Early days in the Evolution of Radioisotope Imaging in the UK 1950 - 1970

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Most of the first developments in radioisotope imaging in the UK were made by hospital physicists. Just after World War II the United States was prohibited from exporting any radioisotopes made in reactors. However some cyclotron produced radioisotopes were available from the US and Cambridge. Even with the limited availability of radioisotopes radioisotope departments were already being set up. One of the first was in the Hammersmith Hospital with Normal Veall, while other groups included those of Harold Miller in Sheffield, Russell Herbert in Liverpool, John Mallard in Hammersmith and then Aberdeen and Val Mayneord in London. It was a time of great excitement and innovation. Much of the original apparatus for measurement and then imaging was home made by workshops within the hospitals. This brief review remembers the contribution made by these pioneers to what is now taken for granted.

First attempts at recording patterns of radioactivity

The availability of radioiodine after World War II soon led to the diagnosis and treatment of thyroid disease. The thyroid gland was being 'imaged' with hand held detectors (initially Geiger and then scintillation counters) and the results plotted as lines of isocount rates. This was a tedious process especially with the Geiger counters whose efficiency rarely exceeded 5%. It was aided later by using a mechanical frame to guide or move the detector by hand in a rectilinear fashion. When scintillation detectors became available their improved efficiency made them the detector of choice speeding up the whole process.

Early radioisotope studies were not limited to the thyroid gland. Many compounds were tried to help brain tumour diagnosis in the days before CT scanning. An early scintillation detector designed for brain studies was made in March 1951 by Belcher and Evans at the Royal Cancer Hospital (now the Royal Cancer Hospital) in London. There was a close association between the Royal Cancer Hospital and the Atkinson Morley Hospital specialising in neurological diseases. It had a collimator for 'directionality'. The photomultiplier tube had to be cooled by liquid nitrogen to reduce the background noise (1;2). To avoid the possibility of frostbite, the patient's skin and the crystal separated by a long Perspex light guide! The choice of crystal was interesting. Calcium tungstate was difficult to obtain at that time and was limited to 3 mm rods. Napthalene (moth balls) and anthracene could have been grown into larger crystals. However in Belcher's counter potassium iodide activated by thallium halide was used. Sodium iodide was considered but not used as 'it was deliquescent' and needed to be protected from the air. There was an arm with a pointer on the opposite side of the counter to assist localisation. The figure below shows the construction of the device, made in the hospital workshop. It was designed primarily for the localisation of brain tumours with I 131 di iodo flourescein. Flourescein was used as a dye to the brain tumour at operation.

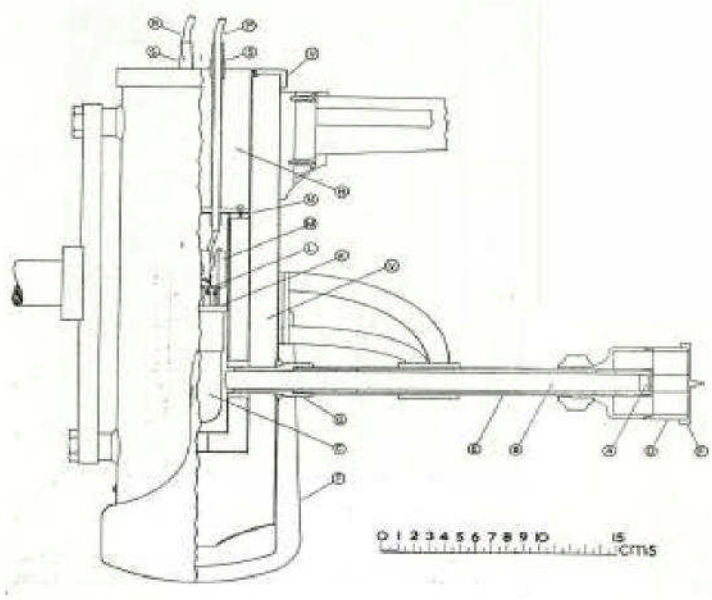

Fig. 1. Scintillation counter

A, crystal; *B*, Perspex light-guide; *C*, photo-multiplier; *D*, lead collimator; *E*, Duralumin tube; *F*, Perspex cap; *G*, thermal insulator; *H*, liquid nitrogen container; *K*, photo-multiplier base; *L*, resistor chain; *M*, output capacitor; *N*, Neoprene washer; *P*, output cable; *R*, e.h.t. supply cable; *S*, rubber sleeve; *T*, lead screening; *U*, Keramot ring; *V*, lagging.

About the same time Benedict Cassen in the United States was constructing his version of a radiation detector for use in ^{131}I thyroid studies. He published a paper on a sensitive directional gamma ray detector in February 1950 (3). It had a single bore collimator and 4 small A" square by ^{3}A" long calcium tungstate crystals.

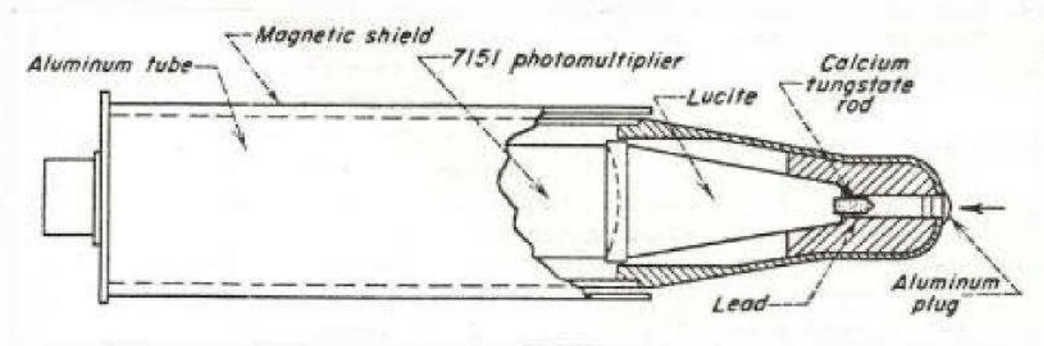

FIG. 1. Hand-held counter for tissue-boundary determination

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The Mark 2 version had calcium tungstate crystals cemented to the face of a photomultiplier tube and this was the detector that was used in his automatic scanner.

Automatic Scanning

Although Benedict Cassen from the United States is usually associated with the `invention of the rectilinear scanner which (first) brought the ability to image patients' (http://snm.org), it is interesting to record that similar developments before and at the same time were taking place in the UK and Europe.

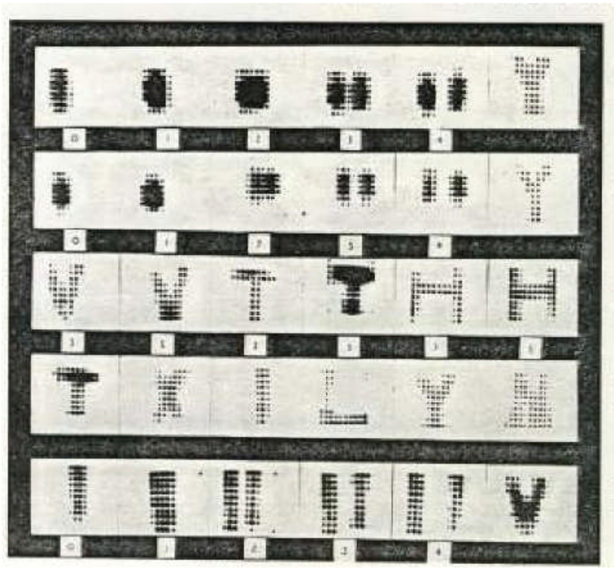
It was an exciting time where regulation was less cumbersome and ideas could be rapidly translated into practical working devices which were in use for clinical studies within weeks.

While Mayneord and Cassen were simultaneously developing automated systems for radioisotope imaging in 1951 probably the first apparatus for scanning patients (indirect autoradiography) had been developed before that. It was presented by Ziedes des Plantes to the International Congress of Radiology in London in 1950 (4).

It was a motor driven rectilinear scanner mounted above the patient with a Geiger counter, a 1.5 cm collimator and a means of outputting the counts on sensitized paper. It was used to produce a two dimensional image of ^{m}I activity in the human thyroid.
He called this technique 'indirect autoradiography'.

In July 1951 'A method of making visible the distribution of activity in a source of ionizing radiation' was published by W V (Val) Mayneord et al. from the Royal Cancer Hospital London (5). The images were those of Tantalum and Gold radioactive wires. The automatic scanner incorporated two Geiger Counters in a single head driven by two cams. It had many innovative features including automatic background subtraction, recording on a Cathode Ray Tube (CRT) with a long persistence screen and a spot with its brightness proportional to the count rate.

The images could be photographed and viewed on a CRT. The results using tantalum wires showed a resolution of better than 2 cm in air using a collimator of 3.0 mm. Some 50 years later these analogue features are now found on present day work computer based work stations. Below is one of the figures showing the images of the sources.



Later in August 1951 Cassen published his 'Instrumentation for ^{131}I use in Medical Studies'(6). The detector sensitivity had been improved with more crystals attached to the photomultiplier.

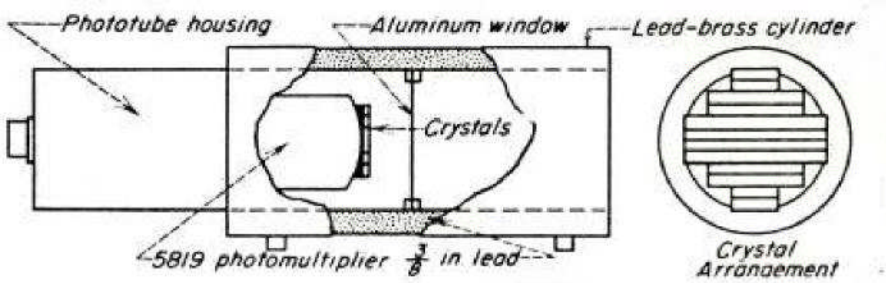


FIG. 2. Wide-angle scintillation counter designed for high sensitivity. The calcium tungstate crystals are cemented to the face of the photomultiplier

48 August, 1951 - NUCLEONICS

It had two electric motors for the x and y directions. The display consisted of a pen attached to an electromagnet making marks in on paper after the incoming counts were scaled.

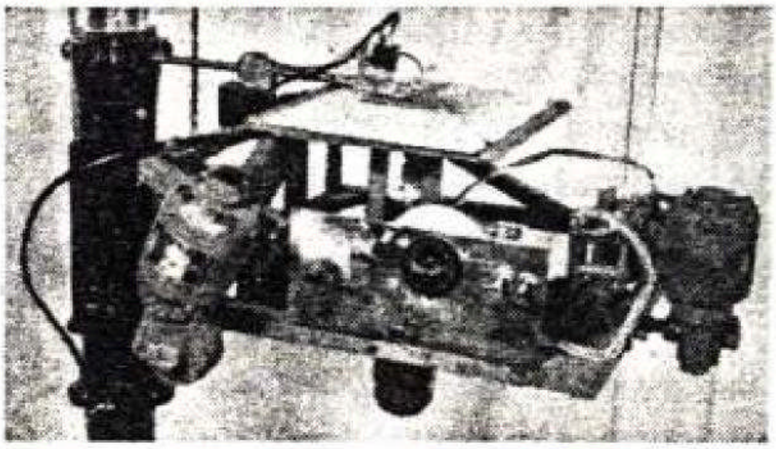


FIG. 4. Automatic scanner and recorder

Unfortunately the magazine Nucleonics has long since disappeared so the above rather poor picture of Cassen's original scanner is taken from an old photocopy. A picture of images from a 'live' patients show the thyroid clearly.

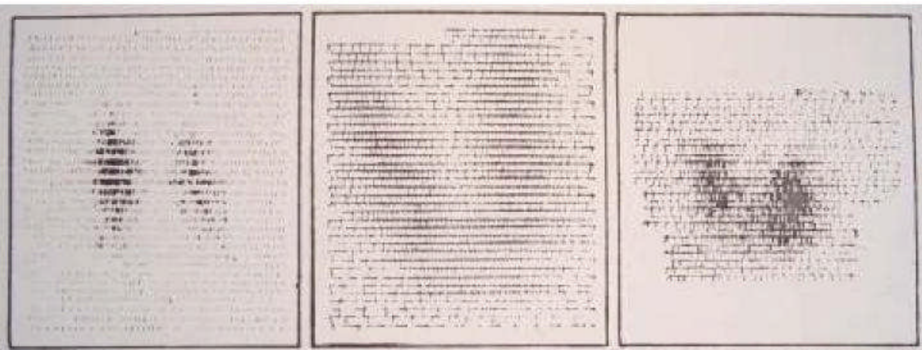
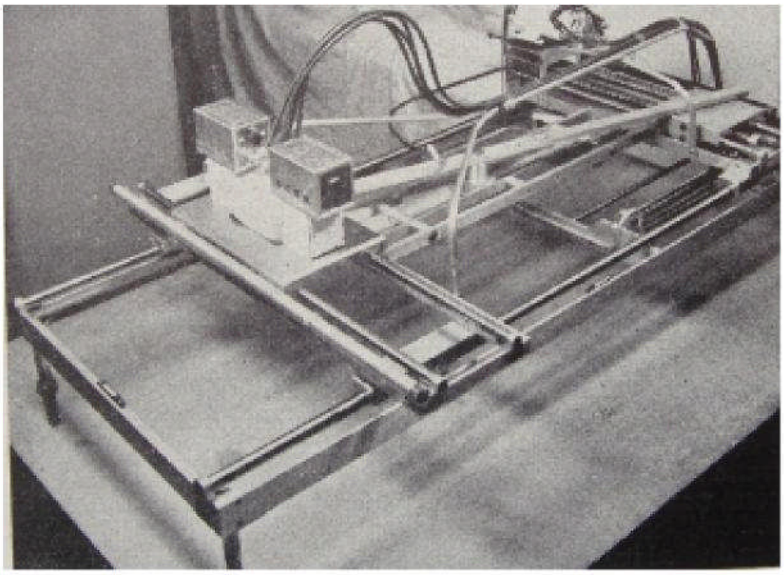


FIG. 6. Automatically recorded outlines of the thyroid glands of live patients

50 August, 1951 - NUCLEONICS

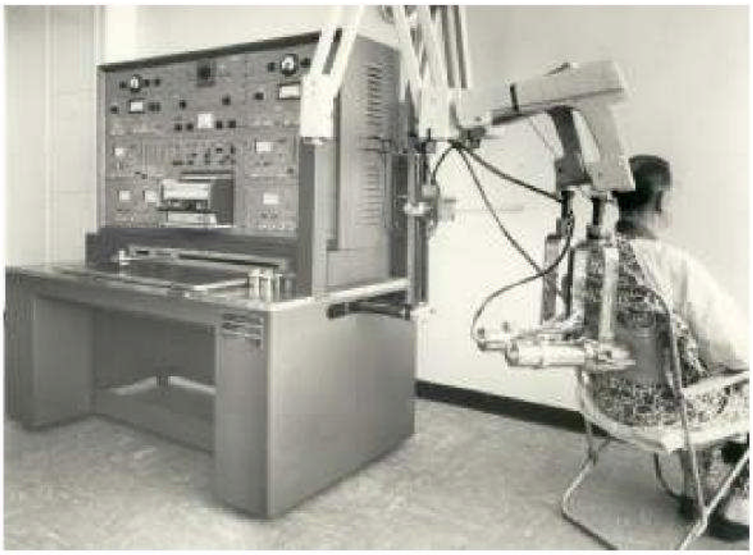
Val Mayneord published a paper on 'A method of making visible the distribution of activity in a source of ionizing radiation' with Newbery and Hodt in Nature in November 1951. The paper was essentially the same as that from the Isotope

Techniques Conference in July 1951. Obviously nothing has changed since then, in that the results of research still need to be published in a widely read journal rather than in a Conference Proceedings.
The original scanner was made into a rectangular imaging device with output still being recorded on the writing mode of a storage cathode ray tube. The sodium iodide crystal in paraffin was placed between two photomultipliers. The objectives were to achieve maximum sensitivity and resolution. An image of a thyroid phantom containing 2500 micro curies is shown below. The x motion used an Archimedean spiral which gave a continuous backwards and forwards motion (7). Unfortunately the original scanner was lost after being cannibalized to make a high resolution automatic ultrasound breast scanner (8) and sadly no longer exists.



This figure shows the Mayneord rectilinear scanner with an image of a thyroid phantom containing 2500 μCi taken using a 3mm collimator.

In 1958 the first commercially made scanner to be installed in the UK was at the Sutton Branch of the Royal Marsden Hospital. It was called the Tri-D scanner. It had two heads with whole body scanning possibilities. Unfortunately it lacked adequate shielding and when used with the high energy of ^{131}I there was considerable background activity. It did not perform well as a scanner but it was useful for renograms and other counting studies.



In this figure a patient can be seen having a renogram. It was always difficult to know the actual position of the kidneys before the advent of ultrasound. Blind positioning was aided by this chair with a transparent back.

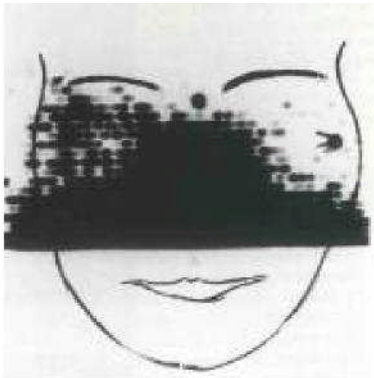
At Hammersmith Hospital in London, the first whole body automatic scanner in routine diagnosis use in the UK was homemade by Mallard and Peachey (9). It was built in the mid - 1950s with a mechanized floating top couch for the rectilinear raster. The display had a colour printer to enhance the differences in uptake between normal and abnormal tissues. The scanner was exhibited at the Medical Electronics Conference in Olympia in 1960. Even at that time, it had positron imaging capacity using two sodium iodide counters. Positron emitting arsenic 72 and 74 was produced by the MRC cyclotron beside the hospital. This scanner provided the basic design for the first British Scanner made by Isotope Developments Ltd and installed in St Bartholemew's Hospital London in 1964. As with many other British developments it did not become commercially viable.

The first whole-body isotope scanner (homemade) in use for detecting a brain tumour, c. 1959.

In 1962 the Picker Magnascanner made its appearance in the UK, having been installed in Russell Herbert's laboratory in Liverpool. Initially it had a 3" crystal, but soon it was available with a 5" crystal. The very heavy 5" crystal was a replacement for the 3" crystal and used the same rack and pinion design. There was a rumour that in one of the London hospitals the larger detector had descended slowly down onto the patient's head. It had a colour printer outputting on paper. The counts were scaled to keep the rate of tapping within the speed limits of the solenoid. Clever patients could workout if a tumour was present by listening to the pattern of the tapping.

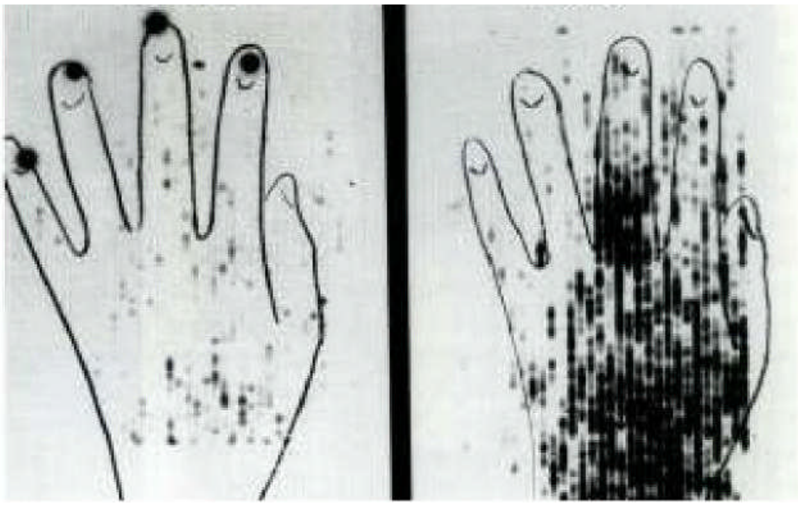
A second output used x-ray film and a light source attached to the beam carrying the detector and colour printing mechanism. It had a clever analogue device called the count rate differential (CRD) to enhance the visualisation of tumours. The minimum point of the CRD range was set up over the background and maximum over the suspected tumour. It then spread the range of the intensity of the light source between the background and uptake in the tumour making even small changes in count rate visible. This was essential as scans usually were made with small activities of ^{131}I or ^{197} Hg neohydrin and the counts over the brain were generally few and far between.

3″ Picker Magnascanner with colour printer



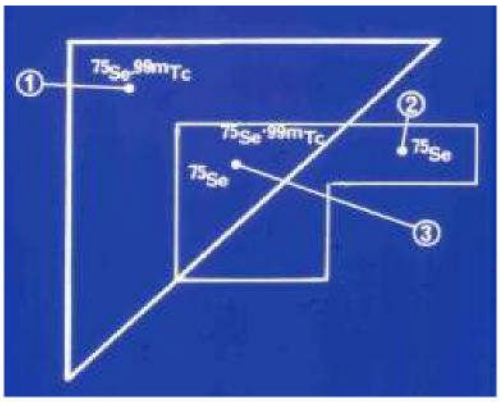
Photoscan demonstrating the CRD enhancement of a small difference in activity between the orbits (due to an unsuspected tumour).

The figure above shows the Royal Marsden Hospital 3" Picker Magnascanner with the colour printer table on the right and the count rate differential system in the middle panel. The scanner was sold by Mike Tunnicliffe from Exal Ltd founded by his father E J Tunnicliffe. Mike went on to marry Rosemary French, the isotope physicist at the Royal Marsden Hospital who had helped develop F-18 as a bone scanning technique using the Picker scanner and F-18 supplied from the MRC cyclotron unit (11).



Picker Magnascanner photoscans using 90 µ Sr 85 on the left and 1.5 mCi F18 on the right

In 1968, Burn, Field and Cottrall at the Royal Marsden Hospital developed an analogue system for imaging the pancreas without the overlapping liver uptake when patients were scanned with ^{75}Se labelled selomethionine (12). The device was made in the workshops of the Institute of Cancer Research at Sutton. The so called ratio subtract scanner measured the count rate of Tc99m colloid over the liver [1] and the count rate of Se 75 over the pancreas [2]. By careful adjustment a fraction of the Se 75 count rate over the liver was subtracted [3] leaving an image of the Se 75 in the pancreas without the Se 75 in the overlying liver (13). It turned out that a similar device had been made by Kaplan in the United States and he had been in print first in 1966 (14). This technique is now familiar for parathyroid scanning, the subtraction being carried out with the aid of a computer.



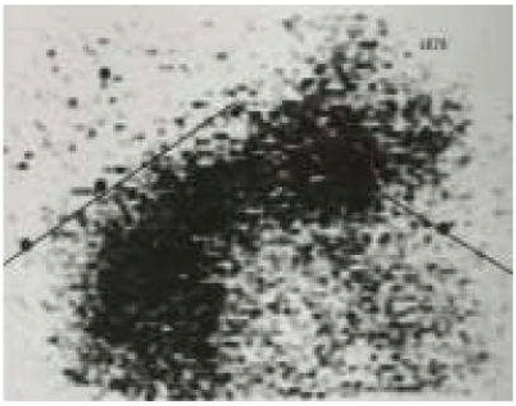


Diagram showing the ratio subtract principle. Se 75 methionine pancreas scan after subtraction

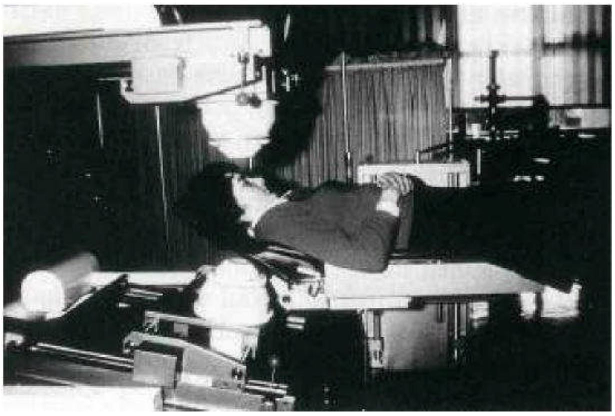
In 1963 Dave Kuhl in America revealed first clinical single photon emission tomography machine. In the UK John Mallard and his colleagues using the same principle constructed a home made whole body SPECT scanner in Aberdeen seen in the picture below taken in 1968. It had two detectors on a scanning frame that rotated around the patient.

The first UK digital whole-body SPECT scanner built in Aberdeen

Early days in the development of physics in medicine have been documented in a seminar held at University College London. Eminent scientists and physicians recalled the early days of isotope techniques and scanning (15).

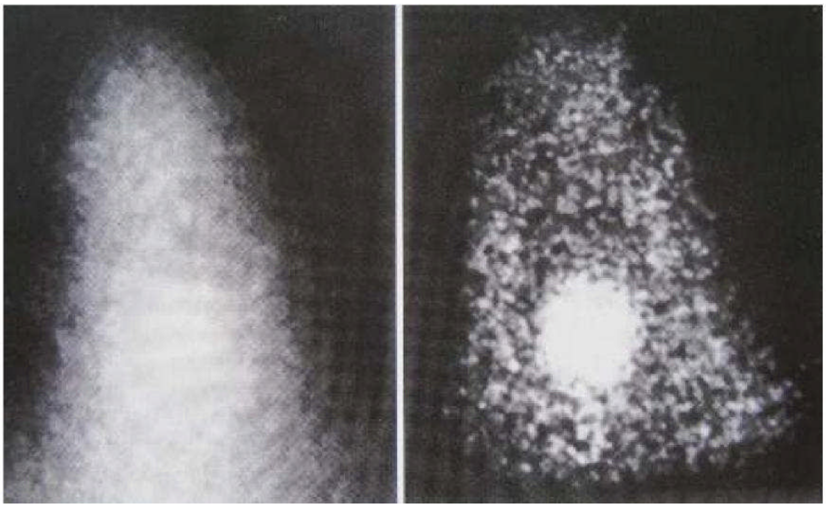
The first UK commercial SPECT scanner was made by J&P Engineering in Reading. The prototype was installed in the Middlesex Hospital London. It was exhibited at the Nuclear Medicine conference in Amsterdam in 1968 (16).

The scanner produced interesting clinical studies but the advent of the gamma camera rapidly led to its demise. It was not a commercial success in the UK but at least one was installed and used in Japan for cerebral blood flow studies (17)



The J&P rectilinear scanner installed at the Middlesex Hospital, London

It was always obvious that the resolution of scanners and then gamma cameras was poor especially when trying to image non radioactive volumes in a background of radioactivity. Roy Parker and his collaborators from the United Kingdom Atomic Energy Authority in 1970 foresaw the benefit of using semi conductor detectors for greatly improved resolution. They used a lithium drifted germanium semiconductor detector. An image of a rat's thyroid demonstrated the amazing resolution achievable at that time by this device and a gamma emitter. However prototype detector was too small and required rather complicated cooling to reduce the background noise (18). It never proceeded past the experimental stage although images of the human thyroid were obtained. Now there is a resurgence of interest in scanning with semiconductor detectors that operate at room temperature. With sophisticated computing reconstruction techniques and high spectral resolution of the solid state detectors, the results are a significant advance on current imaging.



An image of a rat's tiny thyroid on the semiconductor camera compared with a gamma camera image on the left

More information on the development of radioisotope imaging can be found in the review articles written by David Smithers (1954) (19) John Mallard (1965) (20), Ralph McCready (1967) (21), Roy Parker (1970) (22) John Mallard and Nigel Trott (1979) (9).

Acknowledgement

I would like to acknowledge the kind help and advice from Professor SteveWebb, Institute of Cancer Research Sutton.

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