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A study comparing SPECT with CT and MRI after closed head injury

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Abstract

After closed head injury nineteen patients had single photon emission tomography (SPECT) using the lipophilic tracer 99m-Technetium hexamethyl-propylene-amineoxime (HMPAO) to compare the defects shown by CT and MRI. SPECT showed more focal cerebral lesions than either CT or MRI alone or in combination. Most lesions shown by SPECT were not shown by CT or MRI in the corresponding anatomical regions. The most severely disabled patients showed the highest number of SPECT lesions (average four per patient) and the lowest (mean, SE) cerebral blood flow (718, 69 ml/min) compared with the less disabled patients (two per patient and 1058, 51 ml/min, $p < 0.05$). There was a correlation between the Glasgow Outcome Scale grade and the global cerebral blood flow (r 0·74, $p < 0.05$). The perfusion defects may correlate with clinical signs that were not explained by CT or MRI findings. SPECT may complement the clinical evaluation in the assessment of outcome after head injury.

CT is of value in demonstrating large acute haematomas after head injury, and MRI is more sensitive in showing smaller traumatic lesions.[1–3] During early recovery MRI may still be more sensitive in demonstrating cerebral lesions than CT.[4 5] These imaging methods, however, demonstrate anatomical changes produced by trauma. Whilst they may have some predictive value, it is unlikely that imaging techniques reflecting changes in cerebral function, rather than structure, would assess a patient's clinical status and progress more accurately. Positron emission tomography provides an effective measure of cerebral metabolism and tissue function. However, its logistic contraints and expense make it unavailable to many centres. Single photon emission computer tomography (SPECT), using the easily obtainable and convenient lipophilic tracer Technetium-99m hexamethyl-propyleneamineoxime (Tc-99m HMPAO), has made the assessment of regional cerebral blood flow (rCBF) readily available.[6–9] Since patterns of rCBF frequently match the metabolic requirements, and thus the functional status, of cerebral tissue, alterations of rCBF may be useful in defining underfunctioning areas of the brain in many cerebral disorders including head injury.

This pilot study therefore compared the number of structural defects seen on CT and MRI with the number of perfusion defects seen on SPECT in patients sometime after head injury. We also examined whether either the number of defects or measurement of rCBF might have a role in determining outcome following head injury.

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Methods

Nineteen patients (15 male; mean age 29 years, range 10–49) had SPECT, CT and MRI between three and 36 months after severe head injury. The mean post traumatic amnesia was four to five weeks, range 10 days to four months. All scans were carried out within 12 weeks of each other, with one exception, and in random order. Clinical assessment at the time of the first scan was made using the Glasgow Outome Scale, Extended version[10] (GOSE); 1 = death, 2 = persistant vegetative state, 3a = severe disability—needs continuous supervision or help with many activities of daily living, 3b = severe disability—can manage on own with considerable support, 4a = moderate disability—significant problems with either occupational or social functioning, 5a = good recovery with residual symptoms, 5b = good recovery with no symptoms.

Unenhanced CT scanning was performed on a GE 9000 scanner, with 10 mm contiguous slices from the radiological baseline. MRI was performed on a 0·8 Tesla Imatec International machine using TR 1500 ms and TE 64 and 128 ms sequences at 12 mm slices from the radiological baseline. One sagittal section was also made. For rCBF the patient was studied in a quiet room after a full explanation of the test and with a nurse and doctor in attendance. The eyes were not covered. There was a five minute delay between the insertion of the venous line and the start of the study. SPECT was performed 20 minutes after 600 MBq. TC-99m HMPAO was injected intravenously using a GE 400/AT gamma camera with a high resolution collimator linked to a PDP11/73 computer. Raw data was collected over 360 degrees rotation at each of 64 angles (counting 30 seconds per angle) with resolution of 64 by 64 pixels and a zoom factor of 1·2. A series of 10 mm transverse slices were taken parallel to a plane lying approximately 10 degrees to the OM line. Coronal and sagittal sections were also obtained and a computer program was available to select and display corresponding regions in each of the three planes.

CT and MRI scans were read by an experienced neuroradiologist (MC) without

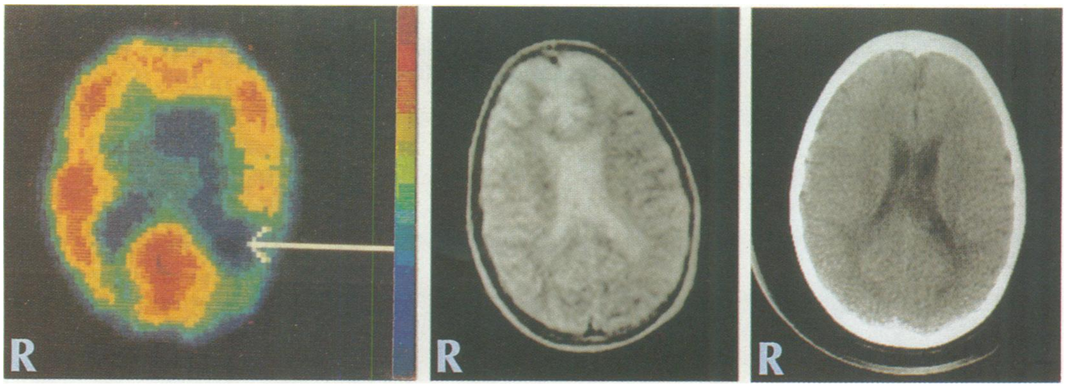


Figure 1a Transaxial slices of SPECT, MRI and CT from a 10 year old with reading difficulties five months after head injury. There is a defect in the left posterior parietal region on SPECT that is not shown on CT or MRI.

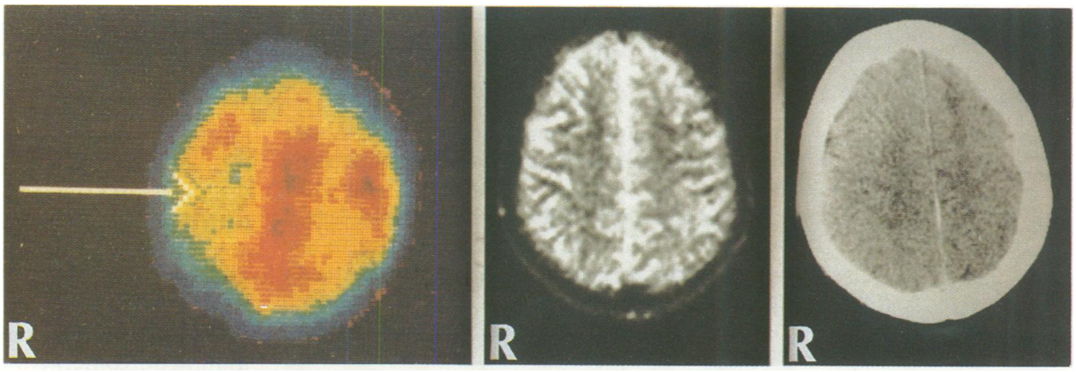


Figure 1b The same imaging sequences are shown from a severely disabled 19 year old with a left hemineglect syndrome three months after trauma. The right parietal abnormality is shown only by SPECT.

knowledge of the patients clinical status and SPECT images were interpreted by a nuclear medicine physician also unaware of the patients clinical state. The number and disturbance of focal lesions was counted for each scan. The normal pattern of Tc-99m HMPAO SPECT is well established[6-9] and a formal control group was not considered necessary. A defect of at least two colour grades on the colour scale shown in fig 1a in comparison with the contralateral or adjacent normal area was used to indicate a defect, and such a defect had to be evident on all of the three planes of section, transverse, coronal and sagittal. No reference to the CT or MRI results was made.

The cerebral clearance (uptake) of Tc-99m HMPAO was calculated by the first pass method of Nimmon[11 12] and is given by the difference between the supply and the cerebral blood flow measured by a non-diffusible tracer Tc-99m human serum albumin.[13] Deconvolution analysis of the input function from a probe over the aortic input with the content curves from regions of interest from the camera placed over the vertex gives the regional impulse retention functions from which the regional mean transit times are obtained. Regional cerebral blood volumes are calibrated using a blood sample taken at three minutes. Division of regional volume by regional mean transit time gives the regional flows in ml/min from Tc-99m albumin. Fitting the upstrokes of the regional impulse retention function from Tc-99m HMPAO to that of TC-99m albumin done serially in the same patient gives the HMPAO cerebral clearance by difference. The calibration of HMPAO clearance against albumin derived cerebral blood flow enabled the global cerebral flow to be obtained from the first pass study of Tc-99m HMPAO alone.[12]

Results

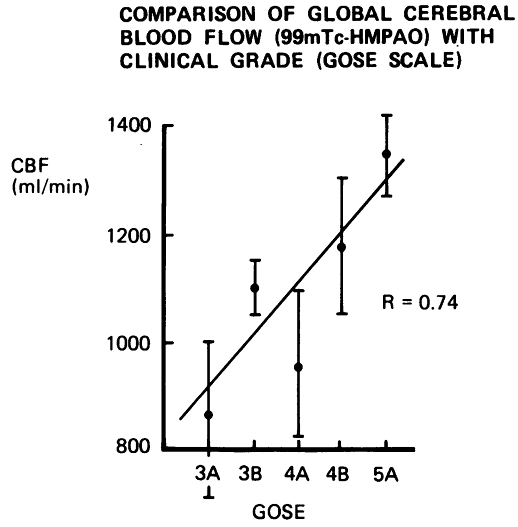
A total of 43 perfusion defects were detected with SPECT in the 19 patients compared with 21 focal lesions shown by MRI and 13 by CT (table). Of those 43 SPECT lesions, 31 were not seen on either CT or MRI. Five of the 21 MRI lesions were unique to that modality, whereas CT showed only four focal abnormalities not seen on SPECT or MRI. Generalised cerebral atrophy, however, was reported most frequently on CT (8/19) compared with MRI (2/19). Interestingly the highest number of lesions on SPECT was seen in the most disabled group of patients, who averaged four lesions per patient in contrast to the less disabled patients who averaged two lesions per patient.

The perfusion defects shown by SPECT and not shown by CT or MRI sometimes revealed interesting clinical correlations. Two examples are illustrated in fig 1. The first patient (aged 10

Table Number of lesions shown in 19 patients imaged with CT, MRI and SPECT, correlated with GOSE rating of outcome

	Number of Lesions			
Clinical State (GOSE)	*N*	*CT*	*MRI*	*SPECT*
3a	4	5	7	16
3b	2	0	2	4
4a	4	3	6	5
4b	6	5	5	13
5a	3	0	1	5
Total	19	13	21	43

Figure 2 Comparison of global cerebral flow measured by Tc-99m HMPAO with GOSE rating of outcome.



years, right-handed) made a good recovery five months after head injury but was left with some difficultly in reading (GOSE 5a). CT and MRI scanning did not reveal a left hemisphere lesion but SPECT showed a perfusion defect in the left posterior parietal region, consistent with his lexical problem.

The second patient (aged 19, right-handed, three months post-head injury, rated 3a on GOSE) had a spastic quadriparesis, dysarthria, dysphagia and poor short term memory (fig 1b). He also displayed neglect of the left side of the body. CT and MRI each showed a small left frontal subdural haematoma and no other abnormality. SPECT revealed defects in the right temporal, cerebellar and parietal lobes.

There was an inverse correlation between the number of lesions obtained with SPECT and the Glasgow Outcome Score ($r = -0{\cdot}82$, $p < 0{\cdot}05$), similar to that noted between MR1 and GOSE ($r = -0{\cdot}84$, $p < 0{\cdot}05$) although fewer lesions were detected with MRI. There was also a significant correlation between the global cerebral blood flow and the GOSE grade (fig 2, $r = 0{\cdot}74$, $p < 0{\cdot}05$). Those patients with three or more SPECT lesions had a mean (SE) global flow of 718 (69) ml/min compared with those with one or two lesions [1058 (51) ml/min, $p < 0{\cdot}05$].

Discussion

This pilot study has confirmed the findings of Abdel-Dayem *et al*[11] who reported changes in rCBF after head injury using SPECT. Their patients were studied within 72 hours of trauma, however, whereas our patients were scanned much later, between three and 36 months after injury, when all were receiving rehabilitation. Our preliminary results suggest that the number of rCBF defects and the global cerebral blood flow correlate with the functional status of the patient. A longitudinal study of SPECT in patients with head injury would be required to show whether the defects shown by Abdel-Dayem *et al*[14] in the early post traumatic period persist in the longer term.

SPECT showed many more lesions than CT or MRI and this scanning technique may have greater value in complementing the clinical assessment of patients seen late after head injury. MRI has been shown to demonstrate more lesions both in the acute[1-3] and recovery[4 5] periods than CT, but has not previously been compared with SPECT. Because of cost implications this method of imaging is not widely available. Equipment for SPECT, however, is frequently used in nuclear medicine departments and the overall cost of SPECT is less than that of MRI. CT of course remains invaluable in the detection of surgically remediable consequences of head trauma such as haematomas and hydrocephalus.

We conclude that SPECT reveals areas of cerebral damage, which may be either contusional or ischaemic, frequently not shown by CT or MRI. Defects on SPECT may correlate with focal neurological deficit. The most disabled patients tend to show the most number of lesions on SPECT. Further studies with SPECT after head injury may define the role of this physiological imaging method in determining outcome.

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