COMPUTED TOMOGRAPHIC SCANNING IN LANCASTER

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INTRODUCTION

The Royal Lancaster Infirmary will shortly start to operate the computed tomographic (CT) scanner which has been bought as a result of our charitable appeal. It will provide an improved diagnostic service to the patients of the Lancaster, Morecambe and Kendal hospitals as well as those in other areas at the request of the referring clinician. The service has been planned in broad detail only. No attempt has been made to form a detailed prospectus since a period of familiarization is necessary for clinicians and radiologists alike. It will take some time for a practice to evolve which takes account of local interests and expertise. Some basic principles are described to help future users understand the uses and limitations of CT scanner.

HOW DOES A SCANNER WORK?

Fig 1 shows a typical CT scanner. The patient lies on the table top and is kept still by a firm but comfortable restraint

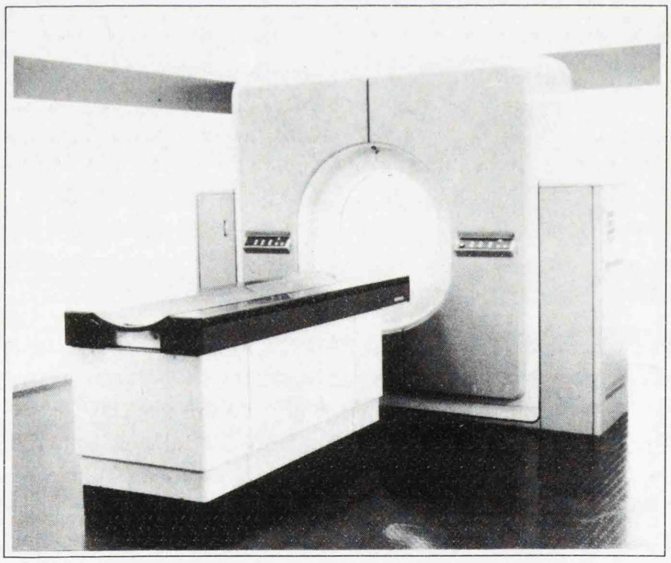


Fig 1 – A CT Scanner

device, usually a velcro band. This table top can be moved in precise increments ranging from one millimetre to several centimetres. The part of the patient which is to be examined is positioned within the central aperture of the scanner and a single scan is obtained whilst the patient traverses the aperture in a continuous movement. This produces an image or tomogram, (Fig 2) from which the radiographer selects the landmarks for the complete examination. There are well established protocols for the conduct of different scans. These dictate the number and thickness of sections, the interval between them and other variables such as angulation

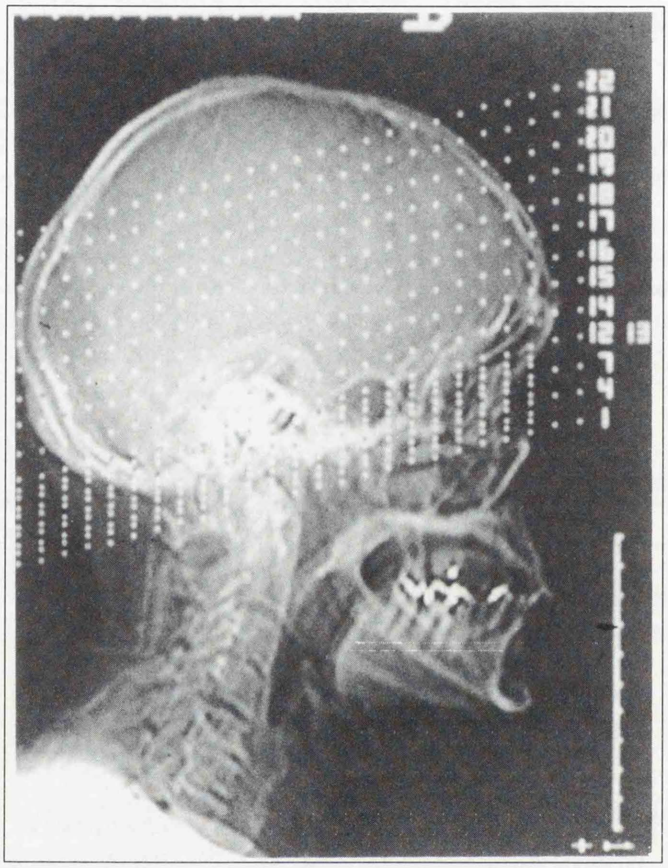


Fig 2 – A tomogram with landmarks for scanning

of the scanner gantry and the use of contrast agents. The programme is semi-automatic once the start and end points have been chosen. The radiographer can interrupt or alter the programme at any time.

The scanner itself contains an x-ray source and a series of detectors with a fixed relationship to each other which can travel on a circular track in the vertical plane. Other planes may be chosen by tilting the apparatus. The x-ray beam is pulsed and may be narrowed down quite finely. Typical beam widths (or slice thicknesses) range from 1.5 or 2 mm in the pituitary fossa to 8 mm in brain scans. The x-ray beam traverses the patient and its energy is altered by different tissues in its path. The x-rays which emerge are measured by the detectors and analysed in digital form by the computer. The computer assigns a shade of grey to each of more than 27,000 identical subdivisions (or pixels) which comprise the picture. Fig 3 shows a greatly magnified image with identifiable pixels. The sheer number of pixels and their small size provide a detailed and accurate representation of internal structures. Fig 4 shows a normal cross section or tomogram. Minute variations in tissue density may be amplified and it is a fortunate fact that body fat shows well on CT scans. The thin layers of fat which surround and

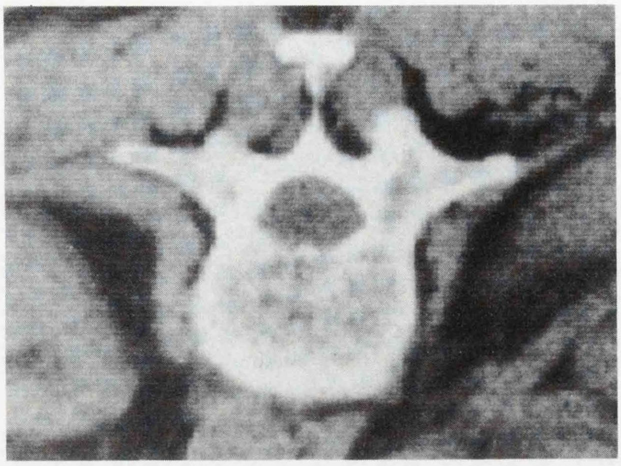


Fig 3 – A cross section of vertebral body magnified to show pixels

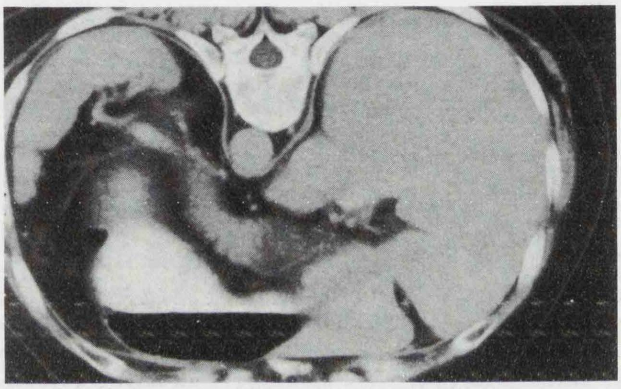


Fig 4 – A normal abdominal section at the level of the splenic vein and pancreas

separate abdominal organs are responsible for defining their margins. Body fat is as welcome in CT scanning as it is unwelcome in ultrasound scanning.

SOME IMPORTANT LIMITATIONS OF CT SCANNERS

It must be remembered that scanners use ordinary x-rays to form an image and that we are duty bound to use the minimum radiation dose we can. All ionizing radiations have a potential for tissue damage and it is reassuring to know that manufacturers have worked hard on scanner design to minimize this dose. Brain scans now result in less dose to the lens of the eye than conventional skull radiographs. There is no room for complacency however; we must be careful in the selection of patients and the performance of scans.

There is another, and possibly more important, consequence of using x-rays. Clinical management often depends on accurate film interpretation and this can be very difficult. It is a surprise to know that the human eye can reliably distinguish only four major x-ray appearances of human tissue (or five if radiographic contrast material is included). These are the densities of air, fat, soft tissue and bone. The soft tissue density includes fluids such as blood or pus, normal and abnormal soft organs, muscle etc. There is no tissue character inherent in a scan which distinguishes an appendix abscess from a caecal carcinoma and film interpretation depends heavily on clinical probabilities and distortions in normal anatomy. Liver metastases may be invisible. Identical pulmonary scans may result from carcinomas, infections, hamartomas and haematomas. Persistent active tumour in incompletely treated malignancy may appear identical to tissue fibrosis and shrinkage with no histological sign of residual tumour. Why should this be so? The answer is given by considering the behaviour of x-ray energy in tissue, especially water.

X-RAY BEHAVIOUR IN TISSUE

The scan image is formed by the x-rays which emerge from the patient. The beam intensity will have been reduced by different tissues and the three major determinants are the thickness of the material, its density and its atomic number. (The atomic number Z indicates the electron charge or number of protons in the nucleus of the atom.) The average total body water is 61% of body weight in males and 51% in females. The body is a great swamp of hydrogen and oxygen molecules of low atomic number and these are the major constituents of blood, pus, muscle, liver, pleural effusions, bronchopneumonia and most cancers. It is fortunate that we are made of more than this. The thorax and skull contain large quantities of air which is of very low density and has little effect on the x-ray beam. Our bones contain minerals such as calcium with a higher atomic number which have a much greater effect. These physical characteristics provide a natural tissue contrast when viewed beside soft tissue densities.

It is important to understand and remember this lack of soft tissue differentiation when reading scan reports. Most problems are solved quickly and accurately, but a lump is only a lump until biopsied or aspirated. It pays to keep a fresh mind when diagnostic images are confusing or contradictory.

OVERCOMING THE PROBLEMS

Great use is made of radiographic contrast agents which can be introduced into specific organs. Virtually all patients for abdominal scans will be given oral contrast to outline the bowel. By now it is aparent that food or fluid in a bowel loop can mimic lymphadenopathy or mass at the porta hepatis. Bowel paralysing agents may be injected to reduce movement artefact. Intravenous contrast may be given as an infusion or bolus to outline vascular structures (eg a dissecting aneurysm) or the renal tract. It may be given to assist in the evaluation of cerebral lesions because the alterations in the blood brain barrier are fairly predictable in many intracranial conditions. However, most head scans done for headache, epilepsy and strokes do not require contrast. The decision is made by the radiologist, usually after review of the plain scan. A history of contrast allergies or atopy must be sought by the referring clinician and recorded on the request form.

Other contrast agents may be used. Air may be injected into the bladder, and by inclusion in a tampon can be placed in the vagina. This is very important in pelvic disease. Most female patients will perform this themselves. If they are unable, a nurse will assist.

Air may be introduced into the subarachnoid space to assess cerebellopontine angle tumours and contrast may be injected into the subarachnoid space in spinal CT.

There is one other naturally occurring contrast agent. Fresh extravascular blood is dense and becomes less dense with time. Figure 5 shows a fresh extradural haematoma. Fresh blood can be detected in small quantities (a few millilitres) in the CSF as in subarachnoid haemorrhage and it helps to distinguish an intracerebral haemorrhage from infarction though it is not reliable.

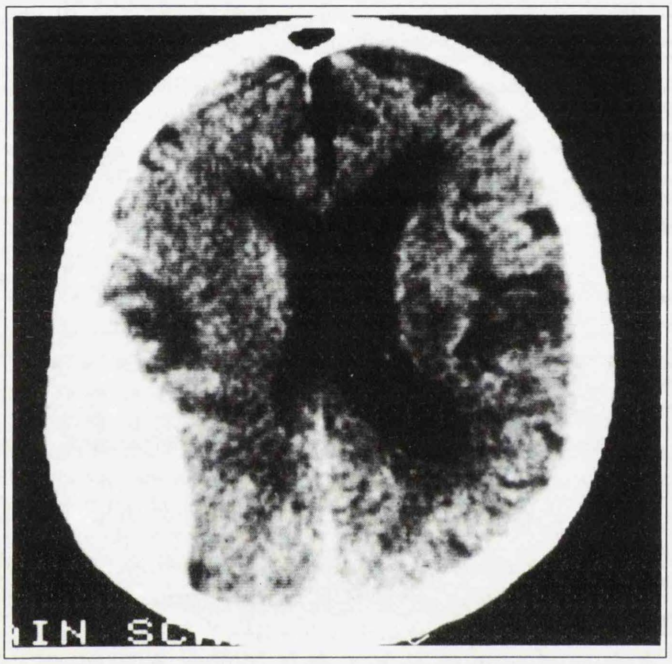


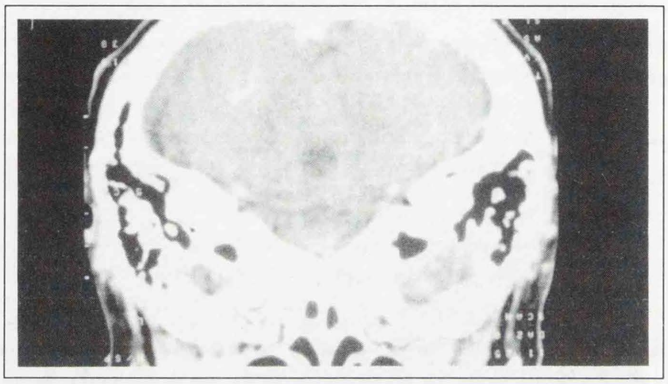
Fig 5 – A fresh extradural haematoma with ipsilateral ventricular compression and displacement

IMAGE INTERPRETATION

CT images are very inert to radiologists. Gut peristalsis, respiratory movement and the action of arterial structures are absent unlike fluoroscopy or ultrasound scanning. Film interpretation, and therefore the clinical importance of CT scanning, depends almost entirely on the simple architecture of each organ at the time of observation. The size, shape, position and density of structures and a knowledge of normal variants form the basis of the diagnostic process. This places an immediate restriction on the assessment of organ function but in practice, small distortions of these simple parameters are sufficient for many diagnoses. Masses may appear, or familiar structures vanish. For example, generalized cerebral oedema in head injury is readily distinguished from unilateral ventricular compression and displacement by an extradural haematoma. CT scanning is most useful in conditions which alter structure. It is virtually worthless in the assessment of pain unless there is a strong clinical suspicion of the cause such as a mass or bone destruction.

The digital nature of the image means that it can be manipulated to examine any chosen structure. Fig 6 shows the identical section adjusted to show bone and soft tissue.

Bone density



Soft tissue density

Fig 6 – A single section at the level of the internal auditory meatus adjusted to show bone and soft tissue densities.

The image can be presented in a plane different to that from which it was obtained (known as reformatting). Fig 7 shows scans of the pituitary fossa presented in this way. This can be

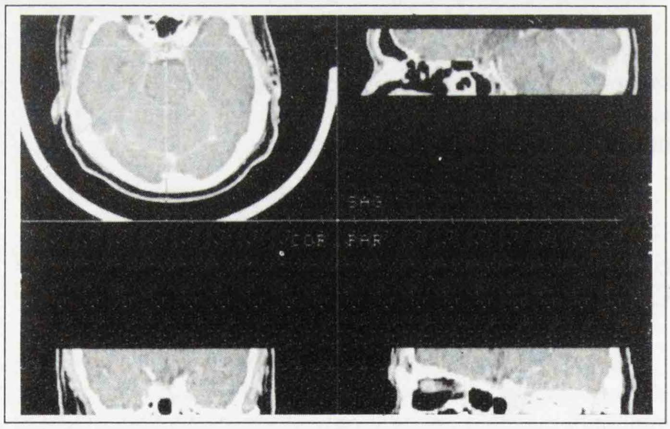


Fig 7 – The pituitary fossa shown in coronal, sagittal and oblique planes from an axial scan

taken to the extreme of pseudo-three-dimensional reconstruction (Fig 8) which looks impressive but is a slow process of uncertain clinical value. It is said to assist surgeons in the repair of trauma.

Once the scan is complete, the images are transferred to a hard copy like any other x-ray. The computer disk has room for a few days work and selected cases will be stored permanently on an optical disc. It is not intended to store the raw data on all patients which is wasteful, especially in normal scans. Anyone contemplating a research project

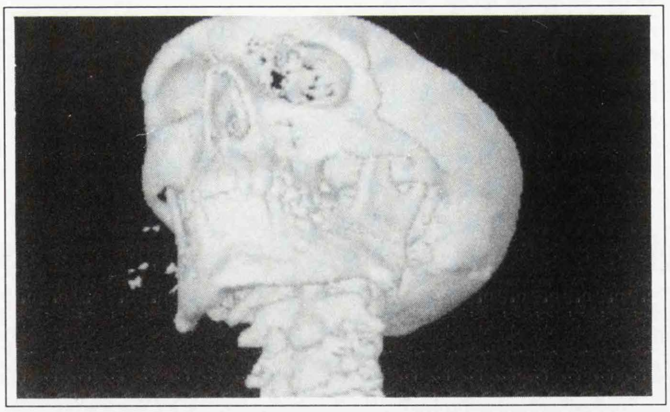


Fig 8 – A pseudo-three-dimensional picture of the skull

involving CT scans must bear this in mind. Unless previously agreed , the only permanent record of most scans will be contained in the x-ray packet.

THE PATIENT

Most patients will have booked scans and will receive an explanatory leaflet with their appointment. A CT scan is not usually unpleasant. Some patients are breathless when flat or anxious when restrained by a headband. A kindly radiographer will usually succeed. Some perceive the scanner gantry as a tubular coffin and worry about claustrophobia, but only a small part of the body is within the aperture at any time. They soon become used to their position and the intermittent rumble of the apparatus. There is two way voice communication with the radiographer and a fixed remote camera views the patient on the side hidden from the operator. It is not uncommon for patients to fall asleep. Small children sometimes have to be sedated but this can often be avoided. A general anaesthetic should be a rare event in patients of any age. It used to be common in older scanners because of problems with patient movement but modern scanners are rapid enough to tolerate a good deal of patient movement. Nurse escorts or parents will be able to stay in the room wearing a lead apron if it is necessary but the practice is not encouraged.

THE CLINICAL USE OF THE SCANNER

Our scanner will be capable of examining any part of the body in patients of all ages. Most clinicians have a clear idea of the role of CT scanning within their own speciality and the majority of clinical applications are not controversial. Requests will only be accepted from a hospital consultant or his staff in line with existing X-Ray Department policy on contrast studies. These requests will be examined by a radiologist before an appointment is given. There will be a new request form. The service will run from 9 am to 5 pm five days a week. Scans outside these hours are termed 'emergencies', about which more later. It is planned to use the early morning and late afternoon for booked cases, usually out-patients. The middle part of the day will be favoured for in-patients, especially acute admissions from the night before. It is hoped that this will provide a 'same day' service for patients seen on morning ward rounds. Naturally, this is a flexible framework which can be changed in line with clinical priorities. CT lends itself to the accurate placement of needles for biopsy or pain relief. Some time will be reserved for both. Most sessions will have a mixed case load though it may be wise to group certain patients such as those having staging scans for malignancy.

An 'emergency' scan will be done only at the request of the consultant responsible for the patient and will follow discussion with the radiologist on call. Requests will not be accepted from non-consultant staff. An emergency is easier to recognize than define but as with angiography and ultrasound scans, the decision is rarely difficult. The majority of emergency scans are done to examine the brain in altered levels of consciousness or the body following violent injury. As a rule, such scans are only justified when the result of the scan will answer a specific question that affects clinical management. Altered consciousness is not, of itself, an indication for a brain scan, even in the acute phase. The distinction between an intracerebral haemorrhage and an infarct may not be relevant to management whereas a possible extra-dural bleed most certainly is.

There may be a computer link with our sub-regional neurosurgery centre at Preston. The idea is a good one, but there are problems with image transmission and existing links in other centres are underused.

ONE YEAR FROM NOW

The number of absolute indications for CT scanning is surprisingly small and the contra-indications are fewer still. Yet it is hard to predict our service one year from now. CT scanning will be a great help and conventional tomography will be abandoned. The acute problems of injury, sepsis, cancer and the evaluation of known or suspected masses are readily agreed, but many chronic problems are not. The published literature is not always helpful. Which patients with epilepsy or dementia should have brain scans? What is the role of CT in headaches or pancreatitis? We may even have a facility such as bone densitometry which no-one will want to use.

It seems reasonable to be flexible in our approach and let the service evolve in response to local problems and clinical interests. The use of the scanner will be monitored to ensure that our charitable money is well spent. Regular clinico-radiological reviews are planned. Until we are all on firm ground, the two most useful questions to ask oneself when considering a scan request are:

1) Will a CT scanner provide better information than the existing x-ray services?

2) Is there a reasonable chance that the answer to the clinical question can be deduced from alterations in anatomy?

An affirmative answer to either one or both of these questions should ensure a worthwhile service.