Review Article

Computed Axial Tomography of the Body with the EMI General Purpose Scanner

A Preliminary Assessment

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SUMMARY

Computed axial tomography (CAT) of the brain has already proved itself to be the first line in the diagnosis of intracranial lesions.

With the installation of the EMI (CT 5005) general purpose scanner at Garden City Clinic in mid-October 1971, we have been utilizing this technique not only on the cranium but on the rest of the body as well. It has proved an invaluable diagnostic tool, in that the diagnosis can often be made with this technique alone. It short-circuits many of the sophisticated routine X-ray studies which require hospitalization, an anaesthetic, and time lost to the patient and doctor. In many cases it has obviated the need for an exploratory laparotomy. In most cases this technique can be performed on outpatients; the patient is perfectly relaxed during the scan, and may be saved days in hospital.

There are limitations, however, and patients should be carefully selected. A discussion of the indications for body scanning in both our own and overseas experience therefore seems in order.


Computed axial tomography (CAT) has already proved its worth with regard to the brain, detecting and localizing intracranial lesions with far greater accuracy than any other diagnostic method.1,2 Technical improvements have extended this technique to the rest of the body, and the general purpose scanner can now be used for both brain and trunk. Hence it is sometimes termed a 'total body' or 'whole body' scanner, but we prefer 'general purpose scanner', since the other terms may imply that the whole of the body is to be 'scanned' on each occasion.

CAT was invented by an Englishman, G. N. Hounsfield, employed by the EMI Company, who first hit on the idea of hitching a computer to an X-ray machine. An experimental model was constructed towards the end of 1969, which shows us how new this technique really is.

TECHNICAL DATA

CAT employs the computer to detect very small differences in tissue density, determined by evaluating the attenuated X-ray beam as it passes through the body from a variety of different angles, and supplies us with the results in the form of a print-out of tissue density numbers for that cross-section of the body. The numbers (known as EMI units or EMI numbers) are units on an arbitrary scale from +1 000 to −1 000. Zero represents the density of water, with dense bone and calcification at the upper end of the scale and air at the lower end of the minus scale. More commonly the results are read in the form of a picture on a cathode ray tube or screen, displayed over a grey scale from black to white, where each shade of grey represents these units.3

Obviously, the human eye cannot differentiate two thousand shades of grey one from the other, but the computer can (in our case there are two computers to do the job). Therefore, there are two variable factors built in, to enable us to see what the computer does.

Window width refers to the width of the grey scale that is being looked at. The particular width can also be viewed at any position up or down this grey scale, known as window level. Once 'scanned', any cross-section of the body can therefore be viewed at an almost infinite number of combinations of window width and window level.

Measure. Moreover, when the window width is turned down to a width of one unit, the window level will correspond in number to the density in EMI units of any particular lesion displayed on the screen. The window level is set in such a way that the lesion in question has an equal number of black and white areas in it.

We can now compare our density reading with a list of known readings for normal and abnormal tissues, and thus determine what we are dealing with, e.g. blood, fluid, fat or tumour.

Matrix refers to the number of different blocks or 'pixels', which make up the picture. The larger these pixels, i.e. the fewer in number, the more coarse-grained the picture, and vice versa. The earlier units had a 160 × 160 matrix, and this was quite adequate for the brain. Body scans require a higher resolution and the CT 5005 has a 320 × 320 matrix.

Measurement and enlargement. Recent developments

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have enabled us to enlarge on the screen any region of interest on a particular cross-section to four times the original size (Fig. 16). There is also a facility for accurate measurement of any particular lesion.

**INDICATIONS AND PATIENT SELECTION**

**Pregnancy.** Scanning should not be done on a pregnant patient or on the unborn fetus, with the possible exception of a brain scan if indicated, and preferably after the first 12 weeks of gestation.

**Cardiology.** Cardiac movement excludes the heart at this time. Future developments where ECG gating will be employed will circumvent this problem (Fig. 1). At present the detection of pericardial or intracardiac calcification, foreign bodies, pericardial effusion, or thickening may be of marginal value.

**Adrenal glands.** An enlarged adrenal gland, especially on the left side, can be seen easily (Figs 2 and 3). Occasionally the right adrenal may be obscured by the liver. The scan will also tell us whether the lesion is cystic or solid, and detect haemorrhage into the gland.

**Thyroid and parathyroid glands.** Radio-isotope studies are of more value here, although detection of very small calcifications and visualization of the thyroid contour may be of marginal value. The parathyroids are too small.

**Blood vessels.** Most of the major blood vessels are seen on a scan. Aneurysmal dilatation of the aorta is easily seen, and scanning is strongly indicated for the detection of abdominal and thoracic aortic aneurysms (Figs 4 and 5). In the chest it can differentiate between an aneurysm and other mediastinal masses, and in the abdomen detect the position of the aneurysm relative to the origin of other important blood vessels, such as the renal arteries. It obviates the necessity of potentially dangerous aortography or exploratory laparotomy. Apart from detection of aneurysms, however, arteriography is superior.

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**Fig. 1.** Section through the lower chest demonstrating the heart, aorta, and inferior vena cava. Cardiac movement has blurred any detail of heart shape. Note the ribs, vertebrae and sternum, as well as the musculature of the chest wall.

**Fig. 2.** This patient has Cushing's disease. There is an hypertrophied left adrenal gland (single arrow). The right adrenal is partly obscured by the inferior vena cava (two arrows) at this level.

**Fig. 3.** At a slightly lower level. There appears to be downward enlargement of right adrenal, and it is irregular in shape. There is a suggestion of haemorrhage into this gland (arrow).

**Fig. 4.** The aorta at the level of the renal arteries is still of normal size, but somewhat irregular in shape.
Mammography. CAT is not as effective as xeroradiography or conventional mammography, mainly because of technical difficulties of positioning the patient.

Pelvis. Lateral pelvic masses and lymph node enlargement are well demonstrated by this technique, as are masses lying between the bladder and the rectum. It is of great value in the detection of lytic or sclerotic lesions of the bony pelvis.

Oesophagus, stomach and intestines. Scanning of these organs is not indicated at this time, except in the detection and follow-up of tumour spread.

Pancreas. Pancreatic disease is one of the main indications, and scanning is of value in at least 80% of cases, enabling us to see localized or generalized enlargement of the pancreas. Cysts and pseudocysts are easily visualized, and extrapancreatic collections of fluid and haemorrhage are visible by this technique. Problems may arise, however, in the patient with severe weight loss, where the lack of cleavage planes between the organs may make separation of the pancreas from adjacent organs difficult or impossible. The presence of contrast medium in the stomach and duodenum may help to delineate the pancreas in such cases (Figs 6 and 7).

Fig. 5. Three centimetres lower down there is an obvious aneurysm, with calcification in the wall.

Fig. 6. A normal head and body of the pancreas can be seen lying C-shaped around the aorta and superior mesenteric artery. The bowel has been marked by giving the patient diluted contrast medium to drink.

Fig. 7. At a slightly lower level the translucency seen in the bed of the pancreas is a lipoma (proved at surgery).

Fig. 8. Large hydatid cyst in the right lobe of the liver.

Fig. 9. At a slightly lower level a number of hydatid cysts can be seen in both lobes of the liver, as well as a dilated gallbladder. Note the compression of the right kidney.
The liver. Surgical and non-surgical jaundice. A scan will show dilated bile ducts and portal vessels, and the gallbladder is also seen. The size and shape of the liver can be visualized, as well as the presence of a cystic or solid mass lesion or abscess (Figs 8 and 9). Fatty degeneration is well seen, and also the presence of metastases. At the same time — in the case of obstructive jaundice — the possible cause such as a stone or lesion in the head of the pancreas will be seen (Figs 10 and 11). The spleen can also be seen on the same body sections as the liver, and its size and shape evaluated.

Fig. 10. There are dilated bile ducts in the liver and a suggestion of enlarged lymph nodes in the porta hepatis.

Fig. 11. At a lower level there is an enlarged, non-functioning left kidney (note the contrast medium in the right kidney). The pre- and para-aortic regions are obscured by enlarged para-aortic and mesenteric lymph nodes.

Masses. Retroperitoneal masses in the abdomen are invariably well demonstrated, as are mediastinal masses (Fig. 12). Their nature can often be determined by size, shape or situation, and the tissue density (in EMI units) will help to determine this.

Bone. Bone metastases, whether lytic or sclerotic, are detected much earlier than by routine radiography or other methods. This applies especially to the trunk area. Work has been done recently on the accurate estimation of bone mineral content, which may eventually prove to be of value.

Chest. Pulmonary metastases and small primary tumours will be detected much earlier by scanning. The pulmonary vasculature is very well seen, and areas where pulmonary perfusion is poor become obvious (Fig. 13). Early pleural thickening becomes obvious before it is seen on routine radiography.

Treatment planning and follow-up in malignant disease. Para-aortic and mesenteric lymph node enlargement, as well as retrosternal and, if big enough, porta hepatis lymph node enlargement, are easily detected. The scanner can also determine direct spread, as well as bone infiltration and erosion. As already mentioned, bone and lung metastases are well seen on a scan. Where lymphan-
giography will demonstrate only a small proportion of involved lymph nodes, the scan will demonstrate them all. Nevertheless, it is still advisable to do both. The lymphogram helps to identify at least some of the lymph nodes, albeit normal ones, on the scan.

Kidneys. Renal cysts are easily demonstrated and differentiated, for example from very vascular or haemorrhagic tumours. Solid tumours can be diagnosed early. In one particular case where a patient had a normal intravenous pyelogram, the scan revealed two renal cysts and an unsuspected tumour in the left kidney (Figs 14 and 15). The detection of bladder masses is only of marginal value at this stage.

Orbit. There is at present no other diagnostic aid that will demonstrate the orbit as well as CAT (Fig. 16).

Nasopharynx and sinuses. Tumours of the nasopharynx and sinuses are well demonstrated, and CAT is the investigation of choice in determining spread in such cases (Figs 17 and 18).

Others. CAT of the body has also been applied to the study of low pressure hydrocephalus, and has proved superior to any other technique in differentiating low or normal CSF pressure hydrocephalus from a case of raised CSF pressure. Unfortunately it requires the use of metrizamide intrathecally, which is not available in this country yet.

Fractures of the facial bones and their displacements are easily detected.

Fig. 14. There is a simple cyst in the right kidney.

Fig. 15. A further cyst in the right kidney, and a solid tumour on the left side.

Fig. 16. The orbits, eyeballs, and rectus muscles can be clearly seen.

Fig. 17. A cross-section at the level of the maxillary sinuses demonstrating the bony outlines.

Fig. 18. At a lower window level, one can now see polyps in both maxillary sinuses not evident before.
CONCLUSION

It is our opinion that the general purpose scanner should be used (i) in all patients with suspected pancreatic disease, liver masses, splenic masses, or retroperitoneal masses of the abdomen; (ii) in the investigation of jaundice, surgical or non-surgical; (iii) in the detection of aortic aneurysms and definition of their extent and relationship to the origin of other blood vessels; (iv) in patients with mediastinal masses or suspected thoracic aneurysm; (v) in the investigation of the orbit, and the determination of tumour spread in the orbit, sinuses or nasopharynx, and facial bone fractures; (vi) in the diagnosis of lymphoma and malignant disease, as well as treatment planning and follow-up in these cases; (vii) in the early detection of renal masses.

In the same way as the scanner is now employed as a screening test for the brain, we feel it should also be used on all patients with upper abdominal symptoms, where barium studies, intravenous urography, or cholan-

REFERENCES