Comparison between emission and transmission computed tomography of the liver

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Abstract

Emission computed tomography (emission CT) and conventional planar gamma-camera imaging of the liver were compared in 242 patients with suspected metastatic spread to liver. Concordant data were obtained in 171 patients (71%). Single large lesions, multiple small lesions, and diffuse disease were accurately defined with this new radionuclide tomographic technique. The smallest lesion detected by emission CT was 8 mm. Emission CT, planar gamma-camera imaging, and transmission (x-ray) CT were compared in 107 patients. All three methods gave identical results in 76 patients (71%). Assessed against other criteria, such as histological findings and follow-up data, emission CT yielded the highest range of accuracy (92–96%), while transmission CT and planar gamma-camera imaging had similar but lower accuracies (78–81%). Emission CT had a false-positive rate of 2·8% and a false-negative rate of less than 1%.

Thus emission CT is highly sensitive in detecting space-occupying disease in the liver.

Introduction

The liver is a common site of secondary and, less frequently, primary malignant disease. Cancers of the stomach, breast, and bronchus often metastasise to the liver, and diffuse or discrete lesions may also be found in many other conditions—for example, Hodgkin's disease and non-Hodgkin's lymphoma. The presence of occult intra-abdominal disease is often responsible for mis-staging of several of these tumours and it is important to investigate the liver to establish the presence or absence of space-occupying disease.

Imaging techniques play an important part in the investigation of these patients. The plain abdominal *x*-ray examination is inconclusive in most cases, and liver angiography is an invasive procedure with a risk of complications which is only moderately sensitive in detecting disease, but several non-invasive imaging techniques are now available for the simple and relatively risk-free investigation of the liver. Historically, radionuclide scintigraphy was the first technique to be widely used clinically. Ultrasound and *x*-ray-based computed tomography grew in the 1970s and have established themselves as powerful tools in the clinical investigation of disease. Nuclear magnetic resonance (or zeugmatography) is looming on the horizon and the first results are beginning to impress clinicians throughout the world. In the near future, however, the three main non-invasive imaging techniques in the investigation of malignancy of the liver are likely to remain traditional ones: radionuclide imaging, ultrasound, and *x*-ray imaging.

Transmission (*x*-ray based) computed tomography (transmission CT) has been used clinically for several years, while emission (radionuclide-based) computed tomography (emission CT) has only recently been extensively used in clinical practice though it was used by Kuhl[1] and others in the mid 1960s. Large clinical trials have compared the efficacy of these two computer-based imaging techniques in the investigation of the brain,[2] but no such studies of the liver have been reported. We report here such a study. Our aim was to establish relative figures of merit for three imaging techniques—conventional radionuclide planar scintigraphy, emission CT or radionuclide section scanning, and transmission CT—in the diagnosis of space-occupying disease of the liver.

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Patients and methods

Two hundred and forty-two patients were studied (134 women aged 18–75 and 108 men aged 10–80). Most patients were referred from an oncology clinic for investigation as part of a routine screening or follow-up programme. Seventy-two patients had carcinoma of the breast, 28 Hodgkin's disease, 22 non-Hodgkin's lymphoma, 29 carcinoma of the bronchus, 22 tumour of the gastrointestinal tract, 15 liver tumours, 13 malignant melanoma, 4 carcinoma of the ovary, 8 carcinoma of the prostate, and 29 tumours of miscellaneous origin. Patients with jaundice (a rare event in the population under study) were excluded.

Examinations by the three techniques were performed within 48 hours of each other. For conventional planar radionuclide scintigraphy 3–4 mCi of ^{99m}Technetium-sulphur colloid was given intravenously. The following views were recorded for each patient 20 minutes after the injection: anterior, erect and supine; posterior; and right lateral projections. Each view consisted of 400 000 counts recorded with gamma camera-computer system with a large field of view (either the IGE 400T/Informatek Simis-3 or the Digicamera, EMI) using parallel hole, low-energy, and high resolution collimation.

Radionuclide (emission) tomography was performed with the Cleon-711 whole body imager.[3] Enough section scans of the liver and spleen were recorded to cover the entire organ. The scanning time per tomographic section was five minutes, with a spacing of 2·5 cm between slices, and images were reconstructed in the transaxial plane only.

For *x*-ray (transmission) tomography the EMI 5005 whole body scanner was used. Enough sections were recorded to cover the entire volume of the liver and spleen. Scanning time per slice was 13 seconds, the slice spacing was 9 mm, and the plane of image reconstruction was transaxial. No intravenous contrast material was given to enhance the contrast.

In our initial protocol, planar scintigraphy was compared with emission CT in all 242 patients. We intended to establish the feasibility and relative figures of merit of these two techniques before extending the comparison to transmission data. Once this study was completed and the feasibility of routine radionuclide liver tomography established 107 patients were investigated with all three imaging techniques. In this protocol the following criteria were used to arrive at a final diagnosis: follow-up of patients for one year, histological evidence from liver biopsies whenever possible, sequential scanning, clear-cut evidence from two imaging techniques other than emission CT, and occasional ultrasound data.

All the images were read without knowledge of other clinical or laboratory evidence. The emission CT scans were read first and a decision made before any other conclusion was reached from the other scans. We tried to classify data from all of the three imaging techniques as positive, negative, or equivocal.

Results

Fig 1 shows the images of a patient with non-Hodgkin's lymphoma in which all three techniques showed negative findings; fig 2 shows

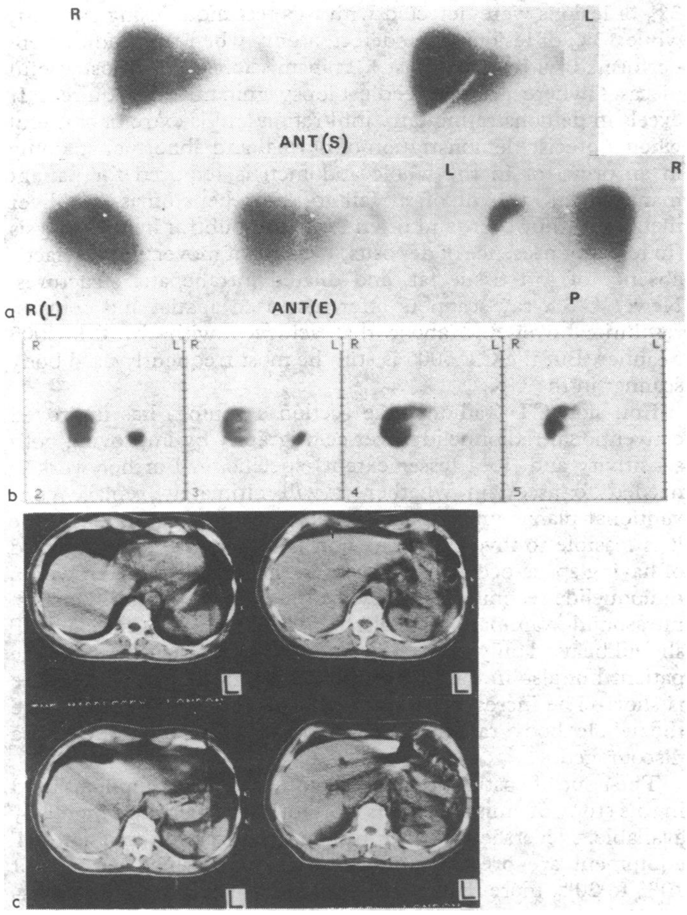

FIG 1—Images from all three techniques of the liver of 59-year-old woman with non-Hodgkin's lymphoma: (*a*) normal five-view planar gamma-camera study of the liver; (*b*) normal transaxial sections by emission CT; (*c*) normal transaxial sections by transmission CT.

the images from a patient in which they all showed positive findings.

In the comparison between planar scintigraphy and emission CT the findings agreed in 171 patients (71%) and disagreed in 36 (15%). Doubtful data were observed with scintigraphy in 6%, with emission CT in 5%, and with both techniques in 3% of all cases.

In the comparison between scintigraphy, emission CT, and transmission CT the findings agreed in 76 patients (71%) and disagreed in 31 (29%). According to the criteria for assessing a final diagnosis, emission CT provided the correct answer in 23 of the 31 cases with discordant data. In the remaining eight cases emission CT was wrong in four (3 false-positives and 1 false-negative), and in four cases no final diagnosis was arrived at. Planar scintigraphy and transmission CT offered the correct answer in only seven of the 31 patients. For each of the three imaging techniques, the four "unknowns" were treated as having been either correctly or incorrectly diagnosed. This allowed us to calculate an accuracy range: values for planar scintigraphy and transmission CT were 78–81% and for emission CT 92–96%. Sensitivity in detecting space-occupying disease in the liver was identical for conventional radionuclide scintigraphy and transmission CT, while emission CT appeared to offer a gain of about 14% in overall sensitivity.

Discussion

The initial study of 242 patients, in which conventional planar radionuclide liver and spleen scintigraphy was compared with emission CT of these organs, offered an interesting insight to the potential of this new nuclear medicine imaging technique. There was an encouragingly high percentage of concordant results. In just under two-thirds of all comparative studies similar interpretation in terms of presence or absence of disease was obtained for both the planar and the tomographic investigations where interpretation remained doubtful. Although this figure should improve with increasing experience of emission CT, there was still a significant proportion of patients with conflicting data, and the need for further research is clear.

A more detailed scrutiny of the data of the initial comparative imaging protocol also showed that single but large lesions were accurately reconstructed and therefore visualised on the radionuclide tomogram, as were multiple but small lesions. Normal tomograms were also recorded in healthy volunteers. Even diffuse liver disease, where large areas of the liver were affected by a malignant process, was correctly identified by the emission scanning technique. At this stage of the study and due to the recording of information in a three-dimensional matrix, it was felt that extra information was obtained from the radionuclide tomograms over and above the information retrieved from the conventional planar projections. The true extent of liver disease was more accurately estimated on the section-scan studies.

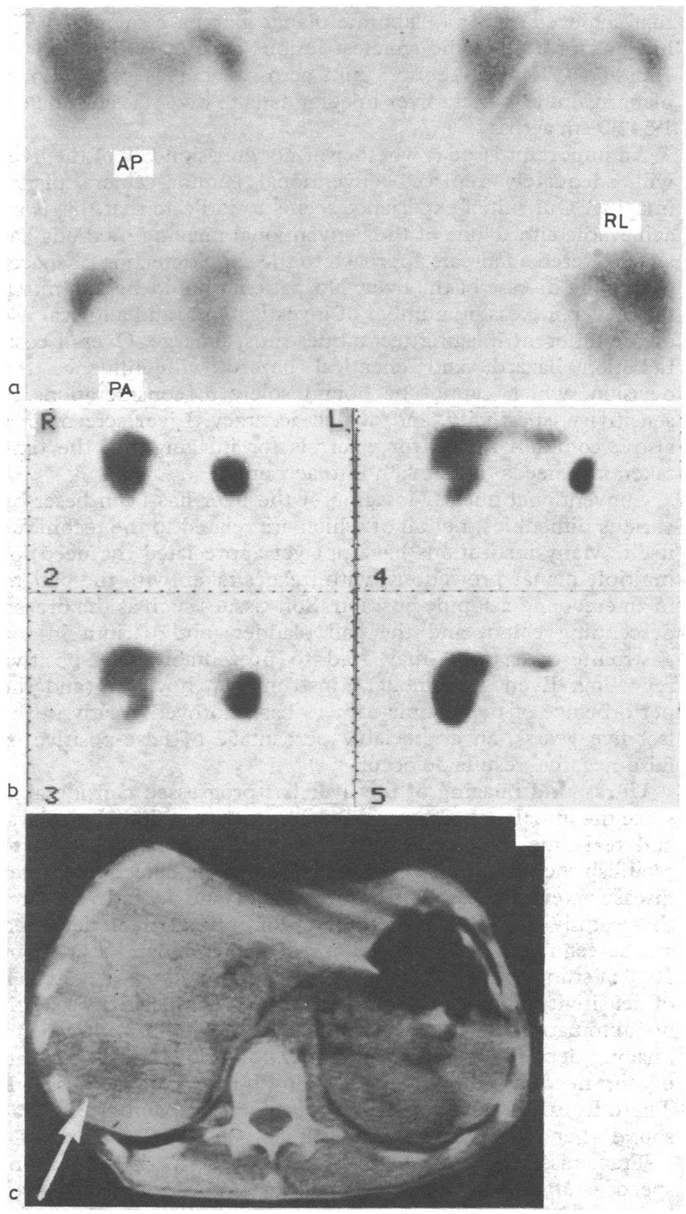

FIG 2—Images of liver of 56-year-old man with carcinoma of the oesophagus: (*a*) gamma-camera images showing single, large, well-defined defect seen best in right lateral (RL) projection; (*b*) emission section scan (transaxial plane) showing single well-defined defect in posterolateral aspect of right lobe of liver; (*c*) abdominal *x*-ray CT scan showing defect in posterolateral aspect of the right lobe of the liver (arrowed).

Better discrimination of intrinsic from extrinsic liver disease was also possible and in several cases the availability of the tomographic study allowed us to exclude or confirm the presence of disease with increased confidence.

In a few cases the reproducibility of tomograms was investigated by serial imaging of the same patient. Emission CT was found to be a useful technique in monitoring the progress of disease, in terms of both growth of a lesion and multiplication of focal lesions. Reproducible data were recorded in stationary disease.

Interesting data also emerged from the comparison between the three imaging techniques. While emission CT appeared to be the most accurate of all three imaging techniques, transmission CT fared no better than conventional planar gamma-camera reporting. Clearly, the advantage of greater spatial resolution available from EMI scanning was upset by the relative loss in contrast resolution in disease of the liver, *x*-ray absorption coefficients being too similar between normal and abnormal liver tissue. This study showed that emission CT was highly sensitive for detecting space-occupying disease of the liver and that a gain in sensitivity of 14% was observed over and above that achieved with an elaborate planar gamma-camera and CT imaging protocol. The smallest lesions accurately detected by emission CT were about 8 mm across, whereas conventional planar gamma-camera liver imaging fails to detect lesions below 1·5–2·0 cm across.

An important issue is whether or not emission CT of the liver will adequately replace conventional gamma-camera planar imaging. Our initial experience seems to indicate that this is an achievable aim. None of the conventional imaging methods has so far offered a fail-safe approach to the early detection of space-occupying disease of the liver. No patient should be submitted to an ever-increasing number of investigations, and a logical use of the different imaging techniques must emerge. Overall cost, radiation hazard, and chemical hazard will influence the decision, which cannot be bound solely to considerations of sensitivity, specificity, and overall accuracy. Liver screening is also a common reason for referrals for imaging and the time taken also needs to be taken into account.

Conventional nuclear imaging of the liver has been beset by various difficulties, not all of which are related to the technique itself. Many institutions have not yet appreciated the need for multiple planar projections, with images taken with the patient in an erect and a supine position. Soft tissues such as the breast, descending colon, and the gall bladder (and barium in the gastrointestinal tract) may lead to preventable false-positive reporting. Even with modern instruments, however (and the performance of the gamma-camera has improved greatly in the last five years), an appreciable percentage of false-positive or false-negative results do occur.

Ultrasound imaging of the liver has progressed considerably since the initial days. Improved scan converters, digital displays, and real-time units with improved resolution have helped to establish the usefulness of this approach to the detection of liver disease. Nevertheless, difficulties remain and include the fact that a study may take 30–45 minutes for optimal lesion detection and screening of the entire volume of the organ, and that about 10% of studies still lead to suboptimal scans and the overall lack of sensitivity (counterbalanced by improved specificity). With no automation of data recording, the quality of ultrasound imaging depends greatly on the operator's skill and there is an urgent need to observe interaction during data acquisition. These features tend to restrict the general availability of ultrasound as an important clinical tool.

Transmission CT excels in the display of spatial resolution, speed, and the demonstration of anatomical data. In vivo, however, it often lacks contrast resolution. This explains the false-negative rate in liver and pancreas reporting in the early stages of disease in these organs. The addition of contrast material has been tried but the procedure is then no longer free of risk. In addition, a comparative study with and without the intravenous administration of contrast media only showed that 3% of lesions were detected with this technique using contrast, while 13% of lesions were detected only when the studies were performed without contrast.[4] Transmission CT is most useful in cases where precise needle biopsy guidance is required. It excels in demonstrating fatty infiltration and is extremely useful when a precise demonstration of normal and abnormal anatomy in an organ or in the whole abdomen is required for patient management. It will often fail to show hepatomas and liver metastases, however, and often leads to doubtful image analysis (in terms of presence of deposits) because of movement artefacts, absence of soft tissue fat, and dilated intrahepatic structures. Newer CT *x*-ray scanners offer increased spatial and contrast resolution, over and above that achieved with the CT 5005 Scanner. But the CT 5005 is still the most frequently used body scanner in the UK.

Emission CT (radionuclide section scanning) has improved conventional radionuclide liver scintigraphy by improving both sensitivity and (to a lesser extent) specificity. Further work is needed to ascertain whether it will ultimately replace conventional planar imaging of liver and spleen. In the meantime it is feasible to investigate the non-jaundiced patient suspected of having space-occupying disease in the liver and spleen with a radionuclide technique initially. Subsequently, if doubt persists, ultrasound examination should be performed. Transmission CT should be used only as a last resort, not only in the interest of the patient but also in the interest of the diagnostician, whose time is short. The increasing tendency in transmission CT to image the whole body rather than the organ of interest should be discouraged.

The issue of cost merits a final comment. The equipment used in this study of emission CT is a prototype and not commercially available. Nevertheless, over 10 manufacturers of emission CT equipment are presently offering machines which cost about 10% to 20% more than a standard conventional Anger gamma-camera (the total cost of a new emission CT system is about £80 000 to £100 000). An emission study of the liver and spleen costs about £7 (estimation based on 10 studies per day and five-year full-time use of the equipment).

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WHEN bilious humours occafion the heart-burn, a tea-fpoonful of the fweet fpirit of nitre in a glafs of water, or a cup of tea, will generally give eafe. If it proceeds from the ufe of greafy aliments, a dram of brandy or rum may be taken.

IF acidity or fournefs of the ftomach occafions the heart-burn, abforbents are the proper medicines. In this cafe an ounce of powdered chalk, half an ounce of fine fugar, and a quarter of an ounce of gum-arabic, may be mixed in an Englifh quart of water, and a tea-cupful of it taken as often as is neceffary. Such as do not chufe chalk may take a tea-fpoonful of prepared oyfter-fhells, or of the powder called cabs-eyes, in a glafs of cinnamon or peppermint-water. But the fafeft and beft abforbent is *magnefia alba*. This not only acts as an abforbent, but likewife as a purgative; whereas chalk, and other abforbents of that kind, are apt to lie in the inteftines, and occafion obftructions. This powder is not difagreeable, and may be taken in a cup of tea, or a glafs of mint-water. A large tea-fpoonful is the ufual dofe; but it may be taken in a much greater quantity when there is occafion. Thefe things are now generally made up into lozenges for the conveniency of being carried in the pocket, and taken at pleafure.