Wisconsin Card Sorting Test Performance After Putaminal Hemorrhagic Stroke

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The purpose of this study was to compare the performance differences in the Wisconsin Card Sorting Test (WCST) between 55 patients with putaminal hemorrhage (PH) 3 months after stroke and 69 age-matched normal controls. Impairment on WCST was defined as performance greater than 1.64 standard deviation below the control mean. A multivariate analysis of covariance (MANCOVA) controlling for education yielded a significant main effect for group but not for education and interaction of group × education. Univariate analyses revealed significant between-group differences in five WCST measures, including perseverative errors (PE), perseverative responses (PR), conceptual-level responses (CLR), number of categories completed (NCC), and trials to complete the first category (TCC). For patients with PH, z-scores for two WCST indices were within the impaired range: TCC and PR. A high percentage of patients (40–47%) scored in the designated impaired range on NCC, PR, PE, and TCC. The WCST variables discriminated patients from controls with an overall accurate classification rate of 91.9%. Of these, the variables that contributed most to the differentiation between patients and normal controls were PE, CLR, and total number correct (TNC) (a standardized canonical discriminant function coefficient > 0.40). Finally, no significant hemispheric laterality effects emerged on any of the WCST variables. The results of this study provide further evidence of impaired mental set shifting in stroke patients with PH. The implications for rehabilitation professionals are discussed, and recommendations for further research are made.

Key Words: Wisconsin Card Sorting Test, putamen, hemorrhagic stroke
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The putamen is one of the major nuclei of the basal ganglia, forming the striatum together with the caudate nucleus. Anatomic studies have proposed the involvement of the basal ganglia in five parallel loops with the different regions of cerebral cortex: skeletomotor, oculomotor, dorsolateral prefrontal, lateral orbitofrontal, and anterior cingulate [1,2]. The putamen is part of the frontostriatal circuit, which receives input from the dorsolateral prefrontal cortex (PFC) [2]. Because the PFC has been implicated in a wide spectrum of higher executive functions (i.e. impairments in selective attention, working memory, verbal fluency, and executive abilities such as cognitive flexibility, inhibition of responses, resistance to distraction, and self-regulation of emotion and motivation), one would expect a striatal lesion to be associated with cognitive deficits comparable to those found with focal frontal damage [3–6].

Indeed, the most prominent cognitive impairments observed in patients with disruption of the frontostriatal circuit, such as schizophrenia, Parkinson's disease, and Huntington's disease, tend to be related to deficient performance on the tests for frontal lobe function [7–9]. However, unlike the caudate nucleus, which has been consistently shown to be linked to executive functioning

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[10–12], the contribution of the putamen to these functions has remained unresolved. For example, some neuroimaging and case studies [7,13–19] ascertained the role of the putamen in cognitive set-shifting in the Wisconsin Card Sorting Test (WCST) [20], whereas others failed to detect a positive relationship between the putamen and impaired performance on the WCST [21,22]. Furthermore, earlier research has often focused on patients with degenerative disorders of the basal ganglia, such as Parkinson's disease or Huntington's disease; vascular lesions restricted to the putamen have been typically reported only on individual patients or small case series. In light of the considerable impact of executive dysfunction on functional outcomes in stroke survivors [23,24], neuropsychologic studies of a larger group of patients with selective lesions of the putamen are warranted to confirm the presence of deficits in this population. Appropriate rehabilitation programs may then be implemented to address the problem.

The goal of the present study was to contribute to an evaluation of the executive-deficit hypothesis of stroke patients with localized lesions in the putamen, relative to a carefully chosen normal group. The WCST was chosen because it is widely accepted as a good measure of executive function in the clinical and research realms [25].

Patients and Methods

Participants

Our sample consisted of 55 stroke patients with putaminal hemorrhage (PH) and 69 healthy controls. Enrolled patients were selected from hemorrhagic stroke subjects consecutively admitted to the neurosurgery department of a large academic medical center in southern Taiwan from 1 August 1998 to 31 December 2001. Patients were eligible for the study if they were 18 years of age or older, had a first-ever unilateral intracerebral hemorrhage at least 3 months earlier, and had a hematoma predominantly confined to the putamen. Exclusion criteria consisted of (1) hematoma secondary to head injury, congenital or acquired coagulation abnormalities, or any secondary cause of hemorrhage requiring surgical treatment such as cerebral aneurysm, arteriovenous malformation, or tumor; (2) history of Parkinson's disease, alcohol abuse, mental retardation, dementia, or psychiatric disturbances that might compromise cognitive functioning, as identified through chart review; (3) comprehension difficulties resulting from Wernicke's or global aphasia; and (4) presence of severe unilateral neglect as measured by the Schenkenberg Line Bisection Test [26]. Diagnosis was made by attending neurosurgeons and confirmed by the findings of neuroimaging studies. Stroke was defined as a rapidly developing clinical manifestation of a focal loss of cerebral function lasting longer than 24 hours, and intracerebral hemorrhage was defined as nontraumatic abrupt onset of severe headache, altered level of consciousness, or focal neurologic deficit that is associated with a focal collection of blood within the brain parenchyma, as observed on computerized tomography (CT) or during autopsy, and is not caused by hemorrhagic conversion of a cerebral infarction [27].

A healthy control sample, screened by a detailed interview for the absence of neurologic and psychiatric disorders, was recruited from the community via advertisements. The patient and control groups were comparable in age ($t = 0.07$, $p = 0.95$) but not educational level (i.e. none, elementary school, middle school, high school, and college) ($\chi^2 = 12.67$, $p < 0.05$) and gender ($\chi^2 = 26.3$, $p < 0.001$). With respect to educational background, a higher percentage of patients had only an elementary school education, whereas a higher proportion of normal controls were found in the high school category. In terms of gender, the normal group comprised a larger number of females. Characteristics of study participants are detailed in Table 1.

Wisconsin Card Sorting Test

The WCST [20] was designed to assess abstract reasoning ability and the ability to shift cognitive strategies in response to changing environmental contingencies. The short form of the WCST (WCST-64) [28–30] was used in the present study to shorten the administration time for most individuals, while retaining the task requirements of the standard version. Convincing evidence supported the comparability of the standard WCST and WCST-64 in neurologic and psychiatric samples [31,32]. Furthermore, findings confirmed the WCST-64 as a valid measure for differentiating subjects with frontal lobe involvement from those whose lesions did not involve the frontal lobes [28].

During the administration of the WCST-64, the subject was given one pack containing 64 response cards, which have designs similar to those on the four stimulus cards, varying in color, geometric form, and number. The subject was then asked to match the 64 response cards with the stimulus cards and told only whether or not the match was correct. Subjects were not informed of the correct sorting principle, nor were they told when the category would shift during the test. When the subject maintained a correct progression through 10 trials, the rule was changed and the

Table 1. Demographic and clinical characteristics of study participants

	PH patients (n = 55)			Normal controls (n = 69)		
	Mean	SD	Range	Mean	SD	Range
Age (yrs)	55.76	9.47	42–77	55.65	8.64	40–70
Initial GCS score	12.47	3.01	3–15			
Onset-testing interval (*days*)	136.05	26.52	91–195			
		n (%)			*n* (%)	
Male		43 (78.2)			22 (31.9)	
Educational level	*n*		%	*n*		%
None	6		10.9	5		7.2
Elementary school	22		40.0	15		21.7
Middle school	10		18.2	17		24.6
High school	10		18.2	29		42.0
College	7		12.7	3		4.3
Craniotomy	26		47.3			
Right hemisphere damage	39		70.9			
IVH	14		25.5			

GCS = Glasgow Coma Scale; IVH = intraventricular hemorrhage; PH = putaminal hemorrhage.

subject had to shift the sorting rule from the previously relevant category to the other rule to yield correct answers. The test continued until the subject had successfully completed three categories (color, form, and number) or until the deck of 64 response cards had been used, whichever one occurred first. There was no time limit to this test. The indices included in the analysis were: total number correct (TNC), perseverative responses (PR), perseverative errors (PE), nonperseverative errors (NPE), conceptual-level responses (CLR), number of categories completed (NCC), trials to complete the first category (TCC), and failure to maintain set (FMS). Several scores were excluded. Total errors were not included because it is a linear combination of PE and NPE. The learning-to-learn index was not used because of missing values for many patients and normal elderly who achieved fewer than three categories. The percentage scores (eg, percent PR and percent PE) were not used in the analyses, partly because the reliabilities of these percent scores are lower than those of their respective basic scores [20].

Procedure

Information on CT or magnetic resonance imaging (MRI) result, diagnosis, stroke lateralization, date of stroke onset, hemorrhages with rupture into the ventricular system, admission Glasgow Coma Scale (GCS) score, medical and psychologic conditions, age, and highest level of educational achievement were abstracted from patients' medical records. In all patients, CT or MRI scans were done within 48 hours after the onset of stroke. CT and MRI scans were read independently and blindly by hospital neuroradiologists, whether or not the patient was included in the present sample. The patient's attending neurosurgeon confirmed the diagnosis of putaminal hemorrhage in the present study. Interdiagnostician agreement was high, with a kappa value of 0.92.

Examiners administered and scored the test in accordance with the standardized procedures as outlined in the test manual, except for the scoring of PR, PE, NPE, TCC, and FMS on the WCST. In the standard scoring scheme for these measures, high scores indicate poor performance. However, in the interests of consistency and ease of interpretation, the scoring of these measures was modified by adding a minus sign to the scores. As such, higher scores represent better performance in these measures. Each subject was typically evaluated in a single session, which lasted approximately 30–45 minutes. The study was approved by the hospital's Institutional Review Board, and written informed consent was obtained from all participants.

Results

Patient characteristics

The mean age of the PH sample was 55.76 years and the average education 8.25 years. There were 43 men and 12 women in the putaminal group, and 70.9% of these had cerebral lesions in the right hemisphere. The mean time between stroke onset and cognitive testing was 136.05 days. Rupture of the hematoma into the ventricular system was found in 25.5% of the patients, and the average admission GCS score was 12.47. Of the PH patients, 47.3% underwent craniotomy.

WCST performances in PH group

Exploratory data analysis was first carried out to determine the score distribution of WCST in the entire sample (n = 124). The average skewness was 0.13, indicating that our data set approximated normal distribution. To analyze and interpret the WCST data between two groups, a one-way MANCOVA was used, with one group (PH patients vs normal controls) as an independent factor. Multiple dependent variables included eight WCST measures. Educational level was entered as covariate in the MANCOVA to account for any possible effect of this variable on group differences in WCST performance. Gender was not included as a covariate because there were no significant gender differences in WCST performance [20].

Before conducting the MANCOVA, the interaction between the covariate and grouping variable was examined to test for homogeneity or equality of slopes. The result revealed no significant education × group interaction (Wilks' lambda = 0.90, $F_{8,113}$ = 1.60, p = 0.13), indicating that homogeneity of regression coefficients has not been violated. There were significant differences between groups on WCST performance (Wilks' lambda = 0.32, $F_{8,114}$ = 30.27, $p < 0.001$), after controlling for education. The overall effect of education did not reach statistical significance (Wilks' lambda = 0.88, $F_{8,114}$ = 1.87, p = 0.72). Subsequently, the MANCOVA was followed by eight univariate analyses of covariance (ANCOVAs). In light of the number of univariate analyses conducted, the Bonferroni α level was set at 0.006(0.05/8) for all follow-up analyses to maintain a family-wise error rate of 0.05. As shown in Table 2, significant differences across the two groups were found on PR, PE, CLR, NCC, and TCC.

To further compare between-group differences in WCST variables, the z value for each WCST score in the control group (SD =1, z = 0) was used as a baseline against which to compare distributions of WCST variables in the patient group. Differences between z values were then calculated for PH patients [ie, (raw score – control mean)/control SD], and a mean z value was found for each WCST measure. By placing all test scores on a common metric, the relative standings of test scores from distributions with different means and/or different standard deviations can be directly compared. The criterion used to determine impairment was a z-score of 1.64 SDs (95% confidence interval, one-sided test) or more below the control mean for all eight WCST measures. This score corresponds to approximately the fifth percentile. One-tailed test of significance was adopted because we hypothesized that normal controls would score higher than PH patients on the WCST. In addition,

Table 2. Univariate group comparisons on WCST scores controlling for education

WCST	Mean (SE) score: PH group (n = 55)	Mean (SE) score: Control group (n = 69)	F	p
TNC	30.46 (1.02)	34.24 (0.91)	7.6	0.007
PR	23.0 (1.77)	9.26 (1.58)	33.27	0.000
PE	–18.98 (1.39)	8.14 (1.24)	208.84	0.000
NPE	9.2 (0.95)	8.19 (0.85)	0.62	0.433
CLR	21.98 (1.35)	29.86 (1.2)	18.8	0.000
NCC	1.51 (0.13)	2.42 (0.12)	25.32	0.000
TCC	32.73 (2.33)	16.21 (2.08)	27.68	0.000
FMS	0.43 (0.11)	0.4 (0.1)	0.05	0.007

CLR = conceptual-level responses; FMS = failure to maintain set; NCC = number of categories completed; NPE = nonperseverative errors; PE = perseverative errors; PH = putaminal hemorrhage; PR = perseverative responses; SE = standard error; TCC = trials to complete the first category; TNC = total number correct; WCST = Wisconsin Card Sorting Test;.

a one-tailed test is more powerful than a two-tailed test (a one-tailed test with α set at 0.05 has approximately the same power as a two-tailed test with α set at 0.10). Table 3 presents mean z-scores for the eight WCST measures for PH patients. As can be seen, mean z-scores fell below the cutoff criterion (a z-score of 1.64 SDs below the control mean) for impairment on the TCC and PR. In these instances, PH patients committed significantly more PRs and required more trials to complete the first category than the normal controls. The PH group performed within an average range (± 1 SD) on the TNC, NPE, CLR, as well as FMS, whereas performance on the PE and NCC was in the –1 SD to –1.64 SD range. The distribution of z values is shown in the Figure.

When the test variables were reviewed in the PH group, the rates of impairment, which were determined by the proportion of patients falling in the designated impaired range, were ranked from high to low in the following order: NCC, PR, TCC, PE, CLR, TNC, FMS, and NPE (Table 2). Of these, the rates of impairment in the first four variables ranged from 40% to 47%. To identify the WCST variables that differentiated the groups, eight WCST scores were entered into a discriminant function analysis. Only one canonical discriminant function was produced (Wilks' lambda = 0.318; $\chi^2 = 135.17$; df = 8; $p < 0.001$) and explained 100% of the variance. The variables that contributed most to the classification of an individual as having PH, with a discriminant value > 0.4, were PE (1.20), CLR (0.45), and TNC (–0.41). The results showed that 91.9% of the original group cases were correctly classified. Group membership was correctly predicted for 81.8% of the PH patients and 100% of the controls. Although group separation was significant, 10 of the 55 (18.2%) PH patients had been incorrectly classified as belonging to the normal control group. In these cases, the average age was 54.9 years (SD = 10.55) (range = 43–77) and the average education was 9.3 years (SD = 5.5) (range = 0–16). The mean GCS score at the time of admission for these 10 patients was 13.8 (SD = 3.46) (range = 4–15).

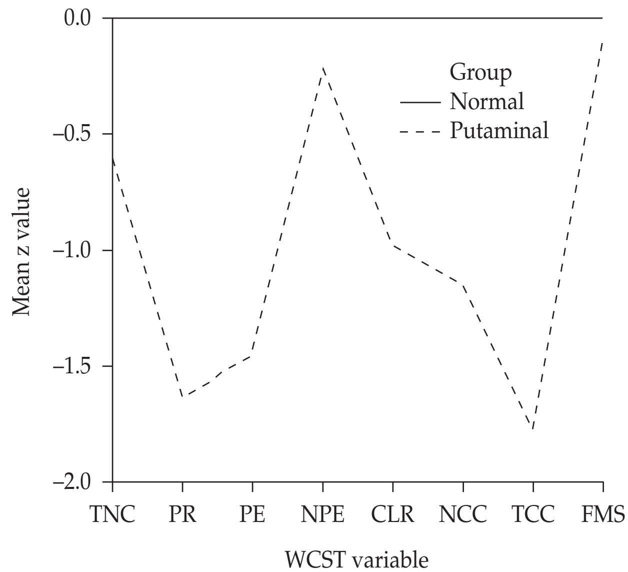

Figure. *Distribution of comparative z-scores for putaminal hemorrhage group. CLR = conceptual level responses; FMS = failure to maintain set; NCC = number of categories completed; NPE = nonperseverative errors; PE = perseverative errors; PR = perseverative responses; TCC = trials to complete the first category; TNC = total number correct; WCST = Wisconsin Card Sorting Test.*

Table 3. Mean z-scores and the ratio of PH patients performing in the impaired range

	PH group (*n* = 55)		
WCST	Mean (SD)	Range	Ratio (%)
TNC	–0.60 (1.39)	–3.37 to 1.86	29.1 (16/55)
PR	–1.64 (1.96)	–5.92 to 1.03	43.6 (24/55)
PE	–1.45 (1.74)	–4.96 to 1.08	40.0 (22/55)
NPE	–0.22 (1.24)	–4.19 to 1.09	9.1 (5/55)
CLR	–0.98 (1.42)	–3.63 to 1.34	34.5 (19/55)
NCC	–1.15 (1.39)	–2.88 to 0.65	47.3 (26/55)
TCC	–1.78 (2.44)	–4.98 to 0.61	41.8 (23/55)
FMS	–0.09 (0.94)	0.45 to –3.12	14.5 (8/55)

CLR = conceptual-level responses; FMS = failure to maintain set; NCC = number of categories completed; NPE = nonperseverative errors; PE = perseverative errors; PH = putaminal hemorrhage; PR = perseverative responses; SD = standard deviation; TCC = trials to complete the first category; TNC = total number correct; WCST = Wisconsin Card Sorting Test.

Effects of hemispheric laterality

To investigate effects of hemispheric laterality on the WCST performance in the patient group, one-way multivariate analysis of variance (MANOVA) was conducted, with side of brain lesion as an independent factor. MANOVA of eight WCST measures revealed no significant effect of group (Wilks' lambda = 0.78, $F_{8,46} = 1.6$, $p = 0.15$). In addition the results for the univariate analyses of variance (ANOVAs) disclosed no statistically significant differences between groups on each of the WCST variables (Table 4).

Discussion

Researchers have attempted to clarify the cognitive processes underlying performance on the WCST by means of factor analytic techniques. Solutions are composed of one to three factors [33,34]. Of these, the most salient factor (often labeled as concept formation/perseveration) across studies, samples, and analytic methods encompasses total errors, CLR, categories completed, PR, PE, and TNC, accounting for 48% to 71% of the variance. This factor was associated with the dorsolateral prefrontal dysfunction and reflected two aspects of executive dysfunction: disrupted concept formation or problem solving (the inability to comprehend the possible sorting rules) and perseveration (the inability to flexibly shift attention and response preparation from one set of rules to another)[5,35]. Because the WCST is regarded as a complex measure of executive functioning that links to the integration of multiple brain regions, of which the frontal lobes are important constituents [36], impaired performance on the WCST was also noted in patients with lesions in the subcortical areas that have robust connections to the frontal lobes, such as basal ganglia and thalamus [8,9,16–18,37]. Nonetheless, it remains unclear to what extent the deficits of individual structure within the basal ganglia–thalamocortical circuits are related to the disturbances in executive function. To our knowledge, this is the first study to characterize performance pattern on the WCST in stroke patients with PH.

With references to z-scores and rates of impairment, the PH group showed prominent deficits in conceptualization and perseveration, measured by TCC, NCC, PR, and PE, in comparison with normal controls. In other words, PH patients as a group in our study showed significant decreases in the achieved categories and significant increases in trials to complete the first category and PR/PE. It is worth noting that PH patients scored within the normal range on measures (ie, NPE and FMS) that did not appear to be related to frontal dysfunctions. These findings are coincident with several other studies [13–19]. For instance, one study found that patients with unilateral vascular lesions of the caudate nucleus, the putamen, and the anterior limb of the internal capsule demonstrated increased perseveration on the WCST similar to patients with PFC lesions [19]. Brain imaging studies [13,15] investigating specific location and pattern of activation in the PFC and basal ganglia while performing the WCST discovered that the activity in the caudate and putamen is analogous to that in the frontal cortex.

Table 4. Univariate ANOVAs on WCST scores between patients with right versus left putaminal hemorrhage

WCST	Mean (SE) score			
	RPH group ($n = 39$)	LPH group ($n = 16$)	F	p
TMC	30.46 (1.02)	34.25 (0.91)	7.65	0.007
PR	23.06 (1.77)	9.21 (1.58)	33.95	0.000
PE	–18.97 (1.39)	8.13 (1.24)	209.80	0.000
NPE	9.22 (0.95)	8.17 (0.85)	0.68	0.410
CLR	21.97 (1.35)	29.86 (1.20)	19.03	0.000
NCC	1.51 (0.13)	2.42 (0.12)	26.09	0.000
TCC	32.78 (2.33)	16.16 (2.08)	28.17	0.000
FMS	0.43 (0.11)	0.40 (0.10)	0.06	0.803

ANOVA = analysis of variance; CLR = conceptual-level responses; FMS = failure to maintain set; LPH = left putaminal hemorrhage; NCC = number of categories completed; NPE = nonperseverative errors; PE = perseverative errors; PH = putaminal hemorrhage; PR = perseverative responses; RPH = right putaminal hemorrhage; SE = standard error; TCC = trials to complete the first category; TNC = total number correct; WCST = Wisconsin Card Sorting Test.

Moreover, a differential activation of caudate and putamen was observed in different stages of set shifting on the WCST. Along this line, a cortical basal ganglia loop involving mid-ventrolateral PFC, caudate nucleus, and mediodorsal thalamus showed increased activity specifically during the reception of negative feedback, which signals the need to shift from the current set to a new response set, whereas the putamen was activated when executing the first match after the set shift, implying a greater involvement in performing an action according to a behavioral rule. Another study also found significant increases in cerebral blood flow in the putamen when using cues to voluntarily direct and shift visual attention [38]. When taken together, these functional imaging findings together with our clinical results lend support to the role of the putamen in mental set shifting when confronted with novel, competing cognitive demands.

There has been some debate over whether cognitive set shifting stimulates predominantly one hemisphere or both hemispheres equally. For instance, in a study with event-related potentials, a left-sided frontotemporal dominance was reported during set shifting in the WCST [39], but other reports described an asymmetry to the right [40] or also bilaterally [13]. Although no statistically significant difference was found in the hemispheric asymmetry of the WCST performance of our PH patients, further investigation with a larger sample of equal numbers having right- and left-hemisphere involvement was recommended to clarify the effect of hemispheric laterality on set shifting.

Another issue relates to the use of percent scores (calculated by dividing the respective raw score by the raw score for the number of trials administered, then multiplying the result by 100) versus raw scores in the interpretation of the WCST. According to the technical manual, percentage scores may be useful in research studies in which differences in the number of trials administered need to be controlled. Nonetheless, the authors stress that use of these percentage scores is not recommended, partly because they involve correcting scores by a measure of overall success on the test (i.e. the number of trials required to complete the WCST), and partly because the reliabilities of these percentage scores are lower than those of their respective elemental scores [20]. In fact, the results of MANCOVA using either percentage scores or raw scores were comparable in the present study (Wilks' lambda = 0.72, $p = 0.000$, in the case of percentage scores; Wilks' lambda = 0.32, $p = 0.000$, in the case of raw scores).

There are several limitations inherent in this investigation. First, our patient sample may not represent all stroke patients with a diagnosis of PH admitted to the study facility during the study period as a result of our stringent eligibility requirements. In this regard, more patients with right PH were recruited, partly because patients with comprehension difficulties resulting from left brain damage were excluded from the study. Second, the limited number of patients with PH in this study suggests that the findings should be interpreted with some degree of caution. Third, some severity-related clinical variables (e.g. hematoma size, hydrocephalus, and midline shift) that were not collected because of unexpected unavailability of CT scan films in approximately 4% of patients might have influenced the interpretation of the study findings. Fourth, it was not methodologically sound to collect information on history of alcohol abuse, mental retardation, dementia, or psychiatric disturbances via chart review. Instead, standardized interviews based on DSM-IV [41] conducted by board-certified psychiatrists should be used when screening patients for eligibility for inclusion into the study. Finally, the WCST represents only a small portion of the complete domain of executive function. Future research that incorporates several tests that broadly sampled a range of cognitive domains that are thought to comprise executive function is recommended. Despite these limitations, our study is valuable in that it provides convincing evidence for a pronounced impairment in conceptualization and perseveration, a subcomponent of executive function [5], in stroke patients with PH.

In conclusion, this study supports a growing body of literature that suggests a role of the putamen in executive control. The focal nature of the lesions and well-matched patient and normal control groups confer sufficient inferential power on the present data. The results of our study are relevant for clinical practice, because they can enhance rehabilitation professionals' awareness of the importance of a regular assessment of potential deficits in executive function following damage to the putamen, which is traditionally considered solely a motoric structure. Treatments aimed at minimizing the adverse effects of executive dysfunction on functional abilities of patients with PH can, thus, be implemented during the early stage of stroke to enhance their rehabilitation outcome.

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被殼出血的中風病人
在威斯康辛卡片分類測驗之表現

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本文的主要目的是要比較 55 位被殼出血的中風病人，在中風後三個月於威斯康辛卡片分類測驗之表現與 69 位年齡相若的正常人之差異。損傷的定義為病人組的標準分數 (z 分數) 低於正常控制組平均數以下 1.64 個標準差。研究結果發現在控制教育程度變項之後，整體而言組別之間有顯著差異，但教育程度與交互作用並無顯著差異。單項變數分析顯示 5 個威斯康辛卡片分類測驗的分數達到組別之間的顯著水準，包括堅持性反應數、堅持性錯誤數、概念程度反應數、所完成的卡片分類數和完成第一個分類所需的卡片數。被殼出血病人組在威斯康辛卡片分類測驗的兩個 z 分數 (亦即完成第一個卡片分類所需的次數和堅持性反應數) 落於損傷範圍，並且 40%-47% 的病人在所完成的卡片分類數、堅持性反應數、堅持性錯誤數以及完成第一個卡片分類所需的次數之得分皆低於損傷範圍。威斯康辛卡片分類測驗的分數在區辨病人與正常人之正確率為 91.9%。其中以堅持性錯誤數、概念程度反應數和總正確數這三個分數最具有區辨力。最後，左右腦側化效果並沒有顯著地顯現於病人的威斯康辛卡片分類測驗之分數。本文的發現提供進一步的證據支持被殼在認知模式轉換能力的角色，對於復健相關專業人員有重要的臨床意義。

關鍵詞：威斯康辛卡片分類測驗，被殼，出血型中風

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