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Chinese Writing Function in Patients With Left Versus Right Putaminal Hemorrhage*

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ABSTRACT

This study was designed to explore the Chinese writing function of patients with subcortical stroke. Two cohorts of patient subjects with either the left or the right subcortical strokes, mainly putaminal hemorrhagic strokes, and one group of normal controls participated in the study. All participants received a writing test battery including the three aspects of writing function, that is, Spontaneous Writing, Writing to Dictation, and Writing from Copy, as well as a battery of non-writing linguistic tests. Comparing with normal controls revealed that writing function change occurred in both patient groups. The deficits in the patients with the left subcortical stroke essentially included Spontaneous Writing, and Writing to Dictation. These impairments were most likely secondary to aphasic disorders. The writing problem, mainly Writing from Copy, was noted in the patients with the right subcortical stroke. This deficit, however, was independent of the core linguistic impairment.

On the basis of the results, we suggest that the lesion involving white matter in the left hemisphere probably interrupts left perisylvian cortical language organization in a manner that produces problems with spontaneous writing and writing to dictation, which are language-related, associated with lesion in the dominant hemisphere. This further suggests that left or right subcortical lesions in the putamen and surrounding white matter are associated with differential effects (language vs. non-language based effects) which are similar to such differences observed with left vs. right cortical lesions.

Keyword: Writing function, putaminal stroke, functional asymmetry

The role of subcortical structures in language function is not yet completely understood, although new imaging techniques, autopsy correlations and stereotaxic surgery provide evidence that these structures do participate in the neuropsychological function of language processing (Crosson, 1992; Kertesz, 1992). The language disorders resulting from the lesions of subcortical areas range from dysarthria to aphasia (Naeser et al., 1982). The type of aphasia is variable. Some of the clinical features are similar to those of the cortical aphasia types, such as global, transcortical motor or transcortical sensory, Broca's, Wernicke's, or anomic aphasia; while others are atypical aphasias (Damasio, Damasio, Rizzo, Varney, and Gersh, 1982) in comparison to the cortical aphasias.

Agraphia with or without aphasia in the patients with lesions in cortical areas has been well discussed. Writing disorder evident in the patients with subcortical lesions was also observed (Cappa & Vignolo, 1979; Naeser et al., 1982; Metter et al., 1983; Tanridag & Kirshner, 1985; Kertesz, 1992) though some contradictory findings were reported (e.g., Fisher, 1979). However, none of those reports of agraphia owing to lesions of subcortical

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structures, with the exception of the Kertesz's study (1992), considered the deficit of writing function in detail.

Written Chinese similar to Kanji is made up of orthographs in which each orthograph is composed of several strokes. These pen strokes may be vertical, horizontal, cursive, or a dot. Correctly written Chinese orthographs, not only require normal visuospatial perception, but also require the accurate transcoding of a phonological specification or a semantic specification into a series of organized motor sequences (Hua, Ku, & Huang, 1992; Huang, 1984). Such a written language therefore is different from the alphabetic language, such as English, French, and German. In this language, agraphia in the patients with cortical lesions was well noted, but only one study (Chia & Kinsbourne, 1987) reported a patient with lesions in the left basal ganglia having mirror writing problem.

Since literature concerning writing function, especially the Chinese one, in the patients with lesions in subcortical structures is relatively scanty in comparison with that of other aspects of language, our study therefore was designed to explore this issue. The specific objective was to examine the following issues: (a) Is there an impairment of Chinese writing function in patients with lesions of subcortical structures, specifically an involvement of the putamen and the adjacent white matter? (b) If so, does the impairment involve all or only some of the writing abilities tested, and is the impairment secondary to the aphasic disorders? (c) Is writing function more sensitive to the lesions in subcortical structures than reading in the Chinese language, as it is in the alphabetical language suggested by the investigators (e.g., Basso, Sala & Farobola., 1987)? And (d) Is there a functional asymmetry between the left and the right subcortical structures in terms of writing function?

METHODS

Participants

Three groups with a total of 45 subjects were employed in the study. Two of them were composed of 18 stroke patients with left or right subcortical lesions, mainly involving putamen (some with internal capsule or corona radiata). Patients with lesions involving cortical areas or ventricles (in case of hemorrhage) were excluded. The lesion locations were verified by brain computed tomography (CT) or magnetic resonance imaging (MRI). The patients' CT scan obtained one week after the onset of stroke (Figures 1–4 were some sample CT scans). However, only 3 (2 left and 1 right subcortical stroke) patients' follow-up CT scans were available and these obtained at least 2 months after the stroke (ranged from 2 to 65 months). Meanwhile, all of the patients were victims of the first time stroke in the absence of any other CNS diseases and psychiatric history. Group 1 included 9 patients with left putaminal hemorrhagic stroke. Their mean age and education were 47 years ($SD = 10.42$ years), and 11.30 years ($SD = 3.71$ years) respectively. Group 2 consisted of 9 patients with right putaminal hemorrhagic stroke. Their mean age and education were 45.70 years (SD = 9.84 years), and 10.40 years (SD = 2.97 years) respectively. The third group was made up of 29 normal subjects who were composed of patients' relatives and friends, and volunteers through newspaper advertisements. The average age and education of this group were 46.80 years (SD = 8.62 years), and 10.90 years (SD = 3.74 years) respectively. The volunteers obtained through newspaper advertisements were paid for their participation (Table 1). The normal subjects reported no history of significant medical illness and psychiatric problem. In order to minimize possible age and education confounds on our writing test battery, we matched both age and educational level of the participants among the three subject groups.

All participants were free of dementia and confusional state. For the patients, the testing began 2 to 3 weeks after stroke when their physical condition was stable. Half of the patients with left putaminal hemorrhagic stroke who were severely paralyzed used the left hand to perform the writing tests. Generally, these patients suffered from larger hemorrhage extended to either internal capsule or corona radiata. All participants were right-handed in which hand dominance was ascertained by the history that the subject has always used his/her right hand preferentially for doing skillful activities, such as writing and holding chopsticks.

Tests and Procedure

Each participant received a battery of nonwriting linguistic function tests, and of writing function measures at the Neuropsychology Lab., Department of Neurology, Chang Gung Memorial Hospital. The non-writing function tests included as follows: Visual Naming (Benton & Hamsher, 1978), Object

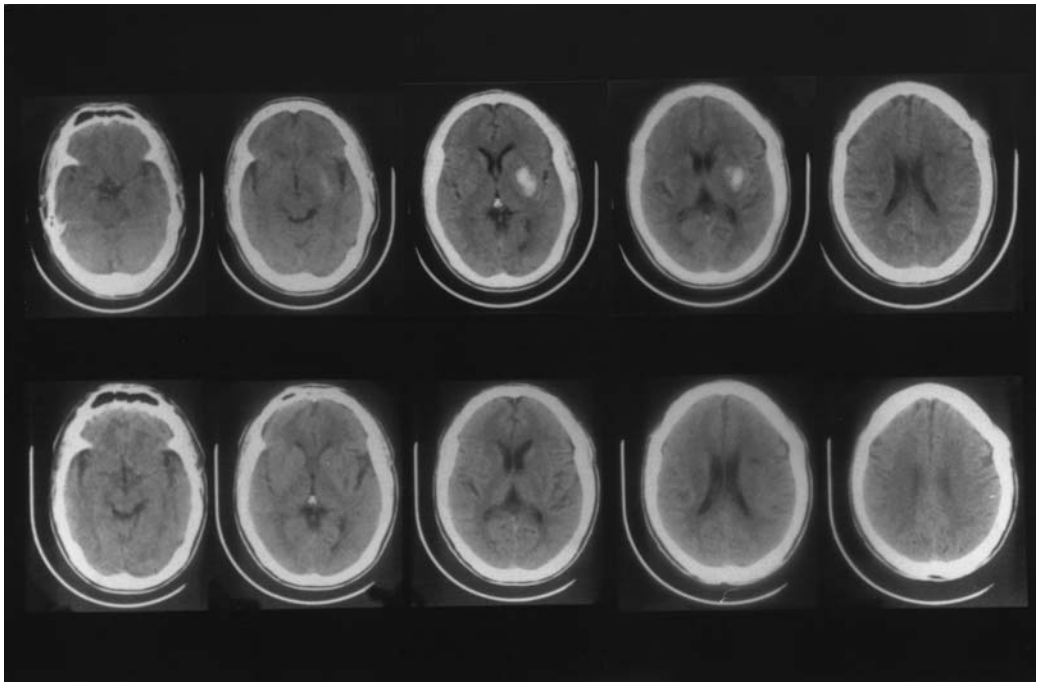

Fig. 1. Computed tomographic scans of Pt. 1(without aphasia) who had excellent performance on the Writing to Dictation of Sentences, Writing to Dictation of Words, and Spontaneous Writing of Name and Address, with left putaminal hemorrhage. Top: CT scan slices where hemorrhage was present at 8 days poststroke; the hemorrhage involved the putamen with slight extension into the posterior limb, internal capsule. Bottom: CT scan slices obtained at 2 months poststroke.

Naming (Spreen & Benton, 1969), Sentence Repetition (Benton & Hamsher, 1978), Semantic Association of Verbal Fluency (Hua, 1988), Token Test (Benton & Hamsher, 1978), Aural and Reading Comprehension Tests (Benton & Hamsher, 1978), and Oral Reading (Hua, 1988). The writing measures consisted of spontaneous writing, writing to dictation, and writing from copying. Spontaneous writing included the subtests of Spontaneous of Story, of Name and Address (Kertesz, 1982), and Spontaneous Writing of Words (Spreen & Benton, 1969). Writing to dictation was composed of the subtests of Writing to Dictation of Words, and of Sentences (Spreen & Benton, 1969). Writing from copying contained the subtests of Copying Words, and Copying Sentences (Spreen & Benton, 1969). All of these tests are Chinese version (Table 1).

The procedures and requirements of the study were explained to each participant. A consent form was signed prior to data collection. A total of 1.5 hours was needed for each participant to complete testing. All participants completed the testing in one session.

RESULTS

Since the sample size of both patient groups was small, we used the cutoff scores which were defined by 2.0 standard deviation below the mean score of the normal control group on both non-writing linguistic and writing tests to determine the impairment level of the patient's performance on these tests. The level of deficit of test performance was defined as follows. The score 2.0–2.3 SD below the mean score of the normal control group was interpreted as a mild level of impairment. The score 2.4–2.7 SD below the mean score of the normal group was specified as a moderate level of impairment. The score 2.8 SD below the mean score of the normal group was illustrated as a severe level of impairment (Table 2).

Table 3 shows the core linguistic test scores, including some of the available follow-up, of the

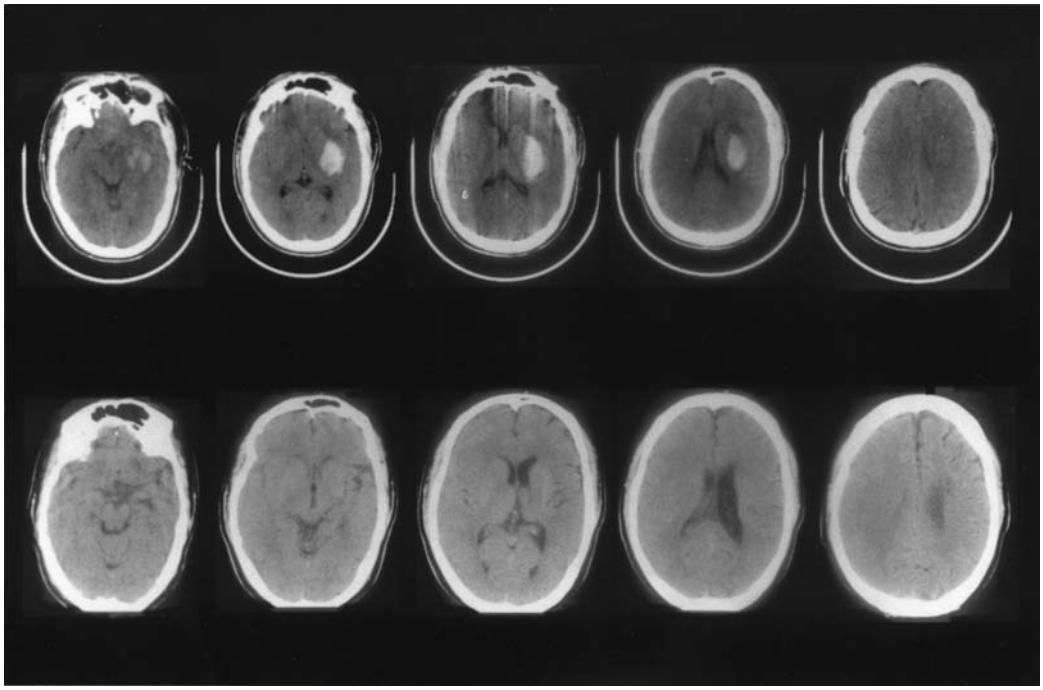

Fig. 2. Computed tomographic scans of Pt. 5 (with global aphasia) who had poor performance on the Spontaneous Writing of Story, and of Words on the initial examination, with left putaminal hemorrhage. Top: CT scan slices where hemorrhage was present at 1 day poststroke; the hemorrhage involved putamen with superior extension into the corona radiata, lateral to the body of the lateral ventricle. Note, this case who had poor performance on Spontaneous Writing also had hemorrhage which extended into the superior white matter, lateral to the body of the lateral ventricle. Bottom: CT scan slices obtained at 50 months poststroke.

patients with left subcortical stroke. For these patients, 6 of 9 patients were impaired in writing function. On the Spontaneous Writing of Story, 3 out of 9 patients were moderately defective, and these three patients were also aphasic (two were global aphasia, and one was Broca's type). On the Spontaneous Writing of Name and Address, 2 out of 9 patients were severely impaired, and these two were global aphasia. On the Spontaneous Writing of Words, 2 out of 9 patients were moderately impaired and they were also global aphasics, and 1 patient who was free of aphasia was severely impaired. With regard to Writing to Dictation of Words, 4 out of 9 patients were severely impaired while only 3 of these 4 patients were aphasic. 3 out of 9 patients were aphasic and also severely defective on the test of Writing to Dictation of Sentences. 4 out of 9 patients were severely impaired on the test of Copying Words, but only 2 out of 4 patients were aphasic. With respect to the test of Copying Sentences, no one was defective (Table 4).

In Table 3, we also tried to make a rank ordering of the difficulty of spontaneous writing, writing to dictation, and writing from copy subtests. The most difficult task, Spontaneous Writing (Story, Words, Name and Address in order) was listed on the top. Writing to Dictation of Sentences and of Words were next, followed by Copying Sentences, and the least difficult one, Copying Words was the last on the bottom. On the basis of this ordering, we re-examined the patients' initial scores on these subtests. Accordingly, we placed the patients # (Pt) 8, 7 and 5 whose performance on these spontaneous writing tasks was severely defective on the left-hand side, followed by patients with mild to moderate impairment, and those (i.e., Pts. 1, 6, and 4) having normal performance on the right-hand side. Figure 5 shows samples of Pt. 5's poor

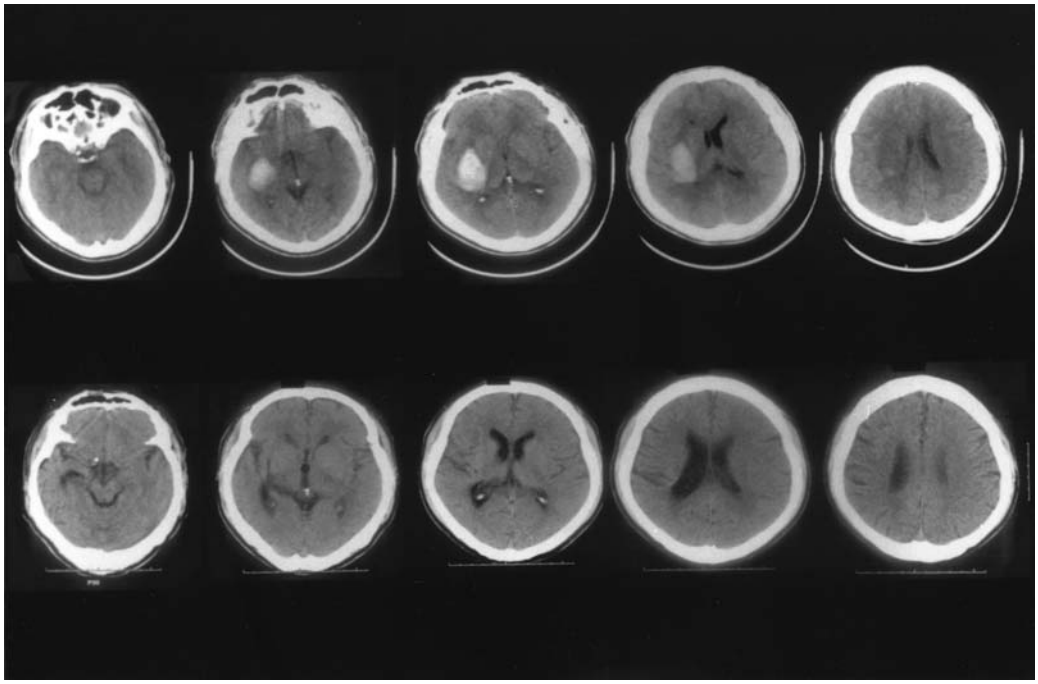

Fig. 3. Computed tomographic scans of Pt. 3 with excellent performance on the Coping Words on the initial examination, with right putaminal hemorrhage. Top: CT scan slices where hemorrhage was present at 1 day poststroke; the hemorrhage involved the putamen with posterior extension into the posterior limb, internal capsule. Bottom: CT scan slices obtained at 65 months poststroke.

performance on the Spontaneous Writing of Words. On the follow-up, the available cases included Pts. 5, 3, 9, and 2. All of these patients, with the exception of Pt. 9 who had a second stroke episode 6 months later, performed normally on these writing tests.

Table 5 shows both of the initial nonwriting and writing test scores of the patients with right subcortical stroke, and some of the available patients' follow-up test scores. None of these patients were aphasic, and there were 4 patients having writing problems. The defective writing performance was evident on the tests of the Spontaneous Writing of Words (1 patient), Writing to Dictation of Words (1) and of Sentences (1), and both Copying Words (3) and Copying Sentences (3). Overall, for these 4 patients, the level of impairment of spontaneous writing and writing to dictation was mild while the level of deficit of writing from copy was almost severe (Table 6).

A rank sequencing of writing from copy subtests from the most difficult one, Copying Sentences on the top, to the least difficult, Copying Words next to it was also tentatively made in Table 5. A re-examination of the initial test scores of the patients with right subcortical stroke based on this ordering was then conducted. Accordingly, the patient with a severe level of performance (i.e., Pt. 7) was listed on the left-hand side, and those with a normal level of performance (i.e., Pts. 6, 5, and 4) on the right-hand side. Figure 6 shows samples of Pt. 7's poor performance on the Copying Sentences. The available follow-up consisted of Pts. 7, 3, 2, 9, and 4. Most of these patients, with the exception of Pt. 9 who had a second stroke 1 year later, had a normal level of performance on these tests.

DISCUSSION

In respect of our first question, is there an impairment of Chinese writing function in the patients with lesions of subcortical structures, specifically

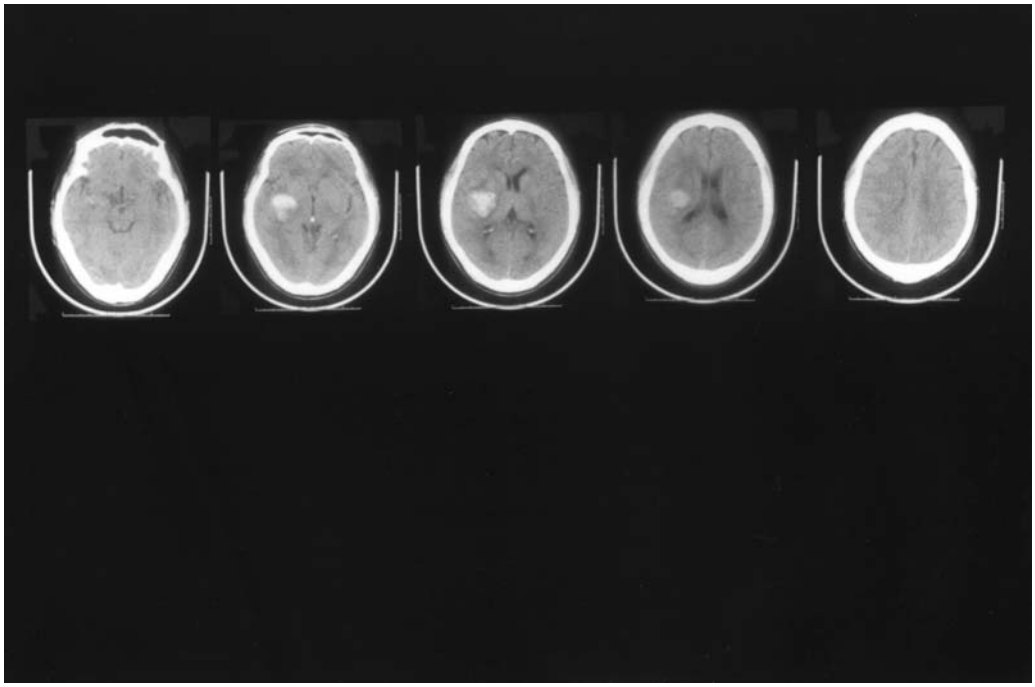

Fig. 4. Computed tomographic scans of Pt. 7, with poor performance on the Copying Sentences on the initial examination, with right putaminal hemorrhage. Top: CT scan slices where hemorrhage was present at 1 day poststroke; the hemorrhage involved the putamen with posterior extension into the posterior limb, internal capsule; and superior extension into the corona radiata, lateral to the body of the lateral ventricle. Note, this case who had poor performance on Copying Sentences also had hemorrhage which extended into the superior white matter, lateral to the body of the lateral ventricle. No follow-up CT scan was available.

Table 1. Demographic Characteristics of Subjects.

	Sex (F:M)	Age		Education	
		M	*SD*	*M*	*SD*
Normal Controls	8:21	46.8	8.62	10.9	3.74
Right Putaminal Stroke	1:8	45.7	9.84	10.4	2.97
Left Putaminal Stroke	1:8	47.0	10.42	11.3	3.71

an involvement of the putamen and the surrounding white matter? The answer is yes. Our results revealed that the patients with subcortical stroke irrespective of the left or the right subcortical lesions had writing problems. The majority of the patients (6 out of 9) with the left subcortical stroke, and about half of the patients with the right subcortical stroke were defective in this cognitive function. Our findings were partially concord with the Western literature that agraphia could result from the left non-thalamic lesions (Laine and Martilla, 1981; Lieberman, Ellenberg, & Restum, 1986; Basso, et al., 1987). Meanwhile, these further substantiated the previous observations (Tanridag & Kirshner, 1985; Chia & Kinsbourne, 1987; Kertesz, 1992) that writing dysfunction could be due to lesions of the left putamen and the adjacent white matter.

On the basis of our limited available follow-up, it, however, appears that the writing impairments

Table 2. Cutoff Scores of Core Linguistic Function Tests.*

	Maximum Possible Score	Normal Controls					
		Mean	*SD*	M-1.5SD	M-2SD	M-2.3SD	M-2.7SD
Visual Naming	60	54.83	5.46	46.64	43.91	42.27	40.09
Sentence Repetition	14	11.97	1.24	10.11	9.49	9.12	8.62
Verbal Fluency	– **	37.39	6.77	27.24	23.85	21.82	19.11
Token Test	44	41.79	2.48	38.07	36.83	36.09	35.09
Aural Comprehension	18	17.34	1.01	15.83	15.32	15.02	14.61
Oral Reading	18	17.52	1.40	15.42	14.72	14.30	13.74
Reading Comprehension	18	17.14	0.92	15.76	15.30	15.02	14.66
Spontaneous Writing of Story	34	25.66	10.96	9.22	3.74	0.45	−3.93
Spontaneous Writing of Words	16	11.74	4.60	4.84	2.54	1.16	−0.68
Spontaneous Writing of Name and Address	18	16.91	2.70	12.86	11.51	10.70	9.62
Writing to Dictation of Sentences	13	12.10	2.07	8.99	7.96	7.34	6.51
Writing to Dictation of Words	11	9.28	2.08	6.16	5.12	4.49	3.66
Copying Sentences	11	10.95	0.20	10.65	10.55	10.49	10.41
Copying Words	16	15.78	0.39	15.19	15.00	14.88	14.73

* Impairment Level: Severe: below M-2.7SD; Moderate: between M-2.3SD and M-2.7SD; Mild: Between M-2SD and M-2.3SD; Borderline: between M-1.5SD and M-2SD;
** No Maximum Possible Score.

of the patients with either left or right subcortical stroke were transient. In fact, the similar manifestation has already been evident in the Kertesz's (1992) study in which he examined writing function in 8 patients with left putaminal stroke periodically following the onset of stroke. The initial examination of writing function in these patients were taken at 2 weeks after the onset of stroke and about half of the patients had writing problems. These patients also received a follow-up at 3 months after the onset of stroke, and all of them, with the exception of one, had normal writing function. Since such a feature of transient writing changes was manifest in the limited attainable follow-up samples of Kertesz's (1992) and ours, further confirmation is necessary.

Does the writing impairment include all or some of the writing abilities tested, and is this impairment secondary to aphasic disorder? The answer for the first part question is dependent upon which side of the brain is involved. For the patient group with the left subcortical stroke, the areas of writing dysfunction were variable. 2 patients in this group were impaired in all aspects of the writing function. 1 was impaired in both spontaneous writing and writing to dictation. 1 was defective in both writing to dictation and writing from copy. 1 was only impaired in writing to dictation; and 1 was only defective in writing from copy. Generally, about one third of these patients had writing dysfunction involving all the aspects. However, the area of writing dysfunction in the patients with right subcortical stroke was more specific, primarily in the aspect of writing from copy.

These results were different from Kertesz's observations (1992) that only a severe impairment of spontaneous writing functioning in his patients with main lesions in the left putamen and its surrounding white matter. Since the sample size of both studies is limited (8 patients in his and 9 in ours), further investigation is merited to clarify this discrepancy. Nevertheless, the different degree of severity in terms of linguistic and motor difficulties, and the combination of these two problems between our and Kertesz's patients with lesions in the left putamen and the surrounding white matter might partially account for these

Table 3. Core Linguistic Test Scores in Patients with Left Subcortical Stroke (N = 9).

	Pt8	Pt7	Pt5		Pt3		Pt9***		Pt2		Pt1	Pt6	Pt4
Testing, month after stroke	1/0.47	1/0.45	1/0.77	2/50.35	1/1.35	2/63.17	1/0.80	2/48.57	1/0.17	2/92	1/0.47	1/0.63	1/0.45
Right Hemiplegia / Paresis	Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	No	Yes	No
Hand Used for Writing or Copying	Left	Left	Left	Right	Right	Right	Left	Right	Right	Right	Right	Right	Right
Aphasia Present	Yes (Broca's Type)	Yes (Global Type)	Yes (Global Type)	No	No	No	Yes (Wernick's Type)	No	No	No	No	No	No
Visual Naming	26	18	18	54	16/16**	16/16**	36	36	58	56	52	56	56
Sentence Repetition	5	2	1	8	7	9	7	7	13	11	11	12	A*
Verbal Fluency	3	15	15	28	21	27	23	17	24	26	29	24	31
Token Test	17	7	6	37	35	16	35	32	43	41	42	43	41
Aural Comprehension	18	9	10	18	17	17	14	16	17	17	18	17	18
Oral Reading	15	6	14	18	14	15	18	15	18	18	18	18	18
Reading Comprehension	13	9	4	17	13	16	16	16	18	18	16	18	18
Spontaneous Writing of Story	0	0	0	23.5	8	9.5	8	8	19	10	20	26	34
Spontaneous Writing of Words	A*	0	0	7.5	3	5.5	5	4	5.5	6.5	15	10	15.5
Spontaneous Writing of Name and Address	3	3	15.5	18	18	18	18	17.5	18	18	17.5	17	18
Writing to Dictation of Sentences	A*	A*	3	13	11	9	11	12	9	13	13	13	13
Writing to Dictation of Words	A*	1	2.5	8	3.5	4	5	6	5.5	6.5	10.5	8.5	11
Copying Sentences	A*	A*	11	11	11	11	11	10.5	11	11	11	11	11
Copying Words	A*	14	16	16	13.5	15.5	16	13	12.5	13.5	16	15.5	16

* Unable to do; ** Object Naming; ***A second hemorrhagic stroke involved in the left cerebellum about 6 months later.

Table 4. Core Linguistic Function in Patients with Left Subcortical Stroke (N = 9).

	Percentage of Cases who scored in the Borderline-to-Severe Deficit Range	Level of Impairment			
		Borderline	Mild	Moderate	Severe
Visual Naming	44.4	0	0	0	4 (3)*
Sentence Repetition	66.7	0	0	0	6 (3)*
Verbal Fluency	77.8	2	1	1	3 (3)*
Token Test	55.6	0	0	0	5 (3)*
Aural Comprehension	33.3	0	0	0	3 (2)*
Oral Reading	44.4	1	0	2 (1)*	1 (1)*
Reading Comprehension	44.4	0	0	0	4 (3)*
Spontaneous Writing of Story	44.4	1	0	3 (3)*	0
Spontaneous Writing of Words	44.4	0	1	2 (2)*	1
Spontaneous Writing of Name and Address	22.2	0	0	0	2 (2)*
Writing to Dictation of Sentences	33.3	0	0	0	3 (3)*
Writing to Dictation of Words	55.6	0	1	0	4 (3)*
Copying Sentences	22.2	0	0	0	2
Copying Words	55.6	0	1	0	4 (2)*

()* Number of cases who had aphasia.

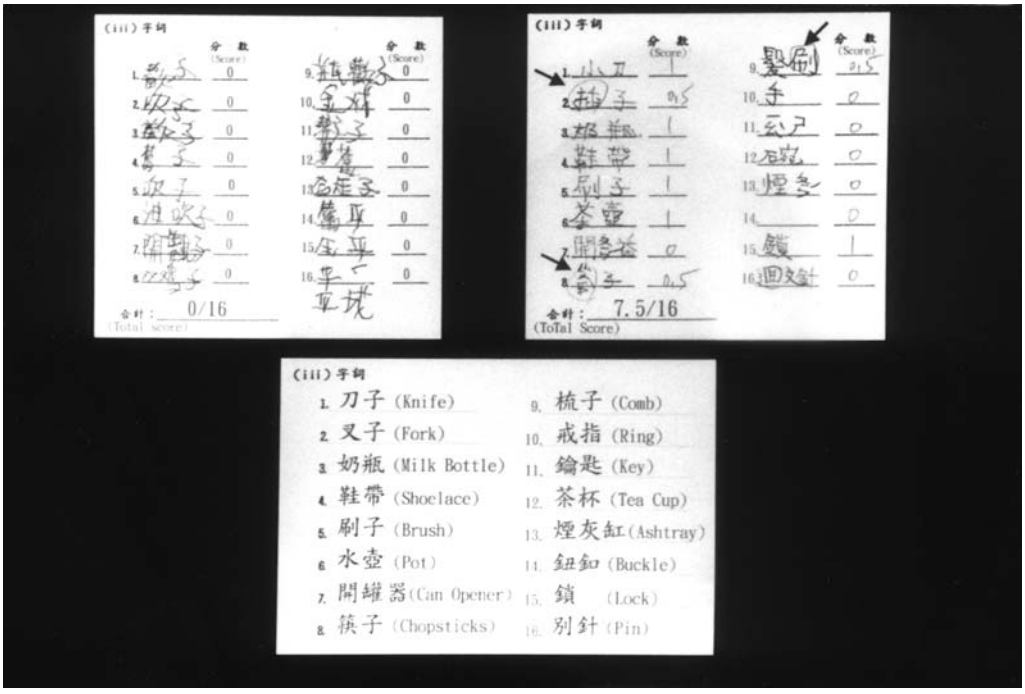

Fig. 5. Samples of handwriting of Pt. 5 with left putaminal hemorrhage (see Fig. 2). Top left: poor performance (none were correct) on the Spontaneous Writing of Words on the initial examination. Top right: better performance, which was within normal limits on this test at follow-up (50.35 months poststroke). Arrows show the incorrect handwriting of three Chinese characters. Bottom: the correct version of the calligraphy of the test where the corresponding words in English for each test item are shown in parenthesis.

Table 5. Core Linguistic Test Scores in Patients with Right Subcortical Stroke.

	Pt7		Pt1	Pt8	Pt3		Pt2		Pt9***		Pt6	Pt5	Pt4	
Testing, month after stroke	1/0.39	2/59.5	1/0.45	1/0.47	1/0.48	2/65.23	1/0.27	2/61.73	1/1.32	2/75.93	1/0.42	1/0.47	1/0.73	2/70.17
Left Hemiplegia/ Paresis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No
Hand Used for Writing or Copying	Right	Right	Right	Right	Right	Right	Right	Right	Right	Right	Right	Right	Right	Right
Visual Naming	52	50	58	58	48	60	56	58	16/16**	16/16**	58	54	60	56
Sentence Repetition	9	12	A*	10	8	8	11	11	10	9	9	10	9	10
Verbal Fluency	31	32	38	46	33	37	37	33	27	13	43	29	32	29
Token Test	42	39	44	42	42	42	44	44	38	34	42	41	43	41
Aural Comprehension	17	18	17	18	17	18	18	18	18	11	18	18	17	18
Oral Reading	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Reading Comprehension	18	18	17	18	16	17	17	18	17	12	18	17	18	17
Spontaneous Writing of Story	A*	17	34	34	15	10	33	34	A*	0	9.5	25	15	24
Spontaneous Writing of Words	5	8	10.5	13	8.5	7.5	12.5	11	A*	0.5	4.5	9	11.5	16
Spontaneous Writing of Name and Address	17.5	17.5	18	18	18	17	16.5	17.5	18	6	18	18	17.5	18
Writing to Dictation of Sentences	12.5	11.5	13	13	12	13	12.5	13	3.5	4	12.5	12.5	13	13
Writing to Dictation of Words	6.5	7	9.5	11	8	7.5	9.5	9.5	3	0	6	7.5	7	9
Copying Sentences	9.5	11	11	11	10.5	11	10.5	11	11	6	11	11	11	11
Copying Words	15	14	15	15.5	16	15	16	16	16	5	16	16	16	16

* Unable to do; ** Object Naming; ***A second hemorrhagic stroke involved in the left pontine area about 1 year later.

Table 6. Core Linguistic Function in Patients with Right Subcortical Stroke (N = 9).

	Percentage of Cases who scored in the Borderline-to-Severe Deficit Range	Level of Impairment			
		Borderline	Mild	Moderate	Severe
Visual Naming	0	0	0	0	0
Sentence Repetition	55.5	1	0	3	1
Verbal Fluency	11.1	1	0	0	0
Token Test	11.1	1	0	0	0
Aural Comprehension	0	0	0	0	0
Oral Reading	0	0	0	0	0
Reading Comprehension	0	0	0	0	0
Spontaneous Writing of Story	22.2	0	0	0	2
Spontaneous Writing of Words	22.2	1	0	0	1
Spontaneous Writing of Name and Address	0	0	0	0	0
Writing to Dictation of Sentences	11.1	0	0	0	1
Writing to Dictation of Words	22.2	1	0	0	1
Copying Sentences	33.3	0	2	0	1
Copying Words	33.3	0	2	0	1

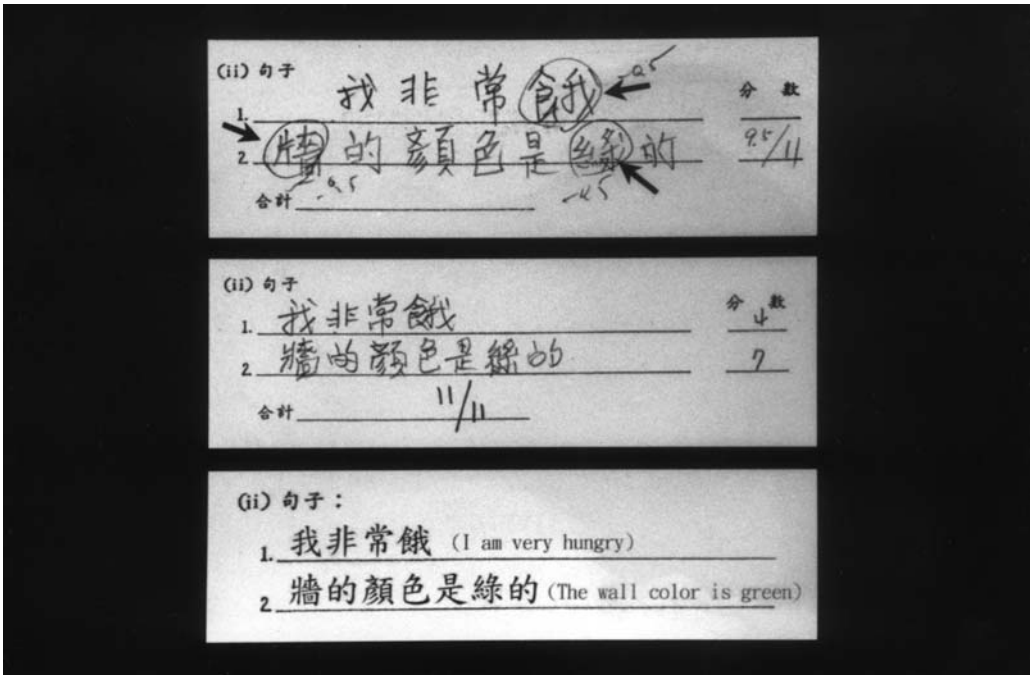

Fig. 6. Samples of handwriting of Pt. 7 with right putaminal hemorrhage (see Fig. 4). Top: poor performance on the Copying Sentences on the initial examination. Arrows indicate the incorrect handwriting of three Chinese characters. Center: correct performance on this test on the follow-up (59.5 months poststroke). Bottom: the correct version of the calligraphy of this copying test where the corresponding sentence in English for each test item is shown in parenthesis.

diverse findings. It seems that our patients suffered from relatively more severely linguistic and motor disturbances than Kertesz's.

Review of literature indicates that agraphia could result from dominant subcortical lesions while no evidence of this problem was due to nondominant subcortical lesions. Our results, about half of patients with the right (non-dominant) subcortical stroke having writing problems (mainly in the area of writing from copy), seems to be contradictory to the literature. Further examination of the error pattern revealed that our patients' writing problems essentially resulted from spatial disturbance or stroke substitution, rather than linguistic difficulty. Correctly Chinese orthographs not only require linguistic and motor processes, that is, the accurate transcoding of a phonological specification or a semantic specification into a series of organized motor sequences, but also demand visuospatial perception (Hua et al., 1992; Huang, 1984). Therefore visuospatial ability in Chinese writing, particularly in the area of writing from copy, seems to be relatively more demanding in comparison with that in the alphabetic language. If this is the case, the writing problem in our patients with the right subcortical stroke could be mostly accounted for by their visuospatial disturbance. The disparity between the literature and our findings, thus, appears to be negligible.

With regard to the question, is the impairment of writing function secondary to aphasic disorders? The answer is partly right. In the patient group with the left subcortical stroke, 6 of them had agraphia in which 4 patients were also aphasic; 2 global, 1 Broca's, and 1 Wernicke's types. These 4 patients' writing dysfunction was highly associated with the core linguistic problems. Consequently their writing disorders were most likely to be secondary to aphasic disorder. However, two patients with writing dysfunction had nothing to with the core linguistic deficits. Pure agraphia mostly occurs in the patients with left cortical lesions including the second frontal convolution (Kaplan & Goodglass, 1981; Sakurai, Matsumura, Iwatsubo, & Momose, 1997), the superior parietal lobule (Basso et al., 1978), and the posterior perisylvian region (Rosati & de Bastiani, 1981). However, it can also be seen in the patients with left subcortical lesions. The lesion areas include the left caudate and internal capsule (Laine & Martilla, 1981), and the left putamen and the adjacent white matter (Tanridag & Kirshner, 1985; Kertesz, 1992). Our findings of pure agraphia in the patients with the left subcortical stroke further corroborate that left subcortical structures, particularly in the basal ganglia and the surrounding white matter, might play an important role in writing. Our results, however, also revealed that in Chinese writing pure agraphia, most likely due to spatial disturbance, could occur in the patients with the right subcortical lesion. On the basis of their observations of hypertensive putaminal hemorrhage cases, Hier, Davis, Richardson, and Mohr (1977) concluded that the aphasia was more severe when the hemorrhage extended in a superior direction, to include white matter lateral to the body of the left lateral ventricle. This conclusion was further confirmed by recent findings (Naeser, Baker, Palumbo, Nicholas, Alexander, Samaraweea, et al., 1998; Naeser, Palumbo, Helm-Estabrooks, Stiassny-Eder, & Albert, 1989). Naeser and her colleagues, thus, conceived that the white matter located lateral to the body of the lateral ventricle, including efferent and afferent white matter pathways for the mouth, and other thalamocortical, intrahemispheric, as well as interhemispheric pathways, is critical, in part, for motor and sensory aspects of speech. In fact, in our initial testing of writing function, a defective pattern, which is fully relevant to Hier and his co-workers' conclusion (1977), was also evident in our cases. That is, we did find that our Taiwanese patients with putaminal hemorrhage which extended into white matter at the level of the body of the lateral ventricle, in either hemisphere (see Figs. 2 and 4) had more severe, initial deficits.

On the basis of their observations, Basso and her colleagues (1987), Crosson (1992), and Kertesz (1992) insisted that writing function is more sensitive to the lesions of the left basal ganglia and the surrounding white matter than reading in Italian and English respectively. Is also written language more sensitive to subcortical lesions than spoken language in Chinese, as it is in the

alphabetical language claimed by these investigators? The answer is yes. Our results also did display that most of our agraphic patients with the left subcortical stroke were free of reading problem.

Finally, is there a functional asymmetry between the left and the right subcortical structures in terms of writing function? The answer seems to be positive if we approach this issue of the functional asymmetry from the points of the aspect of writing involving, and its underlying psychological processes. Most of our patients with the left subcortical stroke had writing problems, spontaneous writing and writing to dictation, which were mostly related to the core linguistic deficits. In contrast, agraphia, mainly writing from copy, manifested in the patients with the right subcortical stroke was most likely due to the impairment of spatial functioning. Thus it seems feasible to suggest that to some extent a functional asymmetry in terms of writing does exist between the left and the right subcortical structures. If this is the case, is the role of left subcortical structures in the Chinese writing function compatible with that of left cortical areas? Unfortunately, the answer for this question is not known because for the present we have not yet had enough patients with cortical and/or subcortical lesions and their follow-up data to make any comments on this issue.

In summary, our study revealed that most of the patients with the left subcortical stroke had writing dysfunction while about half of the patients with the right subcortical stroke were impaired in this function. Furthermore, agraphia in the patients with the left subcortical stroke mainly involved spontaneous writing and writing to dictation, and these deficits seemed to be secondary to aphasic disorder. In contrast, the impairment of writing function in the patients with the right subcortical stroke mainly involved writing from copy, and the deficit was independent of aphasic disorder. On the basis of the features of writing errors, we suggest that there is a functional asymmetry between the left and right hemispheres in writing function, including when the structural lesions are limited to subcortical areas, such as putamen and surrounding white matter.

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