Section of the History of Medicine

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Paper

The History of Neuroradiology

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In order to develop a perspective in the history of neuroradiology we must go back a few decades before 1895, the year Röntgen discovered X-rays.

Until a little over a century ago it was quite impossible for a physician to explore the brain during life. The first advance came in 1851 when Helmholtz discovered the ophthalmoscope. Hughlings Jackson (1863) was quick to see the great importance of this discovery, the first means that the physician had of exploring the brain and actually seeing one of its appendages in life. As he said, it enabled one to make a careful study of the retinal arteries and veins and he hoped to learn something of the circulation of the brain itself in cerebral disease. He was soon to observe the appearances of atrophy and swelling of the optive nerve head. Meanwhile Broca (1861), a French anthropologist and surgeon, had discovered the speech centre. In 1870 Fritsch & Hitzig excited the cerebral cortex of dogs electrically and found that muscles on the opposite side of the body were stimulated. Then in 1874 Bartholow, an American, confirmed that the same applied to man; he stimulated electrically the cortex of a man through a lacuna in the skull produced by a cancerous growth, and he caused the opposite side of the body to move. Thus gradually physicians were able to elicit and interpret physical signs which led them to believe that a space-occupying mass was present within the cranium, and Broca was perhaps the first to define a physical sign of localizing value.

Concurrently in these middle decades of the last century anæsthesia was developing and in 1865 Lister introduced antiseptic surgery in Glasgow. So with physicians feeling their way slowly towards the localization of intracerebral masses and surgeons becoming bolder and bolder in their operative explorations with the aid of anæsthesia and antiseptics, the stage was gradually being set for the surgical exploration of the brain.

William Macewen, a young surgeon in Glasgow, later to become Sir William Macewen, was the first to apply the important applications of the recent discoveries. In 1876, when he was still only 28 years old, he made medical history. The story was as follows. One day in that year an 11-year-old boy came under his care. The patient had just had a convulsion, two weeks previously having suffered a head injury with slight wounding of the scalp, which, on admission was suppurating slightly. The convulsion began on the right side of the face, then involved the right arm and leg and was followed by loss of conciousness. This lasted half an hour after which the right side of the body was paralysed and aphasia had set in. The boy was only able to say 'No, no' and he was apparently distressed by his inability to express himself otherwise. Macewen diagnosed an abscess of Broca's lobe and he proposed to open the skull and evacuate the abscess, but the parents refused. The boy died and Macewen sought permission to expose the brain exactly as he would have done in life. This permission was granted and an abscess about the size of a pigeon's egg was found in the white matter of the brain on the inner side of the left third frontal convolution. Thus the diagnosis was triumphantly confirmed. This was the first example of an intracranial mass being localized by clinical means.

The case was published later in the *Lancet* (Macewen 1881).

In June 1887 Victor Horsley of University College Hospital and the National Hospital, Queen Square, removed the first spinal tumour surgically, the diagnosis having been made by Sir William Gowers, his colleague at both these hospitals. No paraclinical methods existed at that time to help Gowers or indeed Macewen. Lumbar puncture was not discovered until 1891 by Quincke, who was the first to measure the pressure of the cerebrospinal fluid and the protein. Then in 1895 Röntgen discovered X-rays, but it was many years before their applications had much influence on neurology.

Returning again to the first spinal tumour ever removed, Gowers had the great genius to state precisely what X-rays alone could show nowadays at myelography. He had no difficulty in diagnosing 'grave disease of the dorsal region of the spinal cord'. It appeared to him 'that it was practically certain that the spinal cord was damaged by compression and that the cause of the pressure was outside the cord itself. The diagnosis lay between an aneurysm eroding the vertebræ and compressing the cord, a growth springing from the bones of the spine and an intraspinal tumour within the canal, but outside the cord itself.' This was indeed a remarkable clinical assessment of the situation. The tumour was a fibromyxoma of the fourth dorsal root on the left side.

Localization of any mass within the cranium was to become the vital and principal task of the neuroradiologist, to be achieved in a precise way much later with the aid of contrast media and radioactive isotopes. The spinal cord with its easily identifiable metameric arrangement, thanks to paired roots being given off from each segment, presented far less difficult problems. Nowadays by myelography radiology can help greatly in localizing the exact level of a mass in the spinal canal – and often its size and shape and its relation to the spinal cord, that is to say whether it is within the cord itself, within the dura or extradural. In the introduction of his two-volume textbook, 'Diseases of the Nervous System', published in 1886 and 1888, Sir William Gowers wrote:

> 'The nervous system is almost entirely inaccessible to direct examination. The exceptions to this are trifling. The termination of one nerve, the optic, can be seen within the eye. Some of the nerve-trunks in the limbs can be felt; a few, as the ulnar, in the normal state; others only when enlarged by disease.'

With this background it is hardly surprising that Macewen described the brain as 'the dark continent'. To express it in another way, one could not perform a laparotomy on the head. It is in large measure due to various advances in radiology that have taken place since, that this dark continent has become, to some extent, illuminated.

It is worth noting how fortunate man is to be able to apply Röntgen's discovery to his own ends. It so happens that the largest members of our species approach the critical level of X-ray photography. It is well known how difficult it is to obtain a satisfactory radiograph of the abdomen of a very large obese subject. To put it another way, one cannot X-ray the abdomen of a pig or a horse – they are too thick. With regard to the brain, again man is fortunate. His face has shrunk relative to the remainder of the skull and his frontal bone has ascended well above the nasal sinuses. This is a great advantage.

Radiology came very slowly on the scene of neurology, particularly in England, and it was not until 1924 (twenty-nine years after Röntgen's discovery) that any serious neuroradiological discussion took place in this country. I will refer to this discussion in more detail shortly. The long-established English clinical school of medicine which was perhaps second to none in the world has always accepted new methods of investigation very slowly. I venture to say that this still applies today but I would be the last to denigrate the classical clinical approach which is, I think, so well perfected in this country. However, conservatism can sometimes be carried too far and by often turning a blind eye to new paraclinical discoveries, such as those of radiology, we in England sometimes find ourselves behind the leaders of the world in this respect.

The father of neuroradiology was undoubtedly Arthur Schüller. He was born in 1874 in Brunn, Bohemia, then part of the Austro-Hungarian empire but now in Czechoslovakia. His father was a doctor, an ear, nose and throat specialist, and a friend of Politzer. Young Schüller was a brilliant student and he graduated in Vienna with the highest honours, receiving a special prize from the Emperor Franz Josef, a prize which was granted only twice in his long reign of sixty years. Schüller qualified shortly after Röntgen's discovery. Although in his early days he trained as a neuropsychiatrist, he was attracted to Röntgen's revolutionary development in medical science and was introduced to its practice by Holzknecht, the founder of the Viennese School of Radiology. In 1912 Schüller published his textbook 'Röntgendiagnostik der Erkrankungen des Kopfes' (Radiology of Diseases of the Head). The fundamental principles described in this work still form the basis of the plain X-ray examination of the skull. To give one example, Schüller was the first to recognize the importance of the displaced calcified pineal gland, a valuable sign which came to be recognized in this country only in the 1930s. Before World War I the German-speaking and German-influenced countries appreciated the importance of radiology in neurology more than the Anglo-Saxon nations. Fedor Krause, a famous German surgeon at the beginning of this century, included a short chapter on radiology in his three volume textbook 'Surgery of the Brain and Spinal Cord', published in 1907 and translated into English in America in 1910. Referring to radiology Krause wrote:

'Above all other means of diagnosis it furnishes the most useful in tumours with calcareous or bony deposits, as for instance, in exostosis . . . and any injury to the skull may bring on epileptic seizures . . . whenever possible X-ray examination should be made. It is frequently a great aid in clearing up the diagnosis. Even in other forms of epilepsy roentgenography is of urgent need.'

This was in 1907. Here Krause was well in advance of his time.

The writings of Schüller, Krause and others clearly indicate that the Austrian and German schools of neurology immediately became conscious of the value of radiology. Indeed as early as 1906, Fürnrohr, a neurologist at Nuremberg, published a little book 'Die Röntgenstrahlen im Dienste der Neurologie'. This antedated Schüller's publication by six years but was far less complete. Fürnrohr had been a pupil of Oppenheim's in Berlin. It was Oppenheim who confirmed the diagnosis of a pituitary tumour radiologically as far back as 1897.

The following example illustrates how advances were being made in those early days in the correlation of the morbid anatomical and radiological changes to be found in the skull. In 1912 a young Swedish pathologist, Folke Henschen, soon to become Professor and later one of the world's leading neuropathologists, added an important contribution. He was already well known as an authority on acoustic tumours, the surgery of which was subsequently mastered by Cushing. In his communication Henschen gave an excellent up-to-date account of the value and limitations of radiology in the diagnosis of brain tumours and went on to describe how he had found at autopsy that acoustic neuromas nearly always widened the internal auditory meatus. Henschen felt convinced that this feature should be demonstrable radiographically in life, and he sought the aid of his radiological colleague, Dr Gösta Forssell, shortly afterwards to become the first professor of radiology in Sweden. In the opinion of many, and I associate myself with them, Forssell was the greatest personality that the world of radiology has yet seen, and he did more for its progress and status both in Sweden and internationally than anyone before or since. In February 1910 Henschen had a case of suspected acoustic tumour which he submitted to radiography for confirmation. Unfortunately only one side of the head was X-rayed and the patient was allowed to depart. He had to wait just over a year for another case (March 1911). On this occasion he obtained two radiographs, one of the normal and the other of the abnormal internal auditory meatus and demonstrated enlargement of the latter. The patient died the following month and Henschen confirmed the radiographic findings at autopsy.

At about the time of the outbreak of World War I plain radiography of the skull had become quite sophisticated in a few centres. It must be remembered that the apparatus was very primitive, the X-ray tube was always fixed in relation to the plate and angulation of the rays was not possible. With the tubes available the radiation output was small and extra-special attention had to be paid to keeping the patient immobilized. Exposures were timed in minutes rather than in fractions of a second as nowadays. Besides, the radiograph was produced on a glass plate covered with a slowly responding photographic emulsion and furthermore the Potter-Bucky grid, which largely excluded scattered radiation, had not yet been invented. In spite of these difficulties, the accuracy of the radiographic projections and the quality of the pictures was remarkable.

Even so, a breakthrough in neuroradiological methods of diagnosis was badly needed and it came in 1918 from Johns Hopkins with Walter Dandy's discovery of ventriculography. The world owes a debt of gratitude to that great American neurosurgeon. At first the chief value of ventriculography was in the diagnosis of internal hydrocephalus in infants. Dandy did not apply the method to adults originally, but said that he expected to do so in all cases where the diagnosis was obscure. In the light of our experience since 1918 of the great value of ventriculography this is a good example of the well-known reluctance by medical men to accept new methods wholeheartedly. Within a year Dandy had followed up his great discovery by another equally great, that of encephalography, and at the same time he predicted the procedure of air myelography for the localization of spinal tumours. If Dandy had done nothing else in his brilliant surgical life his name would have gone down to posterity for the discovery of these diagnostic methods. His contributions were very slowly accepted by the neurological world, and for several years to come most craniotomies were performed at the behest of a neurologist who did his best to predict the site of the lesion by clinical means. It is said that the idea of ventriculography was put into Dandy's head by Halsted, one of his senior surgical colleagues at Johns Hopkins.

Although Dandy predicted air myelography in 1919 he published nothing on this subject until 1925. By then Sicard & Forestier had shown the value of Lipiodol for localizing spinal blocks and Dandy described the use of both air and Lipiodol in his paper in 1925.

Sicard, a Paris physician, introduced positive contrast myelography using Lipiodol in the year 1921. He was also a pioneer in the study of the cytology of cerebrospinal fluid. However, his main interest was the treatment of pain for which he had developed a great reputation and a large practice and was the leading physician in France in this field. One of the substances he used for the treatment of sciatica and other neuralgias was Lipiodol by injection. He also observed that it was an excellent X-ray contrast substance and was well tolerated without producing any side-effects. It is said that one day a pupil of his injected Lipiodol into the lumbar muscles and when, after injection, he drew back the plunger of the syringe he noticed, to his horror, that he was withdrawing cerebrospinal fluid. He rushed off to Sicard to tell him what had happened and Sicard merely asked him one question: 'How is the patient?' The reply: 'Very well, Sir.' 'All right', said Sicard, 'We will go and look at it on the fluorescent screen.' Sicard screened the patient standing up and observed that the Lipiodol had dropped to the bottom of the spinal subarachnoid space and thus he had the brilliant idea of tilting the patient head down and observing the movement of the Lipiodol. This was long before the days of tilting X-ray tables, so one can imagine that considerable improvization was necessary on Sicard's part.

These new contrast methods of myelography and pneumoencephalography were slow to reach England and, as I have already implied, even plain X-rays of the skull were very little used then by British neurologists. But a stir was beginning and in 1924 the Section of Neurology of this Society discussed Dandy's new method of ventriculography (*see Proc. roy. Soc. Med.*, 1924, **17**, Sect. Neurol. 59, and *Brain*, 1924, **47**, 377). I have already referred to this meeting very briefly. Dr James Collier was the President of the Section that year and the young Geoffrey Jefferson spoke in the discussion. Reading the account it is quite clear that ventriculography was not accepted at all wholeheartedly. It was pointed out that some surgeons had reported a very high mortality from this investigation, something like 30%. Furthermore, as we know in retrospect, no techniques had been developed for manipulating the air appropriately through the ventricular system, and the diagnostic information being gained was relatively meagre. The world had to wait another decade for men like Lysholm of Stockholm, Dyke and Davidoff of New York and Twining of Manchester to unravel the secrets.

The Professor of Medicine in Lisbon, Egaz Moniz, read the report in *Brain*. Clearly the English, he wrote later, were not altogether satisfied with ventriculography. This apparently spurred him on to seek help in another way and led to his great discovery of cerebral arteriography. Moniz argued that it should be possible to outline the brain radiologically with some positive contrast substance, just as his Parisian friend Sicard had done with the spinal theca. As Moniz put it: 'The brain was normally mute to X-rays'—the dark continent again. He was also rather illogically stimulated by the recent work of Graham & Cole (1924) of the Mallinkrodt Institute at St Louis, USA, whereby they succeeded in outlining the gall-bladder following intravenous injection. This of course depended upon a physiological concentration of the contrast substance in the bile and no parallel existed in the brain. Moniz had two methods in mind: (1) The opacification of the brain itself by intravenous or parenteral administration of a substance opaque to X-rays. (2) The intra-arterial injection of some opaque substance. He failed in the first but succeeded in the second. In order to opacify the brain he attempted to flood it by the injection of a radiopaque substance. He injected large quantities of lithium bromide intravenously and also gave it by mouth in large doses. This failed and he then tried strontium bromide. Both substances were well tolerated by his patients but as no positive results ensued this failure led him on to his second method, arteriography. In choosing a suitable substance he considered Lipiodol which Sicard had used for both myelography and ventriculography, but since it was oily Moniz realized that it might produce emboli. He therefore decided on an aqueous solution – an iodine or bromine salt, and favoured iodine on account of its higher atomic weight and thus greater radiographic density. Having made a number of experiments on dogs and rabbits to assess the toxicity of various substances such as bromide and iodide of lithium, sodium, potassium, ammonium and rubidium, he finally chose 25% sodium iodide. Fortunately it was well tolerated by man when given intravenously, apart from producing some pain in the axilla when injected into an arm vein. He then pointed out that there was a precedent for intra-arterial injection since Von Knauer had injected neosalvarsan into the carotid artery percutaneously in 1919 for the treatment of general paralysis of the insane, without harm. This gave him encouragement and he experimented on dogs, using strontium bromide and lithium bromide. At first no contrast was seen on the radiographs, but he obtained a better X-ray machine and with shorter exposures achieved a satisfactory result. Then he passed on to the human cadaver in order to learn the normal radiographic anatomy. Having injected a number of corpses he selected his first patient, a man suffering from GPI. Moniz himself suffered from gout in the hands and was unable to undertake arteriography so this was performed by his pupil and successor Almeida Lima. It is interesting to recall that the injection was made percutaneously just as Von Knauer had injected neosalvarsan into the carotid artery of a patient suffering from the same disease. Seven millilitres of 70% strontium bromide was injected without upsetting the patient, but the radiograph showed nothing. They tried the percutaneous method of injection in 3 more cases but again without success and in the last Moniz thought that the contrast substance had been injected outside the artery. So thereafter it was decided to cut down on the artery. They were finally successful with the ninth case, a young man of 20 with a pituitary tumour, when 5 ml of 25% sodium iodide was injected and good pictures were obtained. Moniz then said: 'Nous avons réalisé notre desideratum.'

This story has been recounted in some detail as it illustrates the tremendous determination of the man. Most people, had they had a similar experience, would have been deterred and abandoned the procedure long before they achieved success. This was in 1927 and he immediately went to Paris to read the paper to describe his success before his master and teacher, the great Babinski. Four years later, in 1931, he published a book describing his first 90 cases. There were 2 deaths, both in arteriosclerotic patients. Babinski wrote the preface of the book and pointed out that Moniz made up his mind to put this project into execution and set forth courageously in his enterprise, as his compatriots Dias and Vasco de Gama had set forth across the ocean in their search for a route to the Indies. Surely no higher praise could be given to anyone, and perhaps only a Frenchman could express it so beautifully.

Moniz had brought a new dimension to neuroradiology and helped very much to chart the dark continent.

Like Dandy's method of ventriculography, arteriography was accepted very slowly, particularly in the Anglo-Saxon countries. This may have been due partly to the fact that the investigation involved making two permanent scars one on each side of the neck, unpleasant stigmata particularly for an attractive woman to carry for the rest of her life, especially if the investigation proved negative. Moniz always insisted on undertaking bilateral arteriography and he abandoned the percutaneous method for good. It was not until 1944 that the Norwegian Engeset revived and firmly re-established the method. Shortly afterwards this technique, or slight modifications of it, became universally accepted and the procedure has now, a quarter of a century later, been placed on a parallel basis to intravenous pyelography.

In 1932 Davidoff & Dyke of New York published a paper entitled 'An Improved Method of Encephalography'; they had already examined 300 patients by this method. The particular striking advance they made in technique was to carry out the whole examination in the X-ray department. The patient was sat up and the head placed in the semiflexed position. Having introduced not more than 20 ml of air they took a radiograph to see how much air was necessary in any particular case for a proper examination. Then in 1941 Graeme Robertson of Melbourne began an attempt to improve the accuracy and reliability of encephalography and to reduce its discomfort and risk. Up to that time ventriculography was used almost exclusively for the localization of tumours, except in some of the Latin and German-speaking countries where Moniz's method of arteriography was beginning to be taken up. Ventriculography is an admirable procedure when used in the appropriate circumstances, particularly when the intracranial pressure is known to be very high. As time went on, however, intracranial masses tended to be diagnosed earlier and before the well-known triad indicating raised intracranial pressure – headache, vomiting and papillœdema – had developed. Naturally the ventriculographic examination of some patients thought to be suffering from an intracerebral mass would be negative; it is highly undesirable to shave the back half of a patient's head and then make parietal burr holes prior to ventriculography, only to find nothing. Besides, the brain was now beginning to be examined for other than tumorous conditions. So it came about that the method of lumbar encephalography was used more and more. This had two advantages over ventriculography: (1) A minor surgical procedure was unnecessary and only a lumbar puncture was required to introduce the air. (2) It was possible to outline the cerebral cisterns and sulci as well as the ventricles, and thus one could obtain more information and often differentiate intracerebral from extracerebral intracranial lesions. But encephalography was very unpleasant for the patient and there was a tendency to introduce far more air than was necessary or desirable. Sometimes when a grossly excessive amount of air was introduced – in many centres it was injected blind with no radiographic control pictures – the arachnoid became stripped away from the dura thus leading to tearing of veins. I have little doubt that the high incidence of subdural hæmatoma reported in infants from some clinics in the 1930s was iatrogenic in many instances. It is astonishing how often in medicine the best technique takes years and years to become universally accepted and bad old methods continue to be applied. One can only regret that controlled fractional air encephalography is still not universally used.

With the firm establishment of percutaneous carotid and vertebral angiography, the technical improvements in achieving rapid serial angiograms, and the maturation of the technique of controlled fractional encephalography, together with tomographic sections in various planes displaying air in the cisterns and ventricles, Macewen's dark continent was becoming well mapped by the explorations made possible by the combined use of X-rays and appropriate contrast media. This was the position a little more than a decade ago.

But it is not the end of the story. An entirely new dimension has since been developed. In 1895, the same year as Röntgen's discovery, Becquerel, a Parisian physicist, discovered natural radioactivity. It was soon learnt that the naturally emitted rays from radioactive sources – so called gamma rays – were of the same nature as X-rays. A few years after Becquerel's discovery his rays were being used for medical treatment, radium being the source, but another half century was to pass before spontaneously emitted rays were used for diagnostic purposes. This is in large measure due to Rutherford's fundamental work which ultimately led to the production of artificial radioactive isotopes.

World War II acted as a great spur to the development of nuclear physics and by the mid-1940s many artificial radioactive substances had been prepared. Their application to the diagnosis of disease began with the thyroid for two good reasons: (1) It was well known that iodine was taken up by the thyroid and radioactive iodine isotopes were some of the first to be prepared. (2) The thyroid is a very superficial structure covered only by soft tissues, and thus the detection of any radioactivity within the gland was a relatively simple matter. The brain was quite another problem in that it was not known to take up selectively any chemical compound or element and even if a suitable isotope could be found its rays would have to pass out through the skull bones. Not only would the skull grossly impede the radiation being emitted, but it would scatter it and thus add to the difficulties of precise localization. It was George Moore, then a young surgeon in Minneapolis, who solved the problem and the story is fascinating. Having known previously that fluorescein was taken up selectively by certain tumours of the eye, Moore postulated that the same might apply to brain tumours. In cases of suspected glioma, immediately prior to operation, he injected a small quantity of fluorescein intravenously. It was found that it could be detected in tissues by ultra-violet light, using a Wood's lamp. When the brain was exposed at surgery the ultraviolet light was shone on the cortex. Normal brain was given a greyish hue while a glioma appeared yellow in colour and its edges could be clearly defined. Besides being successful in his project, Moore was able to delineate gliomas more clearly for neurosurgeons, since it is well known that the edge of a glioma is very difficult to determine macroscopically in that it often merges imperceptibly into normal brain. Moore's next problem was to tag a radioactive substance to fluorescein. He prepared diiodofluorescein, the iodine being radioactive ^{131}I. Having injected this substance intravenously, he attempted to detect the radioactive emissions from the tumour by means of a Geiger counter, this being the tool used for the detection of radioactive emissions at that time. He was immediately successful and localized 12 out of 15 brain tumours. Thus it was that brain scanning, or isotope encephalography, came to be born in 1948. However, many years were to pass before the method became fully established. Other workers did not have the same success rate in detecting tumours and over the next decade many apparatuses of gradually increasing sophistication were built in the United States. By 1960 a few American commercial firms had perfected scanning devices and in 1963 we managed to obtain an American machine at the National Hospital for Nervous Diseases.

Until recently diagnostic radiology could be described as the study of shadows recorded on film after the passage of appropriate rays through the body. The value of the shadowgraph depended upon graduation of blackness which was related to the different atomic numbers of elements contained in animal tissues. With the application of Becquerel's discovery one can now place the ray source *within* the body tissues and photograph the rays as they are emitted from the body. In some countries radiologists are called röntgenologists or röntgenologues. Nowadays they should logically be called 'Röntgen-Becquerelologists'– an admittedly clumsy expression.

Isotope encephalography has revolutionized our approach to the investigation of neurological patients suspected of a great variety of brain lesions. The technique carries no morbidity and can be readily performed on outpatients. Not surprisingly, the demands are increasing annually.

A more recent application of isotopes in neuroradiology is so called 'isotope cisternography' which consists in injecting a suitable isotope into the lumbar theca (by lumbar puncture) and detecting its passage through the CSF pathways. It is a useful confirmatory test in diagnosing so-called communicating hydrocephalus and also in detecting the site of the lesion in CSF rhinorrhœa or otorrhœa. Besides this it enables us to learn more about the physiology of the CSF.

Two other subsidiary techniques have been introduced in recent years, echo-encephalography or ultrasound, and thermography. Both of these can be performed on outpatients and carry no risk; on the other hand they are of limited value. In echo-encephalography the object is to determine whether the mid-line structures of the brain are deviated. This can be achieved by taking echo soundings on each side of the head and photographing the echo as it is recorded on a cathode ray oscilloscope.

Ultrasonic waves were first produced in 1880 by the brothers Curie, one of them later to become Marie Curie's husband. They discovered the piezoelectric effect, noticing that if certain crystals were mechanically compressed an electric charge was produced between the opposite surfaces; conversely, if a difference in potential was applied across an appropriate crystal then mechanical stresses were set up and ultrasonic waves were generated. Similarly when ultrasonic waves struck the crystal it was compressed and electrical energy was liberated. Thus one crystal or transducer, as it is called, can be used both for emitting the ultrasonic wave and for collecting the echo and turning it into electrical energy which can then be represented on a cathode ray oscillograph and photographed.

Thermography applied to neurology is too much in its infancy to deserve more than a passing reference.

Now that three-quarters of a century has elapsed since Röntgen's and Becquerel's discoveries, we see how the methods of investigating a patient suspected of harbouring an intracranial mass have developed over the years. But we have not reached the end of the road and the dark continent is still not fully explored. For example we often cannot demonstrate the smaller brain tumours, particularly metastases, and in this respect the technique of scanning is limited at the moment to demonstrating masses of 2 cm diameter and greater.

Another problem which we still have, and which might be solved in the fairly near future, is the achievement of the definitive pathological diagnosis of intracranial masses. We can of course be quite precise in very many instances. Thus, for example, the angiographic appearances of a subdural hæmatoma are quite pathognomonic. Similarly the plain X-rays and angiograms of most meningiomas are characteristic, and so on. But we are left with too large a residue of intracranial masses on to which we cannot put a precise pathological label; for this reason one sometimes cannot predict whether a mass is operable or inoperable. It is not enough to show its size, shape, and position. Professor T Planiol has gone some way to achieving the pathological diagnosis in a number of cases by noting the rate of accruement or fade of isotopes in various lesions. If her method can be further perfected it might save suffering, as it would gradually eliminate many brain biopsies or exploratory craniotomies which still have to be undertaken to decide whether or not the lesion is surgically remediable.

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