Post-traumatic Neurobehavioral Dysfunction: A Positron Emission Tomographic Study

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Introduction

A limited number of studies using Positron Emission Tomography (PET) for evaluation of patients with traumatic brain injury have been reported. PET cannot distinguish between metabolic abnormalities related to structural damage and those without such findings. In the former the metabolic dysfunction can extend far beyond the boundary of anatomical lesions (1,2). Also PET abnormalities can be demonstrated in patients with poor clinical outcome following a minor brain trauma and without evidence of brain damage on computed tomography (CT) and magnetic resonance imaging (MRI), although positive neuropsychological examination (3,4). Crossed cerebellar diaschisis as well as ipsilateral cerebellar hypometabolism have been reported in head injury patients with supratentorial lesions (5).
Single photon emission computed tomography (SPECT) studies have yielded results similar to those found with PET in head trauma patients (6-10).
In acute states, soon after head injury, a dissociation can occur between blood flow and metabolism. Two haemodynamically different traumatic contusions can be identified by SPECT, those with a decreased regional cerebral blood flow (rCBF) and those with a rCBF equal to that of the surrounding brain tissue. The latter may result from luxury perfusion to these areas with subsequent uncoupling of CBF and cerebral metabolism (11). Early ischaemia after severe head injury is due to compromise of the microvasculature rather than to vasospasm of the larger conductance vessels (12). Discordance between glucose metabolism and brain perfusion can also occur as result of cerebral hyperglycolysis, following severe acute traumatic brain injury in humans (13-15).
PET and SPECT findings can be variable in the acute stages of cerebral trauma with focal and diffuse lesions. On the other hand, in patients with a remote history of brain injury, only areas of decreased blood flow and metabolism are observed (3-10). The question raises to what extent these deficits correlate to the persistence of neurobehavioral changes following head trauma.
The present PET study analyses, in a small series, the most common findings in patients with persistent post-traumatic neurobehavioral changes.

Patients and Methods

The study population included 10 patients, 6 males and 4 females between 21 and 76 years of age, with persistent complaints following a brain trauma. One patient had a mild injury and suffered from post-traumatic emotional instability. Four patients had a moderately severe accident and 5 a severe one, leading to complaints varying from persistent headache, irritability, concentration disturbances

FREQUENCY AND DISTRIBUTION OF HYPOMETABOLIC REGIONS IN SEVEN OUT OF TEN PATIENTS WITH POST-TRAUMATIC NEUROBEHAVIOURAL DYSFUNCTION

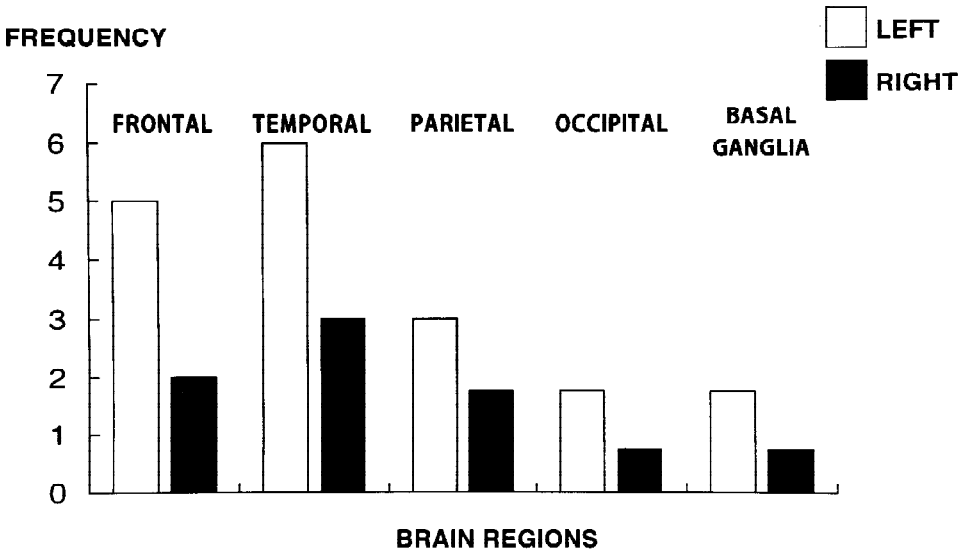

Fig 1 : Summary of the PET findings

to severe mental and neurological deficits. The PET examination was performed between 2 and 72 months after the head trauma. CT or MRI findings of the brain were considered normal in 6 and revealed structural changes in 4 patients at that time (table 1).

Six patients underwent a PET examination with 2-fluoro [^{18}F]-deoxy-D-glucose (^{18}FDG) for determination of the regional metabolic rate of glucose and 4 with oxygen-15 according to the steady state inhalation technique for determination of regional cerebral blood flow ($C^{15}O_2$) and regional metabolic rate for oxygen ($^{15}O_2$) (16). Ellipsoid regions of interest (ROI's) with axial axes of 30 mm and lateral axes of 15 mm were drown over the entire cortical mantle and circular ROI's, according to their sizes, were used for the basal ganglia and the cerebellar hemispheres.

In the semiquantitative analysis the ^{18}FDG, the $C^{15}O_2$ and the $^{15}O_2$ uptake in the frontal, temporal, parietal and occipital cortex, basal ganglia of both cerebral hemispheres were compared using the cerebellum as reference region. In normal volunteers the uptake of radioactivity is approximately equal in cerebral cortex, basal ganglia and cerebellum (17,18). In our patients a decrease of more than 30% in the different cerebral cortical ROI's and basal ganglia was considered an indicator of hypometabolism.

Results

In 3 patients with mild to moderate head injury and minor remaining complaints (cases 1, 2, 3) neuroimaging and PET findings were normal. In 3 other patients with a severe head trauma, but without structural changes on CT or MRI of the brain, areas of hypometabolism were observed (cases 4, 8, 9). Patients with clear contusional lesions all had hypometabolic zones with predominance in the left cerebral hemisphere (cases

TABLE 1: STUDY POPULATION POST-TRAUMATIC NEUROBEHAVIOURAL DYSFUNCTION

CASE No	GENDER	AGE (YEARS)	INITIAL DEGREE HEAD INJURY	REMAINING SYMPTOMS	CT/MRI FINDINGS
1	F	56	Mild	Functional complaints	Normal
2	M	34	Moderate	Headache	Normal
3	M	63	Moderate	Headache Memory disturbances	Normal
4	F	21	Severe	Memory disturbances	Normal
5	F	36	Severe	Paraplegia Memory disturbances	Contusions B - F - T
6	M	67	Moderate	Frontal syndrome	Contusions B -F -T
7	M	63	Moderate	Aphasia	Contusions L -F - T
8	M	33	Severe	Frontal syndrome Memory disturbances	Normal
9	F	68	Severe	Dementia	Normal
10	M	76	Severe	Dementia Parkinsonism	Global atrophy

B : bilateral, L : left, F : frontal, T : temporal

5, 6, 7), although in some of them MRI showed bilateral lesions (cases 5, 6). One patient with severe posttraumatic parkinsonism-dementia syndrome and global atrophy on CT (case 10) showed diffusely decreased ^{18}FDG uptake in both cerebral hemispheres on PET (table 2).

As a whole, patients with post-traumatic neurobehavioral dysfunction displayed predominant hypometabolic changes in the left fronto-temporal regions (Fig 1).

None of the patients had significant differences in flow and metabolism between the right and the left cerebellar hemisphere, compatible with crossed cerebellar diaschisis.

TABLE 2 : PET FINDINGS IN POST-TRAUMATIC NEUROBEHAVIOURAL DYSFUNCTION

CASE No	PET EXAMINATION		HYPOMETABOLIC ZONES									
	TIME (1)	TRACER	L-F	L-T	L-P	L-O	L-BG	R-F	R-T	R-P	R-O	R-GB
1	16	^{18}FDG	-	-	-	-	-	-	-	-	-	-
2	36	$^{15}O_2$, $C^{15}O_2$	-	-	-	-	-	-	-	-	-	-
3	24	$^{15}O_2$, $C^{15}O_2$	-	-	-	-	-	-	-	-	-	-
4	72	^{18}FDG	+	+	-	-	-	-	-	-	-	-
5	24	^{18}FDG	+	-	-	-	-	-	-	-	-	-
6	3	^{18}FDG	-	+	-	-	-	-	-	-	-	-
7	24	^{18}FDG	+	+	+	-	-	-	-	-	-	-
8	36	$^{15}O_2$, $C^{15}O_2$	+	+	-	-	-	+	+	-	-	-
9	2	$^{15}O_2$, $C^{15}O_2$	-	+	+	+	+	-	+	+	+	+
10	62	^{18}FDG	+	+	+	+	+	+	+	+	-	-

L = left; R = right; F = frontal; T = temporal; P = parietal; O = occipital; BG = basal ganglia

Discussion

Focal PET changes were observed in our series, correlating to the severity of the head injury and of the post-traumatic neurobehavioral dysfunction. Neuropsychological findings are known to correlate poorly with functional imaging in head trauma patients (19). In our patients hypometabolic areas could be observed in the absence of structural changes on MRI or CT scan of the brain. On the other hand these imaging techniques could also demonstrate more extensive contusions, that PET examination was not able to demonstrate. However, persistent neurobehavioral changes following traumatic brain injury seem to be correlated to hypometabolism of the left frontal and temporal lobes. In patients with severe cognitive decline the PET changes involved both cerebral hemispheres.

Most previous studies with SPECT (20-22) and PET (23) are in agreement with our findings of predominant hypometabolism and hypoperfusion in the left frontal and temporal regions in persistent post-traumatic neurobehavioral syndrome. Only Abdel-Dayem et al (24) found basal ganglia hypoperfusion on SPECT more common than frontal and temporal lobe abnormalities.

Most of our patients were injured in a car or motorcycle accident, not allowing determination of the precise direction or mechanism of the causative traumatic force. In cases with reliable information concerning the mechanisms of the trauma, the regions of hypoperfusion did not often correlate with the site of impact or the contralateral side (20). Consequently, no clear explanation can be given for the predominant left-sided fronto-temporal hypometabolism in our head trauma patients.

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