Emission and transmission brain tomography

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Summary and conclusions

Comparative emission and transmission brain tomograms were obtained in 209 patients to establish the diagnostic accuracy of a new emission tomographic scanner in detecting space-occupying disease in the brain. Concordant results were obtained in 169 patients (81%). Computed transmission tomography (transmission CT) yielded an overall rate of false-positive results of 0.48% and a false-negative rate of 6%. Emission CT yielded a false-positive rate of 0% and false-negative rates of 2.4% for malignant disease and 10% for vascular disease. The higher rate of false-negative results for vascular disease with emission CT occurs because transmission CT can detect old infarction. The rates of detection of recent vascular disease with emission and transmission CT are identical.

Thus emission CT is highly sensitive in detecting space-occupying disease in the brain. It represents an ideal screening procedure.

Introduction

In a conventional diagnostic radiograph the shadows cast by features at different depths are superimposed in the image. These are usually viewed from standard projections (anterior, posterior, lateral). Tomographic imaging discloses these superimposed features by displaying them at different planes of interest. In a tomographic image only those features from pre-determined depths are displayed. So emerged the revolutionary concept of Hounsfield's EMI scanner (computed transmission tomography; transmission CT), which proved the immense value of the tomographic approach.

In a conventional radionuclide scan the radiation emitted by features at different depths is also superimposed in the recorded image. These features are also usually viewed from the standard projections (anterior, posterior, lateral). Equivalent techniques to those applied by Hounsfield have emerged, allowing for the emitted radiation coming from these different features to be displayed and assigned to individual planes and depths (computed emission tomography; emission CT).

Although transmission and emission CT use similar concepts in generating an image, clearly the inherent advantage of the x-ray technique lies in its extremely fine spatial resolution. Emission CT may be regarded as in-vivo autoradiography, displaying in three dimensions the biochemical interaction between the structure to be scanned and the radiopharmaceutical used.

This has naturally led to renewed interest in the clinical potential of emission CT.¹⁻³ In 1978 we reported appreciable improvement in the technical solutions offered by specialised instruments for recording emission tomograms and initial

clinical results. Since then we have aimed at establishing the place and clinical value of emission CT as compared with the now conventional transmission CT in screening and detecting intracranial space-occupying disease. A trial was organised between the two European centres that evaluated the new emission tomographic brain scanner.⁵⁻⁸ Since March 1978 data on 209 patients for whom emission and transmission brain tomograms were available were collected in London and Bordeaux.

Patients and methods

We studied 209 patients referred for investigation of space-occupying disease in the brain. Most were referred from neurological centres, general wards, and radiotherapy units. All patients underwent full clinical and neurological examination, and electroencephalography was carried out whenever relevant for diagnosis. Emission and transmission CT was performed in all patients, and contrast angiography whenever appropriate for management. Radionuclide angiography was performed in all patients, and conventional four-view studies with an Anger gamma-camera in 156 (75%). The data were collected between March 1978 and March 1979, and follow-up data were available during this period. In all patients a final diagnosis was made based on the combined clinical, laboratory, surgical, and follow-up data.

Emission CT was carried out with a Cleon-710 tomographic brain imager. A standard dose of pertechnetate (^{99m}technetium; ^{99m}Tc) was given intravenously (15-20 mCi) and scanning started one hour after injection. The scanner was operated with window settings for ^{99m}Tc (130 keV), a scan time of four minutes/slice, and slice spacing of 1.25 cm. A fixed background cut-off of 25% was chosen.

In London transmission CT was carried out with an EMI CT5005 scanner, a scan time of 20 seconds/slice, and slice spacing of 8-13 mm. In all patients studies were performed with and without contrast material. In Bordeaux the transmission tomograms of the brain, again with and without contrast, were recorded on a CGR ND 8000 scanner, with a scan time of 40 seconds/slice and slice spacing of 5 mm.

Data were reported independently in London and Bordeaux, and in both centres emission and transmission CT scans were reported independently.

The clinical results fell into three categories: those for malignant disease (comprising intracranial primary and secondary tumours, including meningiomas); those for vascular disease (comprising cerebrovascular accidents, haematomas, subdural haematomas, and arteriovenous malformation); and those that were normal (in patients in whom clinical history and outcome and silent emission and transmission tomograms failed to show evidence of intracranial space-occupying disease).

Results

Figure 1 shows the normal anatomy and physiology of the brain as seen by emission CT. Figure 2 shows abnormal emission tomograms, with typical tracer uptake pattern.

Emission and transmission CT yielded concordant data in 169 patients (80.9%): 74 with malignant disease, 58 with vascular disease, and 37 who were judged to be normal. Discordant data were obtained in 40 patients (19.1%). In 13 (6.2%) only the emission CT scan showed evidence of disease. Of these 13 patients, three had malignant disease and 10 vascular disease. In the remaining 27 patients (12.9%) only the transmission scan showed evidence of disease: five patients had malignant disease and 21 vascular disease, and in one a recurrence of a meningioma was falsely diagnosed.

Thus the rate of false-positive results was 0% for emission CT and 0.48% for transmission CT. Rates of false-negative results obtained with emission CT were 2.4% in malignant disease and 10.0% in vascular disease; and with transmission CT 1.44% in malignant disease and 4.8% in vascular disease.

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FIG 1—Normal anatomy and physiology of brain as seen by emission CT.

Discussion

We obtained concordant results in 81% of patients using these two types of CT. Of the 74 patients with malignant disease in whom we obtained concordant results, 26 had multiple cerebral secondary deposits from various primary tumours and the remaining 48 had primary brain neoplasms. Of the 58 patients with vascular disease, nine had intracerebral haematomas, two chronic subdural haematomas, one arterio-venous malformation, and 46 had had strokes.

Of the 13 patients in whom transmission CT gave a false-negative result, one had a parietal glioma, two multiple cerebral secondary deposits, two isodense chronic subdural haematomas, and eight had had strokes. Of the five patients with malignant disease in whom emission CT gave a false-negative result, one

had multiple cerebral metastases, one astrocytoma, one frontal and one parietal glioma, and one an epidermoid cyst (shown at operation). Of the 21 patients with vascular disease in whom emission CT gave a false-negative result, one had bilateral chronic subdural haematomas, 11 had had an infarction over seven weeks previously, and nine had had strokes less than five days previously.

Clearly, therefore, emission CT is highly sensitive in detecting intracranial space-occupying disease. It represents an appreciable improvement over conventional Anger gamma-camera imaging. Indeed, 5% of all lesions were detected only by emission CT when the results obtained with this method were compared with those achieved with the gamma-cameras. In about 20% of all cases, however, lesion location in depth was appreciably improved with emission CT. This was particularly apparent in differentially diagnosing secondary deposits of the skull from those of the brain and in precisely locating lesions in the cerebellopontine angle, posterior fossa, and base of the brain. Only 75% of the patients were scanned simultaneously with Anger gamma-cameras, since one of the two centres participating in this study no longer considered gamma-camera studies to be justified owing to the superior imaging characteristics of the emission tomographic scanner.

This study also shows that emission CT gives a high false-negative rate for vascular disease. This, however, mainly occurs as a consequence of the ability of transmission CT to detect old infarction. In early cerebrovascular disease (less than five days)

FIG 2—Abnormal emission tomograms seen in chronic subdural haematoma (top), cerebrovascular accident in middle cerebral artery (middle), and multiple secondary deposits in brain (bottom).

emission CT will be negative owing to lack of uptake of tracer in the lesion. In terms of detection (sensitivity) this remains a drawback of emission CT. If these patients are scanned during the two weeks when tracer concentration peaks within the lesion emission and transmission CT achieve the same detection rate, which explains the high percentage of concordant results obtained in the patients with vascular disease. Transmission CT, however, yields a few false-negative results in isodense vascular disease.

In this series the rate of false-positive results obtained with emission CT was 0% and the rate of false-negative results was extremely low (2.4% in detecting primary or secondary intracranial neoplasms).

Emission CT is becoming more available. Within the past year at least seven centres in the UK alone emerged with the technical infrastructure required to record computed emission tomograms. We do not doubt that further work will progressively show its clinical potential.

In terms of patient throughput, total scan time with an emission brain scanner averaged 30 minutes. Other systems exist whereby data collection may be completed in 15-20 minutes. We hope to cut our total scanning time by half to 10-15 minutes per patient. This may be achieved without appreciable loss in image detail. In terms of radiation exposure, a standard ^{99m}Tc brain scan delivers a dose in the order of 100 mrad; the dose to a slice in the brain from transmission scans varies from 1.5 to 2 rad.

With every new technique the question of costs arises. Purchase costs for available emission CT equipment are known, but cost-effectiveness is difficult to assess. A camera computer system designed to perform emission CT may cost from £10 000 to £20 000 over and above the expenditure necessary to buy the camera computer system (of the order of £80 000). The cost of our instruments falls within this range.

Requests for reprints should be sent to PJE.

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Computed tomography for determining liver iron content in primary haemochromatosis

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Summary and conclusions

Dual-energy computed tomography (CT) was used to estimate hepatic iron concentration in eight patients with primary haemochromatosis with varying degrees of iron overload. The values corresponded closely with those derived from chemical analysis of liver tissue obtained by biopsy (correlation coefficient 0.993).

Dual-energy CT therefore seems to provide an accurate and non-invasive alternative to liver biopsy as a means of measuring liver iron concentration in patients with primary haemochromatosis and possibly other iron overload states.

Introduction

Physicochemical measurement of iron concentration in tissue obtained at liver biopsy is the most reliable index of total body iron stores in primary haemochromatosis.^{1,2} The presence of increased hepatic iron in this disease may be suggested by computed tomography (CT),³ but the use of CT for estimating the amount of hepatic iron has not been described in primary haemochromatosis.

In this study we compared estimates of hepatic iron concentration obtained with CT using a dual-energy technique with results obtained by chemical analysis of liver biopsy material.

Methods

Seven men and one woman with primary haemochromatosis were studied. The diagnosis was established clinically and by a raised liver iron content in the absence of another cause for siderosis. Two patients had a family history of the disease. All patients had had a liver biopsy within six weeks of CT scanning and no patient had been venesectioned between the time of CT scanning and biopsy.

IRON STUDIES

Serum iron concentration, total iron binding capacity, and percentage iron saturation of iron binding capacity were measured using standard laboratory methods. Serum ferritin was measured by radioimmunoassay.⁴

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