins 1964). Following successful dilatation Dotter said that “the patient will happily announce the return of adequate blood flow to the troubled extremity.” Dotter recorded that the procedure could sometimes be completed in 10 or 15 minutes. It is worth noting that Dotter recorded that failure of his technique was not associated with harm to the patient.

Dotter stated that “It seems reasonable to expect that the transluminal technique for recanalization will extend the scope of treatment beyond the limits of present-day surgery. The method offers early treatment of the ischemic leg. In view of its simplicity and low morbidity, it is now feasible to treat intermittent claudication without waiting for more serious symptoms to occur or collateral circulation to develop.” He predicted that PTA would become the treatment of choice for patients suffering from arteriosclerotic ischemia of the lower extremities.

The technique of PTA became known as “Dottering,” and Dotter had considerable success in Europe and other places. Unfortunately, in the U.S. the technique was not to become popular until the middle of the 1970s and many saw it as a short-lived fad. There was a reluctance on the part of surgeons in the U.S. to refer patients—a well-known request to Dotter for a left femoral arteriogram has underlined and in capitals on the request form the comment “VISUALIZE BUT DO NOT TRY TO FIX!”

There has been a blossoming of interventional radiology since the time of Charles Dotter including the use of balloon catheters and stents, and many traditional surgical techniques have been avoided or replaced.

### 18.17 Godfrey Hounsfield and the CT Scanner

It is difficult to overestimate the impact that the EMI/CT scanner has had on medicine. The neuroradiologist James Bull said in 1977 that Godfrey Hounsfield’s invention was the most important advance in radiology since Röntgen had radiographed his wife Bertha’s hand in November 1895 (Bull 1977). Within five years of the introduction of the EMI scanner there were CT machines throughout the world, and the technique was rapidly adopted into clinical practice. It is now difficult to imagine how medicine was practiced before the introduction of CT scanning. Illustrated is the brochure for the EMI1010 scanner “the most advanced system for neuroradiological examinations” and is signed by Hounsfield (Figure 18.32).

The history of the development of CT is complicated (Bull 1981, Webb 1990). The need for tomography lies in the fact that in conventional radiography a three-dimensional object is displayed as a two-dimensional image with no depth information. Classical tomography was well developed by the 1950s, the pioneer work having been done by Bernard Zeides des Plantes and published in the 1930s. In classical tomography the X-ray source and the detector both move and the points of pivot all lie in the same plane. Objects out of the plane are blurred and those at the level of the pivot are in focus. This tomographic image gives information in one plane and helps in diagnosis.
The award of the Nobel Prize for Medicine and Physiology to Godfrey Hounsfield and Allan Cormack in 1979 emphasized the arrival of the new technique of CT, although there were many others who had worked in this field. The mathematical basis for image reconstruction started with Johann Radon who published in 1917 his work on the “Radon transform” with the idea of reconstructing a function from a set of projections therefore plays a significant role in the development of computed tomography.

In the mid-1940s Shinji Takahashi in Japan had worked on the principles underlying rotational radiography and developed sinograms. In 1957, B. I. Korenblyum and his co-workers build a medical CT scanner in Kiev in the then USSR. In 1960, William Oldendorf made experiments to demonstrate the feasibility of CT scanning using a rotating phantom made of nails and mounted on a track. In the early 1960s, David Kuhl and Roy Edwards developed an apparatus for emission CT scanning. It is very interesting to observe the number of disconnected workers considering the same problem but coming from different directions.

Cormack developed the basis of what became CT scanning, and developed a mathematical approach looking at the problems of variations in body tissues that are important in radiotherapy. In 1957, he made experiments using a phantom that had circular symmetry, and by 1963 Cormack was ready to make experiments on a phantom that did not have circular symmetry. The
results were presented for publication in graphical form and were published in 1964 (Cormack 1964). There was almost no response to the publications, and certainly there was no commercial interest.

In the 1960s, Hounsfield was working at EMI Ltd in Hayes, Middlesex (Bates et al. 2012). He was interested in pattern recognition. He considered a closed box with an unknown number of items inside that could be looked at from multiple directions using a radiation source and a radiation detector. The results of the transmission readings could then be analyzed by a computer and presented as a slice in a single plane. Hounsfield developed a mathematical approach in a process of reconstruction. The original apparatus was simple and resembled that used by Cormack and was a simple lathe holding the object to be examined. The early experiments were made using Perspex phantoms of varying complexity. It took nine days to take the picture and fifteen minutes computing time to reconstruct the picture. Following the use of Perspex phantoms a section of human brain in a Perspex box was examined. Most of the pictures from the lathe bed were scanned in 1969 and 1970.

Hounsfield looked at practical applications and approached the Department of Health in London in 1968. He met Cliff Gregory and Gordon Higson, who were scientific advisers at the Department of Health and Social Security (DHSS). Hounsfield was then introduced to Evan Lennon, a radiological adviser who knew Frank Doyle from the Hammersmith Hospital. Doyle gave Hounsfield two lumbar vertebrae of different densities. Hounsfield examined the vertebrae and returned to Doyle with computer printouts of numbers in the coronal plane of the vertebral body. Hounsfield had already worked out a scale of numbers and Doyle was impressed with the result. Lennon also made contact with two other radiologists, James Ambrose and Louis Kreekl. Ambrose was a neuroradiologist from Atkinson Morley’s Hospital in South London and Kreekl was from the Royal Free Hospital, subsequently moving to Northwick Park Hospital in Harrow where he did pioneer work using the EMI body scanner. Ambrose later discovered that Hounsfield had been previously dismissed by an eminent London radiologist as a crank.

It became apparent that EMI would not spend any more money without the support and a contribution from the DHSS. Work continued on specimen radiography and then on January 14, 1970 there was a meeting at the DHSS between the three radiologists and Dr. Evan Lennon, Mr. Cliff Gregory and Mr. Gordon Higson. The initial results were promising and it was agreed to produce a prototype brain machine to be located at Atkinson Morley’s Hospital.

The prototype scanner was installed at Atkinson Morley’s Hospital on October 1, 1971. It is quite remarkable that Hounsfield went in one jump from the primitive lathe bed apparatus to the prototype CT scanner. This prototype looks very similar to our modern CT scanners and the original is on display in the Science Museum in South Kensington, London, UK. The scanning time was 4 minutes per slice and the slice thickness was a little over 1 cm. There was no computer attached to the machine and the data was taken by car on magnetic tape to be analyzed by EMI at Hayes. The data was reconstructed using an ICL 1905 mainframe computer and a picture with an $80 \times 80$ matrix took 20 minutes to reconstruct. It would have been possible to have reconstructed the data using a $160 \times 160$ matrix but that would have taken very much longer. The first patient scanned was a 41-year-old woman with a possible frontal lobe tumor. The data was acquired and the tapes were sent to EMI. The results were returned after 2 days. The cystic tumor in the left frontal lobe was clearly shown, and Ambrose said the result caused Hounsfield and himself to jump up and down like football players who had just scored a winning goal (Ambrose 1996). The preliminary results were presented at the 32nd Annual Congress of the BIR, which was held at Imperial College in April 1972. The paper produced a sensation and the first press announcement was in The Times on April 21, 1972 (Ambrose 1973, Ambrose and Hounsfield 1973, Hounsfield 1973). EMI then started the production of a brain machine and made five: one for the National Hospital, Queen Square, one for Manchester, one for Glasgow and two for the United States, one for the Mayo Clinic and the other for Massachusetts General Hospital. All machines were installed in the summer of 1973. Radiology was changed forever.

CT scanning has continued to develop since the 1970s. Spiral CT represents a significant advance in the technology of CT scanning and has significantly increased the clinical value of CT. The first clinical cases and performance measurements were presented as work in progress by Willi Kalender, Peter Vock and Wolfgang Seissler at the 75th anniversary meeting of the Radiological Society of North America in 1989 (Vock et al. 1989, Kalender et al. 1989, Kalender et al. 1990). The development of spiral CT and multi-slice scanning was made possible by the advances in computing. Data no longer have to be taken away for analysis but can be reconstructed almost instantaneously. There are remarkable results with modern multi-slice scanners with improved spatial resolution with virtual endoscopy and faster scanning enabling complex dynamic studies. This dramatic improvement was made possible because of the provision of higher continuous X-ray power and improvements in computers.

18.18 PACS

The idea of Picture Archiving and Communication Systems (PACS) started in the early 1980s (Lemke et al. 2000). An attempt was made to create a fully filmless radiology department at St Mary’s Hospital in London. Funding was requested from the DHSS and in June 1985 the Minister of Health promised assistance. However, it became apparent that the technology in 1985 was not adequate for the task proposed. There was no filmless X-ray cassette, no clear means to rapidly transmit the vast amount of data and little knowledge about the role of image compression. In 1987 David Allison at Hammersmith Hospital became interested in developing an entirely filmless hospital, and this coincided with technological developments. The British government gave a grant in 1990 and computed radiography was introduced in 1993, with Hammersmith Hospital becoming filmless in 1996.

Developments were taking place in other hospitals in Europe. In the Netherlands, Dr. Bakker and others worked on “The Dutch PACS Project.” This was sponsored by the Ministry of Health Care and based at Utrecht University Hospital and was carried out from 1986 to 1989 with the aim of evaluating a Philips PACS prototype and to research the relationship PACS and Hospital Information Systems (HIS), the quality of diagnostic images.
and assessment of technology. The first “digital reading room” was built at Utrecht University Hospital with the first coupling of PACS-RIS (Radiology Information System). They accomplished the complete digitization of a small medical intensive care unit and the images and reports could be accessed at all times. The referring clinicians were very enthusiastic about the project since the radiological images were easily accessed without delay. It was concluded that earlier availability of radiological images would increase the speed of diagnosis and treatment, which would reduce the average length of inpatient stay. At that time it was concluded that PACS at Utrecht University Hospital would be approximately four times as expensive as conventional radiography; however, they estimated that by the year 2000 the cost of PACS would be the same as that of a conventional film-based system.

One of the few multivendor PACS installations began in 1986 at the University Hospital of Brussels working with the Multidisciplinary Research Institute for Medical Imaging Science. The University of Brussels was concerned about communication in hospitals and particularly communication between systems and also between users and systems. Working with others they were concerned with modeling the PACS-HIS coupling, evaluating image transfer using high-speed networks, developing network structures, developing a multimedia software database which would enable intelligent information retrieval and designing an adaptive user interface to increase diagnostic efficiency.

The first PACS Project in Austria started 1985 as a project between Siemens and the Department of Radiology in the University Hospital of Graz (Hruby 2001). The Department of Radiology at Graz had developed an in-house RIS and they contacted Siemens in 1985 to initiate a PACS pilot project. The aim of this PACS-RIS was for a sequential implementation, which would meet the needs of both radiologists and clinicians. There would be digital acquisition, storage and communication of radiological images from all imaging modalities and there was emphasis on the need “to determine the efficiency, usefulness and economy of Roentgenologic telecommunication.” There were further developments in the 1960s and following an airplane crash at Logan Airport in 1962 a new medical department was set up at the terminal by Kenneth Bird. Bird connected Logan with the Massachusetts General Hospital which was 2.7 miles away using a telemedicine link. This microwave link was used by R. Murphy and co-workers in 1970 to transmit chest radiographs for remote interpretation. Murphy selected 100 chest radiographs of patients from a TB hospital, and a panel of 3 reached agreement in 92 of the cases and when compared to the radiology report there was 77% agreement. Further studies were performed in the 1970s using a slow-scan television and images sent on ordinary telephone lines and while images were acceptable for low-resolution nuclear medicine images they were not acceptable for radiographs. By 1976 Lewis Carey in Ontario (Carey 1985) was using the Hermes satellite to investigate interactive telecommunication within a regional health care system. Over 5 months Lewis Carey and his team provided 297 radiological consultations, and remarkably gave live supervision to 14 television fluoroscopic examinations which were being performed by a radiologic technician. Carey concluded that the consultation service was 90% as effective when compared to direct film viewing.

There were more teleradiology studies in the 1980s in the U.S. (Gitlin 1986), with a large field trial in 1982 located at the Malcolm Grow Hospital in Andrews Air Force Base, which served as a central location providing radiographic interpretation to one civilian and three military clinics. The radiographs were scanned using a video camera and the digitized X-ray images from the remote clinic were sent via telephone lines to the central medical center, and the radiological report was returned again by telephone lines. The results of the trial were successful and in 1984 the Uniformed Services University in Bethesda, Maryland replaced to Malcolm Grow Hospital as the hub linking the four sites. In the 1984 study, a matrix density $1024 \times 1024$ pixels was used. The radiographs were scanned and converted to a digitized image. The results of the 1982 and 1984 trials were very encouraging with only a few discrepancies between the video and film reports.

In 1985 Lewis Carey reviewed teleradiology and was predicting that “Improved access to radiologists, 24 hours a day, will provide a level of service heretofore not possible.” This has proven to be the case and studies are now routinely reported by radiologists at home or transmitted between hospital sites for reporting.

### 18.20 Conclusions

We are now so accustomed to modern imaging that we do not realize how difficult it was to make even what now are quite straightforward diagnoses a few decades ago. Peripheral vascular disease, bronchiectasis, renal disease and pelvis masses can be elegantly demonstrated non-invasively. There is a steady increase in workload, and many more patients are now referred for high-resolution CT to exclude bronchiectasis than were ever referred for bronchography. This has resulted in a paradigm shift. Traditionally there was invasive diagnosis and invasive treatments. We now have non-invasive diagnosis and minimally invasive therapy. Indeed the one implies and leads to the other.
Minimally invasive therapy needs an accurate pre-intervention
diagnosis so that the procedure can be planned and executed.
In some respects the 1970s can be seen as a golden decade
for radiology with many new techniques becoming available. In 1979 Robert Steiner asked who would have thought 10 years ago
that such momentous developments were possible (Steiner 1979).
There were many who felt the diagnostic radiology had reached
its peak and ultimate goal and that there were no further room for
new ideas and developments. How wrong they were in their ideas
and predictions. We are only at the beginning of the application
of these newer techniques: it is quite impossible to predict how
far they will advance our abilities to establish ever more accurate
and definitive diagnoses.

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