Regular Review

New imaging techniques: their relation to conventional radiology

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Technological developments over the past few years have led to substantial advances in medical organ imaging and a broadening of diagnostic radiology. Some of the new techniques use ionising radiation somewhat similar to orthodox radiology, as, for example, isotope scanning, but ultrasound and nuclear magnetic resonance use different physical principles to produce images. A further important factor is the non-invasive nature of such investigations.

To some extent we are only at the beginning of the application of some of these newer techniques, and how far they will advance our ability to establish more accurate and definitive diagnoses cannot yet be predicted. Quite probably, however, the time may come when a reliable tissue diagnosis will become possible in vivo with results on a par with a histological interpretation of a biopsy specimen. The important question then will be how much further will advances in detailed diagnostic ability help the management of patients if these advances cannot be matched in treatment? Such thoughts are entirely speculative at present and must not in any way influence our forward thinking in the application of the newer imaging techniques; but one further question will soon be widely asked—is the time coming when routine diagnostic radiology will be outdated and replaced by some of these new investigative techniques? Again, this question cannot be fully answered at present, since our total experience is not broad enough to provide the final answer. At present the techniques discussed below are complementary and in no way competitive in their application.

Ultrasonography

Ultrasonography, using non-ionising radiation, has probably made the biggest advances over the past two decades in imaging. The practical management in obstetrics has changed considerably with the use of diagnostic ultrasound, and this all began when Donald and Brown in 1961[1] described the techniques for making measurements in vivo of the diameters of the fetal head. In the next year Campbell[2 3] established the value of the measurements of the maximum coronal and biparietal diameters, thus making possible the estimation of fetal maturity and accurate monitoring of fetal growth. Further gains included the diagnosis of early pregnancies[4] and fetal abnormalities[5] and locating the placenta in patients with antepartum haemorrhage.[6]

Ultrasonography has also made a big impact in the imaging of organs such as the liver, pancreas, and kidney. The technique can show bile ducts, the gall bladder and biliary calculi, and primary and secondary tumours.[7] Ultrasonography is now the method of choice in the diagnosis of jaundice, particularly in patients in whom laboratory and clinical assessment has failed clearly to indicate the differences between "medical" and "surgical" jaundice.[8] In the kidney ultrasonography shows mass lesions with considerable accuracy and can differentiate between a solid tumour and a cyst.[9] The pancreas can be outlined in many patients,[10-12] but the detection of pancreatic tumours is less satisfactory, and in this particular circumstance computed tomography scanning is still the method of choice.

Yet another area where ultrasound has made a major contribution is in imaging the intra-abdominal vessels, particularly the aorta, where aneurysm or aortic dissection can be recognised without difficulty.[13] Doppler ultrasound can be used to assess blood flow in superficial vessels,[14] so making possible the locating of haemodynamically important stenosis and to some extent helping to assess the efficiency of the collateral circulation.[15]

In cardiology ultrasonography has made it possible to outline not only the myocardium, cardiac cavities, and pericardial effusions but also the heart valves, congenital abnormalities such as septal defects, and other congenital lesions.[16] Indeed, since ultrasonography is non-invasive and provides such important and helpful information, in many instances it is now used as a screening technique and the first method of investigation. Only if further detailed information is required which cannot be provided by ultrasonography are further invasive radiological studies such as angiography indicated.

Isotope imaging

Though isotope imaging is based on ionising radiation, its clinical use and its relevance to diagnostic radiology must be mentioned briefly. This has become one of the important non-invasive techniques, providing information which in many instances is complementary and different from that obtained by other modalities. Unlike conventional radiology, ultrasonography, computed tomography scanning, and even nuclear magnetic resonance, isotope images do not depict detailed anatomical structures: they are much more of a functional nature. Indeed, if purely anatomical information is required isotope imaging is not the method of choice. On the other hand, if the clinical problem requires an answer in terms of function then isotope imaging is the ideal technique, as it is non-invasive, harmless, and well tolerated by the patient.

One of the most useful techniques using isotopes is in the diagnosis of pulmonary emboli.[17-19] Similarly, ventilation perfusion scans[20 21] can be very helpful in the evaluation of lung function and provide rapid and satisfactory information, particularly when compared with the plain chest film. In cardiology, too, isotope imaging is now of considerable importance, particularly with the advent of thallium-201 as a myocardial scanning agent. This is useful in showing the state of the left ventricular muscle in patients with ischaemic heart disease either as a single image scan or in multiple dynamic studies. In many instances such isotope studies will provide adequate information about left ventricular function and ischaemia without having to resort to any further examinations.[22 23] Further useful information in cardiology can be obtained by labelling the blood with an isotope tracer and then recording the flow through the heart, looking at the behaviour of the chambers, or assessing possible right-to-left shunts.[24] Alternatively, the blood pool can be imaged at equilibrium at different phases of the cardiac cycle in order to look at ventricular function.[24] Such techniques are often used clinically to show a right-to-left shunt or to study cardiac function in a whole variety of disorders.[25-27]

A further useful application of isotope imaging is the search for metastatic deposits in bone. This technique is now used as the primary investigation and is much more sensitive than routine radiography.[28] The technique is well tolerated by the patient, very sensitive, and easily carried out. One proviso is that the isotope scans must be compared with standard radiographs, since non-malignant lesions—such as a fracture with callus formation, an active bone lesion related to erosive arthritis, or even degenerative arthritis—may appear as "hot spots" not dissimilar to metastatic deposits. The appropriate radiograph and isotope image are complementary.

Isotope scanning is also used in many other organs. In the urinary tract it gives information on abnormalities of perfusion of the kidney, on differential renal function, and on obstruction, thus supplementing findings of conventional urography or even renal angiography.[29 30] Isotope scanning is now rarely done for brain lesions since computed tomography is diagnostically much more definitive. In diseases of the liver and biliary tract, too, ultrasonography provides quicker and easily obtainable information and so will computed tomography if more detailed answers are required.

One further promising recent development is the use of isotopes to label white cells and platelets in the laboratory after the separation of whole-blood constituents.[31 32] With the injection of the labelled cells into patients abscesses can be located, especially in the subphrenic space or pelvis—a technique complementary to plain radiography of the abdomen or to ultrasonography.

Nuclear magnetic resonance

Nuclear magnetic resonance is the newest imaging modality not using ionising radiation; the production of images depends on magnetic fields and radio frequency pulses. The actual images are not dissimilar to those obtained by computed tomography—which was, in fact, the major stimulus for the development of nuclear magnetic resonance. Computed tomography is now being compared with nuclear magnetic resonance in several organ systems to assess their future place in clinical medicine. Most of the published clinical studies relate to British contributions, and no full assessment has been provided of the diagnostic place of nuclear magnetic resonance. The clinical evaluation of this new technique and comparison of its results with other more orthodox imaging modalities has only just begun.[33] So far as we know, nuclear magnetic studies are harmless, non-invasive, and well tolerated by patients.[34]

In the brain nuclear magnetic resonance can differentiate very clearly between white and grey matter,[35] thus making possible the diagnosis of demyelinating disease in life; for example, lesions produced by multiple sclerosis (which in the past have been shown only at necropsy) can now be seen.[36] Disease in the posterior fossa, which is inadequately visualised by computed tomography owing to bone artefacts, can be shown quite clearly by nuclear magnetic resonance.[37] Hence it will be possible to visualise tumours, demyelinating disease, and other lesions without any difficulty, so avoiding the use of invasive techniques such as angiography and pneumoencephalography. It is also possible to produce longitudinal and sagittal scans of the brain and spinal cord. This may open yet another topic of great interest where other techniques have so far failed or have been invasive and unpleasant to the patient. In certain circumstances myelography may be replaced by nuclear magnetic resonance, and similarly nuclear magnetic resonance seems certain to play an important part in neuroradiology, where it will not only complement computed tomography but in some instances be superior.

In diseases of the liver nuclear magnetic resonance provides detailed information which is not available by using other standard techniques and can differentiate between various parenchymal diseases.[38] For instance, primary biliary cirrhosis appears very different from ordinary cirrhosis on the nuclear magnetic resonance scan,[39] suggesting a possibility of tissue characterisation in some circumstances. The technique can also show the myocardium without contrast medium, and in the kidney differentiate between the cortex and the medulla.[40]

Future of radiology

Any attempt to put the new imaging techniques into perspective and to contrast them with conventional radiology shows that medical imaging has expanded explosively in the past few years and is still rapidly developing.

In the light of present knowledge can we now define the role of conventional radiology? I have no doubt that radiology as we know it today will still remain the standard technique of imaging since it is the investigation which provides most diagnostic answers: just consider the plain chest film, bone studies, the barium meal, and the excretion urogram. On the other hand, the new modalities are providing us with a great deal of new information which can be obtained simply and without detriment to the patient. Some radiological examinations will inevitably be supplanted by these new imaging techniques. In most settings they will be complementary or be used for screening in the first instance. It is therefore vital that those who are practising clinical medicine and are the generators for investigative work of this kind must at least be familiar with these investigations and be able to appreciate their value and the contributions that they can make. But, even more important, their limitations too must be understood.

Diagnostic radiology is one of the fastest growing specialties in medicine, thus putting a great deal of responsibility on those who practise it. As some of the newer investigations are non-invasive and well tolerated by patients demands for such studies are growing rapidly. With all the wealth of imaging possibilities available, definitive pathways for studying various diseases in patients will therefore have to be laid down in the future to make the radiologists' work more rational, but even more important, to avoid unnecessary investigations.

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