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Short communications

Cerebral blood flow SPECT imaging in right hemisphere-damaged patients with hemispatial neglect. A pilot study

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Abstract

BACKGROUND: Hemispatial neglect is characterised as a failure by a brain-damaged patient to attend to contralesional space. It is hypothesised to be a result of damage to a network involving the frontal, parietal and cingulated cortices, basal ganglia and thalamus.

MATERIAL AND METHODS: The aim of this preliminary study was to verify this model of neglect in 22 right hemisphere-damaged acute stroke patients, using single photon emission-computed tomography (SPECT). The presence of a single right-sided vascular brain lesion was confirmed on CT and/or MRI. Hemispatial neglect, assessed with a battery of drawings, line bisection and line and shape cancellation tests, was observed in 12 cases.

RESULTS: Patients with neglect (compared with those without neglect) had more extensive hypoperfusion in the frontal and parietal cortex, as well as striatum and thalamus. Left-sided hypoperfusion in the parietal cortex and the thalamus was also significantly associated with neglect on SPECT imaging. Performance in three out of five psychological tasks commonly used to detect the presence of hemispatial neglect, such as drawing tests and line bisection test, was exclusively linked with damage to the parietal cortex of the right hemisphere, while the line cancellation test might be attributable to the lesion of the right striatum.

CONCLUSIONS: These findings support the model attributing hemispatial neglect to a unilateral defect in a cortico-striato-thalamo-cortical loop. CBF SPECT imaging may provide a reliable description of the brain pathology associated with hemispatial neglect.

Key words: hemispatial neglect, cerebral blood flow, single photon emission computed tomography, stroke

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Introduction

The introduction of single-photon emission computed tomography (SPECT) in the 1980s had a dramatic impact on behavioural neurology. Given the fact that SPECT allows a successful demonstration of regionally decreased cerebral blood flow (rCBF), functionally relevant to neuropsychological syndromes and not detected by computed tomography (CT) scanning and magnetic resonance (MRI), the method is increasingly used with the aim of improving diagnosis, selecting treatment or evaluating prognosis [1]. Among a wide range of neurological disorders, for instance, SPECT is a reliable and useful tool for the study of neuroanatomical correlates of language and speech disturbances (predominantly following left hemisphere damage), as well as their mechanisms of clinical recovery [2].

Some focal lesions in the right hemisphere (RH) may result in hemispatial neglect (HN), known also as unilateral neglect syndrome or hemi-inattention. The most severe forms of HN are usually seen in the acute stages of the evolution of extensive vascular disorders in the territory of the middle cerebral artery. The patient lies in bed with eyes and head rotated toward the half space ipsilateral to the damaged hemisphere and may fail to look to the contralateral half space if he is addressed from that side. Later, during the neuropsychological examination, he may attend only to stimuli from the half space ipsilateral to the lesion and typically omits in drawing tasks one half of the models having a symmetrical configuration, such as a human face or a house. Hemianopia is present sometimes, although not necessarily [3, 4].

Although the relationship between HN and lateralisation of damage to the RH is commonly accepted, data discussing neurological basis for particular variants of HN are scarce and/or inconsistent. According to recent SPECT studies, HN seems to be a result of damage to a network involving the frontal, parietal and cingulated cortices, basal ganglia and thalamus [5–7].

We undertook this SPECT study to determine the neuroanatomical correlates of visual HN in stroke patients with a focal right-hemisphere-damaged lesion on CT and/or MRI. In this study, lesion location and severity on SPECT were correlated with neurobehavioural tests of HN in visual domain. Damage in the right-parietal and thalamus was hypothesised to be a predictor of left-hemispatial neglect.

Material and methods

Patients

Twenty-two stroke patients (18 males and 4 females) admitted to the Department of Neurology of the Medical University of Gdańsk were selected according to the following criteria: right-handedness, no history of any previous neurological event, absence of generalised mental deterioration (progressive dementia), presence (on CT and/or MRI) of a single right-sided vascular brain lesion.

The mean age of the patients was 55 years (range 45–68 years) and they had a mean of 11 years of education (range 7–17 years).

The psychological assessment of hemispatial neglect was performed at mean 16 days (5–46 days) after cerebrovascular accident (CVA) and SPECT about a week later. The patients underwent CT scanning, approximately 72 hours after stroke. A repeated CT and/or MRI scan was performed within 2 weeks for clinical purposes to document the extent of the lesion, if no appropriate lesion was seen on the baseline scan.

CBF SPECT imaging

CBF SPECT scanning was performed 1 h following the intravenous injection of 740 MBq (20 mCi) of 99mTc-ECD (FAM, Łódź, Poland). Scanning was performed on a triple-head gammacamera Multispect-3 (Siemens, Erlangen, Germany) using a low-energy, high-resolution collimator. Regional CBF abnormalities were assessed semi-quantitatively by calculating the cerebellar index.

The CBF SPECT control group were 30 healthy volunteers.

Psychological assessment of hemispatial neglect

Considering the fact that even in only one modality HN can take on a number of different forms which can occur in relative isolation from one another [3, 8], we applied a comprehensive battery of neuropsychological tasks commonly used to detect the presence of this disorder [5, 9]. The battery involved five tasks presented to the patients in the same order: Test of Visual Neglect [10], Mesulam's Nonverbal Cancellation Task [9], Line Bisection Test [11], Copied Drawing Task [3], Spontaneous Drawing Test (Clock drawing) [12].

For a detailed description and correct administration procedures of first three tests we refer to the work of Lezak [9]. However, the average reader, the nuclear medicine specialist, may not be familiar with those psychological methods, therefore we would like to give a short description of some of them — drawing tests — because of their non-standardised character.

The scoring system for all techniques in the battery was identical. The severity of the disorder was calculated separately in each task on the basis of the difference between numbers of left and right omissions or errors. A Percent Deviation score (PD Index) was derived by means of the formula: $[(L - P)/(L + P)] \times 100\%$.

The letter 'L' reflects a number of omissions or errors on the left side of the sheet or the stimulus, while the letter 'P' means a number of right-sided omissions or errors.

Statistical analysis

Values are expressed as mean ± standard deviation. ANOVA test was used to examine inter-individual differences in rCBF, using the SPSS software package (Version 9.0 for Windows). In order to identify correlation between SPECT and psychological data, linear regression analysis (stepwise model) was conducted. P values < 0.05 were considered statistically significant.

Results

The presence of HN in each patient was assessed according to the mean value of the PD Index (of five indexes/5). This global measurement was used in the analysis only to classify the patients behaviourally as either "normal" (without HN) or "impaired" (with HN). Neglect was observed in 12 cases (Global PD Index > 0) out of 22. There were no statistically significant between-group differences for sex and education, but age and time after onset differed significantly; patients with HN were older (respectively 58 ± ± 6 years for neglect patients, and 52 ± 7 years for no neglect patients) and experienced cerebrovascular accident earlier than no neglect patients (respectively 20 ± ± 11 days post-onset for neglect patients, and 10 ± 6 days for no neglect patients).

Table 1 gives the mean values and standard deviations of hemispheric perfusion and regional CBF in six regions of interest (ROIs). Four regions in the right hemisphere: the frontal cortex, the parietal cortex, striatum and thalamus, were significantly more hypoperfused in the neglect group. Overall, patients with neglect had lower mean CBF in the right hemisphere of the brain, but not in the left. However, neglect patients, surprisingly, had a greater reduction also in parietal and thalamic CBF on the left.

Linear regression analysis in which behavioural (neglect tests) measurements were taken separately as a dependent variable and the SPECT data as independent variables (all six key regions: frontal, temporal, parietal, occipital, striatum and thalamus) was used in order to assess the relationships between HN, evaluated by particular psychological tests, and a reduction in regional CBF. These correlations are shown in Table 2.

The right-parietal cortex damage emerged in the regression analysis as significantly related to performance in three out of five tests: Line Bisection Test, Copied Drawing Task and Spontaneous Drawing Test. In comparison, the frontal lobe and thalamic hypoperfusion, as being involved in HN as well (Table 1), did not emerge from this analysis.

Table 1. CBF in the two patient subgroups as a function of hemispatial neglect (rCBF given as a percentage of cerebellar uptake)

		Patients		
		Neglect (n = 12) Mean (SD)	No neglect (n = 10) Mean (SD)	Fisher--Snedecor's Test (*F* value)
			Hemispheric	
R-mCBF		0.77 (0.14) **	0.90 (0.08)	6.78
L-mCBF		0.87 (0.11)	0.93 (0.08)	1.96
			ROI CBF	
Frontal	R	0.65 (0.21) *	0.82 (0.08)	5.28
	L	0.86 (0.13)	0.93 (0.10)	1.59
Temporal	R	0.88 (0.21)	0.98 (0.16)	1.39
	L	0.91 (0.16)	0.97 (0.12)	0.80
Parietal	R	0.74 (0.21)***	1.00 (0.05)	13.50
	L	0.87 (0.13)**	1.00 (0.06)	7.77
Occipital	R	1.1 (0.17)	1.03 (0.18)	0.12
	L	1.1 (0.13)	1.02 (0.19)	0.01
Striatum	R	0.64 (0.14)**	0.78 (0.07)	7.37
	L	0.80 (0.08)	0.83 (0.09)	0.42
Thalami	R	0.68 (0.09)**	0.80 (0.08)	10.61
	L	0.75 (0.13)§	0.83 (0.07)	3.12

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$, §trend close to statistical significance ($p = 0.09$)

Table 2. Linear regression analysis for neglect psychological assessment and SPECT data

Test	ROI	Statistics		
		Beta	T	*p*
Test of Visual Neglect	Striatum R	–0.482	–2.461	0.05
Nonverbal Cancellation Task	None in the equation	–	–	–
Line Bisection Test	Parietal R	–0.579	–3.176	0.01
Copied Drawing Task	Parietal R	–0.604	–3.390	0.01
Spontaneous Drawing Test	Parietal R	–0.459	–2.316	0.05

Discussion

Although the parietal lobe has been recognised as an important neural component associated with neglect for over half a century, the results of more recent reports suggest that neglect occurs with damage to the other cerebral areas [5–7]. The current study provides evidence that a larger volume of damage to the right cortical-subcortical loop, specifically involving the frontal cortex, the parietal cortex, striatum and thalamus can cause neglect. These regions were hypoperfused more frequently in neglect patients as compared to RH patients without neglect. Also, an important finding was that the contralateral (left) hypoperfusion was related to neglect as well. The other regions involved were the left parietal cortex and the left thalamus. Patients with neglect therefore presented a more generalised bilateral hypoperfusion when compared with patients without neglect. According to some authors [5, 6], neglect is not related to the subcortical lesion *per se*, but is also due to cortical hypometabolism, or to a disconnection within a neural network leading to a deprivation from afferent input to the cortex akin to diaschisis. It is our impression that the above interpretation, at least in part, might also be helpful in explaining the decrease in the left parietal and thalamic CBF. Nevertheless, it should be noted that the assumption about left-sided diaschisis seems controversial since neglect patients and no neglect patients did not differ with regard to mean hemispheric CBF. Thus, whether neglect occurs due to a larger volume of brain dysfunction or as a result of diaschisis in an underlying network subserving attention cannot be inferred clearly from our results.

With regard to the relationship between performance in particular neglect tests and rCBF, dysfunction to the parietal cortex appeared to be the most predictable region associated with neglect. Specifically, performance in three out of five tests correlated with this localisation of brain dysfunction seen on SPECT findings: both Drawing Tests and Bisection Test. However, it could be argued that the subtests from the battery used in this study preferentially tested extrapersonal visuospatial neglect, and thus would be more sensitive to damage in the parietal lobe. By assigning a crucial role in spatial cognition to parietal regions, our results suggest that parietal cortical involvement is necessary for the occurrence of hemispatial neglect.

In summary, hemispatial neglect is clearly a complex and multifaceted phenomenon. Also, we would like to underscore the need for caution in generalising from our study since it represents a relatively small sample of patients. Brain SPECT imaging can be considered very useful in gaining a full understanding of the neuroanatomical underpinnings of this disorder.

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