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Language performance and cognitive function in persons with nondominant-hemispheric stroke

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Abstract This study investigated the relationship between language performance and cognitive function in stroke patients after nondominant hemisphere damage. The results of a battery of formal language tests, K-WAB, of seventy-eight patients were analyzed. The correlation between their K-WAB and K-MMSE scores was analyzed. Multivariate analysis of covariance adjusting for educational years in each of K-WAB and K-MMSE was conducted in accordance with the brain lesion location. Only 35.9 % of patients were classified as normal and the remaining 64.1 % were categorized as subnormal by K-WAB. There was a positive correlation between their language and cognitive functions. Outcomes differed according to lesion location, as the SAH group exhibited a significantly lower performance in both language and cognitive evaluations than the other groups. Cognitive-communicative disorders in stroke patients with nondominant-hemispheric lesions present in different ways. In-depth language evaluation of all brain-damaged patients should be conducted so that language defects of patients are not ignored.

Keywords Nondominant-hemispheric stroke · Cognitive function · Language performance · Cognitive-communication disorder

Introduction

The left hemisphere almost always contains the regions of the brain responsible for language. Ever since the 19th century clinicians have agreed that left hemisphere damage leads to significant language impairment. Thus, it is recognized that language assessment

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and therapy for patients with left hemisphere damage are essential. However, though there is no question that the left hemisphere is the superior language processor, a growing body of research has demonstrated significant linguistic ability in the nondominant right hemisphere. Language-related brain regions are embedded in complex and highly interconnected networks in such a way that lesions may impair language processes by affecting neural structures that are connected to specialized brain areas and/or their mutual connections without damaging the specialized areas themselves (Démonet et al. 2005). Consequently, anatomical lesions located a significant distance from language-related regions can still affect language function (Démonet et al. 2005).

Reports of language disorders caused by nondominant-hemispheric lesions have either addressed crossed aphasia after right brain damage in dextrals or cognitive-communicative disorders. The former remains rare, so an exclusive right-hemispheric contribution to language is still considered exceptional. The latter, cognitive-communicative disorder, is a broad term that is used to describe a wide range of communication problems that can result from damage to regions of the brain. When the term "cognitive-communicative disorders" is used to indicate communication disorders other than aphasia, they can be largely divided into extralinguistic deficits and nonlinguistic deficits (Lindell 2006; Ross & Monnot 2008; Schmidt et al. 2007; Miller et al. 1998). While linguistic deficit is limited to deficits in core elements of language—phonology, morphology, syntax, and semantics—extralinguistic deficits include difficulty with figurative language, reduced accuracy of core concepts and inferences, reduced eye contact, reduced sensitivity to emotional prosody, reduced appreciation of shared knowledge, reduced use of prosodic features, and reduced ability to interpret humor. Nonlinguistic deficits can cause communication disorders related to cognitive disorders such as left neglect, anosognosia, and attention impairment. In other words, cognitive-communicative disorders could be considered collateral communication disorders with cognitive malfunction caused by nondominant-hemispheric damage.

Some studies have shown that nondominant-hemispheric patients display various deficits at all levels of language processing, with patterns of defective performance qualitatively similar to aphasia after left-hemispheric lesions (Joanette et al. 1983; Cappa et al. 1990). Previous studies have reported that cognitive functions other than language are closely associated with language processing. Furthermore, cognitive impairment can cause impairments in language processing, such as attention deficits for auditory comprehension or memory deficits for lexical recognition and retrieval. Despite these findings, the relationship between communicative function and cognitive function has not been fully investigated in stroke patients.

One of the reasons is that a number of researchers so far have regarded language as one of the independent modules of cognitive function and confined the language disorder to the incurrence of language impairment without defects in cognitive function. This language-centered definition induced an approach that focuses only on the linguistic aspect in patient evaluation and treatment in practice (Helm-Estabrooks 2002). However, looking at the studies on the relationship between language and cognitive function accumulated so far, an opinion is gaining persuasive power that views language as an epiphenomenon at the upper level rather than as one of the independent fields in cognitive functions. That is, language appears through a harmonization of the left and right brain where diverse cognition, perception, and sentiment, such as attention, memory, visual perception, feeling, etc., interact.

Hence, it is necessary to make an effort to investigate the relationship between language disorder and cognitive impairment among stroke patients. However, it is difficult to investigate cognitive function in an aphasic group because most cognitive test tools require proper language skills to complete most of the neuropsychological tests. Thus, non-dominant-hemispheric stroke patients—whose core problem is not deemed to be linguistic disorder—serve as the ideal population for evaluating the impact of cognitive impairment on language processing.

The purpose of this study is to investigate language performance in stroke patients confirmed not to have aphasia after nondominant hemisphere damage. In this study, nondominant hemisphere deficit is not limited to right hemisphere deficit only. Rather it covers all areas of the brain other than the left cerebrum, which is known to cause aphasia when damaged. The present study has three main aspects. First, the results of a battery of formal language tests conducted on these patients were analyzed on the basis of a standard norm. Second, the correlation between the results of the language test and the cognitive test was analyzed in order to investigate the relationship between language performance and cognitive impairment. Third, the relationship between linguistic and cognitive findings and lesion location was studied.

Method

Participants

Subjects were recruited from stroke patients seen at the rehabilitative medicine department of Korea University Medical Center. The primary prerequisite for study participants was that they had had a brain stroke in the nondominant hemisphere. Among the stroke patients, those with damage in the left cerebrum were omitted; the remaining patients included SAH (subarachnoid hemorrhage) patients and patients with lesions in the right side of the cerebrum, cerebellum, or brainstem. Among the potential participants, left-handed or ambidextrous patients were excluded; the remaining patients were all right-handed. Those who had a history of cognitive or language malfunction before the stroke were also excluded. Out of a total of 78 study participants, 42 had suffered a single nondominant-hemispheric CVA infarction and 36 had suffered a hemorrhage. There were 43 males and 35 females, with an average age of 64.7 ($SD = 11.7$) and an average of 8.6 years of education ($SD = 5.5$). The clinical characteristics of the study participants are provided in Table 1.

Procedures

Personal information, educational background, and hand preference (Oldfield 1971) of the subjects were obtained by reviewing their medical history. The time elapsed since the stroke and the type of cerebral lesion were recorded as characteristics of the stroke. The location of the cerebral lesions was categorized based on the modified Oxfordshire Community Stroke Project classification into anterior circulation (branches of the internal carotid artery), posterior circulation of the right hemisphere (branches of the vertebral and basilar arteries), and SAH (Aerden et al. 2004; Rovira et al. 2005; Amarenco et al. 2009).

Language function was assessed using the Korean version of the Western aphasia battery (K-WAB) (Kim & Na 2001). The K-WAB examined the four areas of spontaneous speech, auditory comprehension, repetition, and naming, along with the Aphasia Quotient (AQ).

Table 1 General characteristics of the patients ($n = 78$)

Variable		Value (mean ± SD)
Age (year)		64.7 ± 11.7
Education (year)		8.6 ± 5.5
Onset to K-WAB (days)		54.2 ± 97.2
Onset to K-MMSE (days)		53.2 ± 97.3
K-MMSE		19.2 ± 7.5
Aphasia quotient (K-WAB)		79.8 ± 21.1
Handedness	Right	78
Type of stroke	Infarction	42
	Hemorrhage	36
Site of lesion	Right hemisphere	63
	Ant. circulation	43
	Post. circulation	20
	Subarachnoid hemorrhage	15

K-WAB Korean version of Western aphasia battery, *K-MMSE* Korean version of mini-mental state exam

We evaluated cognitive function using the Korean version of the mini-mental state exam (K-MMSE) (Kang 1997). We analyzed the total score and the subarea scores of the K-MMSE, excluding the overlapping pentagons—namely, orientation toward time and place (10 points), memory (6 points), attention and calculation (5 points), and language (8 points). The area of memory was set as a total of six points, consisting of three points in memory encoding and three points in memory retrieval. The language area comprised a total of eight points: two points in naming, one point in repetition, one point in reading, one point in writing, and three points in carrying out verbal orders.

All patients were evaluated with the K-WAB and K-MMSE, with no more than one week separating the tests. Informed consent to the procedures was obtained from all participants, and the Health Service Human Research Ethics Committee and the Committee on Experimental Procedures Involving Human Subjects of Korea University approved this study.

Analysis

The results of the K-WAB were analyzed and patients were grouped based on a standard norm as normal or as having specific aphasic symptoms. The correlation between the K-WAB and K-MMSE scores was analyzed. Finally, multivariate analysis of covariance adjusting for educational years was conducted to compare the K-WAB and K-MMSE scores in accordance with the brain lesion location.

Results

Out of a total of 78 patients, 43 had lesions in the anterior circulation of the right hemisphere (55.1 %), 20 had lesions in the posterior circulation of the right hemisphere (25.6 %), and 15 were SAH patients (19.2 %). The average K-WAB and K-MMSE scores of all patients were 79.8 ($SD = 21.1$) and 19.2 ($SD = 7.5$), respectively (Table 1).

Based on the standard norm of the K-WAB, 28 patients were classified as normal (35.9 %) and the remaining 50 patients were classified as aphasic (64.1 %). The 50 aphasic patients were further classified according to the K-WAB: 30 patients were classified as having anomic aphasia, 11 patients as having Wernicke's aphasia, 4 patients as having transcortical sensory aphasia, 3 patients as having global aphasia, 1 patient as having conduction aphasia, and 1 patient as having transcortical motor aphasia. Patients with low K-MMSE scores were deemed to have severe aphasia (Table 2).

There was a positive correlation between total K-MMSE scores and the aphasia quotient at $r = 0.788$ ($p < 0.05$) (Fig. 1). Similarly, there was a positive correlation between entire sub-domains of the K-MMSE and the K-WAB ($p < 0.05$). Total K-MMSE scores were also significantly correlated with spontaneous speech ($r = 0.780$, $p < 0.05$), verbal comprehension ($r = 0.763$, $p < 0.05$), repetition ($r = 0.639$, $p < 0.05$), and naming ($r = 0.690$, $p < 0.05$) in the K-WAB test. The aphasia quotient was significantly correlated with all K-MMSE subareas, including orientation, memory, calculation, and language (Table 3).

In terms of the lesion location, there were significant differences among the three groups on the K-MMSE scores ($F_{(3,\ 75)} = 5.625$, $p < 0.01$). A Bonferroni post hoc test revealed that the anterior circulation and posterior circulation groups did not show significant differences in any items. Although the SAH group had a younger average age and higher educational level than the other groups, the SAH group scored significantly lower than the anterior circulation and posterior circulation groups in all subareas of the K-MMSE except for calculation ($p < 0.05$). On the K-WAB test, there were significant differences among the three groups on the K-WAB scores ($F_{(3,\ 75)} = 5.758$, $p < 0.01$). A Bonferroni post hoc test revealed that the SAH group had significantly lower scores than the other groups on all items except for repetition ($p < 0.05$) (Table 4).

Discussion

For the purpose of investigating the relationship between language performance and cognitive function among stroke patients, this study examined the test performance of patients who had experienced a nondominant hemisphere stroke. Two tests were used, a language test and a cognitive test. The study results can be summarized as follows. Only 35.9 % of stroke patients with a nondominant-hemispheric lesion were classified as normal

Table 2 K-WAB results

Type of aphasia classified by K-WAB	Frequency (%)	AQ (mean ± SD)	K-MMSE (mean ± SD)
Normal	28 (35.9)	93.4 ± 2.7	25.1 ± 3.5
Anomic	30 (38.5)	85.6 ± 3.0	19.8 ± 5.2
Conduction	1 (1.3)	75.4	17 ± 0.0
Transcortical sensory	4 (5.1)	72.9 ± 10.6	15.8 ± 6.2
Wernicke	11 (14.1)	52.9 ± 7.3	11.0 ± 4.2
Transcortical motor	1 (1.3)	55	2.0 ± 0.0
Global	3 (3.8)	12.4 ± 10.6	1.25 ± 2.5

K-WAB Korean version of Western aphasia battery, *K-MMSE* Korean version of mini-mental state exam

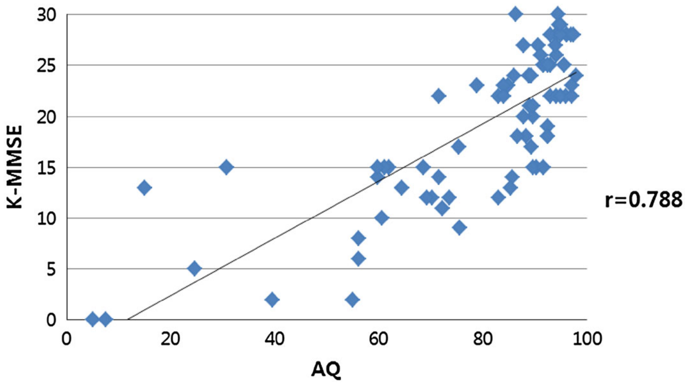

Fig. 1 The correlation between AQ and K-MMSE ($r = 0.788$)

Table 3 The correlation between K-WAB and K-MMSE subgroup scores

	Orientation	Memory	Calculation	Language	K-MMSE total
Spontaneous speech	0.630*	0.670*	0.503*	0.780*	0.780*
Auditory verbal comprehension	0.620*	0.701*	0.530*	0.728*	0.763*
Repetition	0.430*	0.660*	0.446*	0.632*	0.639*
Naming	0.545*	0.744*	0.476*	0.627*	0.690*
Aphasia quotient	0.626*	0.748*	0.531*	0.755*	0.788*

K-WAB Korean version of Western aphasia battery, *K-MMSE* Korean version of mini-mental state exam

* All presented data are $p < 0.05$

by language evaluation, with the remaining 64.1 % categorized as having aphasia. Patients had different severities of aphasia and exhibited all types of aphasia except for the Broca type. Their language performance was significantly correlated with cognitive functions. Differences were found with regard to lesion location, as the SAH group showed significantly lower performance on cognitive and language evaluations than both the anterior and posterior circulation groups.

Many participants showed poor performance on the language test, and the results of the language test showed a positive correlation with the results of the cognition test. In this study, all participants had brain damage in the nondominant hemisphere, and their core problem is likely to be cognitive deficit, rather than linguistic deficit; the study results probably reflect this point. If so, the results may be interpreted from the following two positions.

A first position to consider is that language is a higher level cognitive function. Language has long been considered an independent module among cognitive functions, and aphasia has been regarded as a language disorder without cognitive function defects. Nevertheless, to summarize the current literature on the association between aphasia and cognitive functions, language is not an independent area among cognitive functions but is the result of interactions between different cognitive, perceptual, and emotional functions, such as attention, memory, visual perception, and emotions; this view posits that language

Table 4 Subgroup analysis according to vascular territory ($n = 78$)

	Ant. circulation ($n = 43$)	Post. circulation ($n = 20$)	SAH ($n = 15$)
Age	66.7 ± 11.4	65.4 ± 11.8	57.9 ± 10.3
Education	8.7 ± 5.9	6.5 ± 5.6	11.1 ± 2.9*
K-MMSE			
Orientation (10)	6.9 ± 2.5	8.1 ± 2.5	3.9 ± 3.2*
Memory (6)	4.4 ± 1.5	4.5 ± 1.3	2.5 ± 1.9*
Calculation (5)	1.8 ± 2.0	1.9 ± 1.6	1.3 ± 1.8
Language (8)	6.3 ± 2.1	7.0 ± 1.1	5.0 ± 2.7*
Total (30)	19.9 ± 7.1	22.3 ± 5.3	13.1 ± 8.2*
K-WAB			
Spontaneous speech (20)	16.8 ± 4.1	17.3 ± 2.3	12.7 ± 5.6*
Auditory verbal comprehension (10)	7.9 ± 2.2	8.5 ± 1.5	6.5 ± 3.1*
Repetition (10)	8.6 ± 1.9	8.7 ± 1.6	7.2 ± 3.7
Naming (10)	8.0 ± 1.8	8.1 ± 2.0	6.1 ± 3.4*
Aphasia quotient (100)	82.8 ± 18.1	84.8 ± 15.1	64.5 ± 29.1*

K-WAB Korean version of Western aphasia battery, *K-MMSE* Korean version of mini-mental state exam

* $p < 0.05$

is a high-level epiphenomenon of harmonious left and right hemispheres (Helm-Estabrooks 2002; Nickels 2002). This theory is supported by the results of the present study, which suggest that there is a positive correlation between language and cognitive evaluation outcomes. Damage to the nondominant hemisphere may have decreased cognitive functions and resulted in language defects in the study participants.

The second position focuses on the influence of cognitive functions on the performance of language tasks. Unlike the argument that cognitive defects may trigger language defects, this position contends that cognitive defects may influence task performance rather than language itself, resulting in low task performance scores due to cognitive defects. This hypothesis is supported by the second language education area (Purpura 1997), which shows that speakers with similar linguistic capabilities may have different scores depending on how they employ cognitive strategies. In particular, memory strategies had the greatest influence on test results (Purpura 1997). This hypothesis is applicable to the results of the present study. In other words, cognitive function defects did not result in decreased language function. Instead, study subjects only received poor language evaluation results. This interpretation suggests that language evaluation results should not be viewed as an accurate reflection of language capabilities, and that existing static language evaluations have limits.

In short, decreased language performance in patients with a nondominant-hemispheric lesion may be due to decreased cognitive function or the negative effects of cognitive defects on task performance in language evaluation. Our results demonstrate that it is unreasonable to expect the absence of any impairment in the language capabilities of patients with nondominant-hemispheric lesions. Thorough language evaluation of all brain damage patients should be performed so that the language defects of such patients are not ignored. Language disorders that may be caused by brain injury or stroke are not confined to aphasia. Communication disorders with different presentations may be triggered by lesions in different locations, including right hemisphere lesions and SAH. Cognitive dysfunction can also accentuate aphasic symptoms in left-hemispheric brain lesion patients.

We expected to see differences in the cognitive and language evaluation results between the anterior and posterior circulation groups, but the results of the two groups did not differ in the present study. This finding indicates that lesions located in the right hemisphere, the nonlanguage-dominant hemisphere, did not directly affect cognitive and language capabilities. Furthermore, the anterior circulation blood vessels supply a wide area, so that patients with different lesion locations and diverse clinical characteristics may have been included in the anterior circulation group.

SAH patients were found to have more severe cognitive and language disorders than patients in the other two groups. Several different pathological mechanisms have been proposed to explain how cognitive disorder develops in SAH patients, including diffuse injury caused by ictal intracranial circulatory arrest (Lindberg et al. 1992; Carter et al. 2000), exposure of the brain to subarachnoid blood (Hunt & Hess 1968), hydrocephalus (Lindberg et al. 1992), and delayed cerebral ischemia or infarction (Lindberg et al. 1992). Clear underlying mechanisms have not been verified yet but it is known that SAH results in defects of verbal and nonverbal memory, psychomotor speed, executive function, visual-spatial function, and other cognitive domains (Hunt & Hess 1968; Le Roux et al. 1996). It is likely that diffuse effects on the brain induce cognitive degradation so that patients will exhibit decreased language function or lower performance on language tests.

It is noteworthy that none of the patients was categorized as having Broca's aphasia. Possibly, this is because overall cognitive function affects linguistic comprehension more than linguistic production. Interestingly, repetition was not significantly different among the three groups in this study, as each group obtained the best results in the language areas. Auditory verbal short-term memory participates in repetition among cognitive areas, and a previous study (Warrington et al. 1971) suggested that the supramarginal and angular gyri of the left hemisphere were associated with verbal short-term memory. Accordingly, the fact that the all the subjects in the present study had a nondominant hemisphere lesion with preserved supramarginal and angular gyri of the left hemisphere may help to explain the results.

Some studies point out that in the aphasia screening evaluation of the Frenchay Aphasia Screening Test (FAST), characteristics of participants such as visual perception deficiency, visual neglect, attention deficit, illiteracy, hearing impairment, confusion, etc., can have a negative impact on the specificity of the test (Al-Khawaja et al. 1996; Enderby et al. 1987). That is, even if it is a test that screens for aphasia, it is possible that not only the aphasia patients, but also those with other cognitive-communication disorder can be diagnosed as aphasic. The situation is similar in Korea. A research study that investigated the validity and reliability of the Korean version of FAST (K-FAST) in stroke patients showed that the test had low specificity (Ha et al. 2009). It is recommended that use of K-FAST with patients who are suspected of various cognitive dysfunctions requires special caution due to the potential false-positive error. In other words, the influences that the function of the nondominant hemisphere has on language or language evaluation are commonly recognized regardless of the language area.

In addition, there is a unique characteristic that should be accounted for in the case of Korea. It is the handedness of the subject. In previous literature, a number of research subjects who were diagnosed as having language disorder despite the lesion being in the nondominant hemisphere turned out to have left-handed or ambidextrous family members

(Joanette et al., 1983). This implies that a family history of left-handedness or ambidexterity affects the lateralization of language. These results show that it is necessary to investigate the family history of handedness when selecting a research sample, and the lack of such investigation is thought to be one of the limitations in this study. Meanwhile, the study excluded left-handed and ambidextrous people by examining the handedness of the subjects themselves. However, it is possible that this does not guarantee reliable selection either, considering the unique cultural context in Korea. Traditionally, using the left hand has been culturally avoided and such tendency remains strong, especially among elderly people. Left-handed people used to be forced to use their right hand from childhood, and those with natural left-handedness have eventually been corrected to be right-handed. There is a previous study which argues that behavioral handedness and neural handedness should be distinguished, considering the cultural pressure surrounding handedness in Korea (Pyun 2013). Hence, this study is likely to contain subjects who are behaviorally right-handed, but neurally left-handed or ambidextrous. The language impairment of these people can be a problem of language itself rather than a cognitive problem, similar to the symptom of aphasia patients with left hemisphere damage. Therefore, the clinical approach to these people will be different from patients with nondominant hemisphere lesion. Considering this, it is necessary to conduct more in-depth assessment of language function in the case of Korea, even if the subjects are patients with nondominant hemisphere lesion.

It was reported in 2003 that the survival rate of stroke patients had increased to 85 % (www.strokecenter.com, 2003). This implies that the number of survivors with impairment in mobility, sense, cognition, language, etc., is increasing. In Korea, the proportion of the population aged over 65 was 7.2 % in 2000 and had increased to 11.8 % in 2012. In 2030, the proportion is predicted to reach 24.3 %, making the nation a super-aged society (National Statistics Office, 2012). Stroke is one of the representative geriatric illnesses whose occurrence rate increases with age. It is conjectured that people who live a second life while embracing the aftereffects from the disorder will continue to increase. Accurate diagnosis of the types and severity of disabilities among stroke patients along with their impact is a starting point for rehabilitation. The results from this study propose that it is necessary to evaluate not only the superficially observable impairment, but also the possibility of potential disabilities caused by the primary impairment.

The results echo an earlier study by Benton & Bryan (1996), who observed linguistic deficit in 50 % of stroke patients with damage in the right hemisphere. However, the results of this study do not mean that a majority of stroke patients with damage in the nondominant hemisphere had linguistic deficits. It should be noted that the data collected here are the results of a one-time test. That is, the results only show that the participants took a K-WAB language test and scored low due to deteriorated task performance. It cannot be decided whether their language ability had actually deteriorated or they just did poorly and scored low on the particular test. Three participants scored less than 20 in AQ and were accordingly classified as having global aphasia (Table 2; Fig. 1). If these participants did not cooperate well during the test due to severe lack of attention, and thus the test was not conducted smoothly and the score was low, they might do much better in another study if their ability to concentrate can be improved. In this case, it cannot be said that the patients have linguistic disorder. More in-depth tests need to be conducted, instead of a one-time test, to determine whether the patients really have linguistic disorder or simply scored low on a particular test.

A limitation of the present study is that the K-MMSE used—a cognitive screening test—was not able to examine the relationship between the degree of impairment of subareas and language test performance in necessary detail. More in-depth research on cognitive disorder traits and language characteristics in a larger number of patients should be conducted. In particular, it should be explored whether decreased language performance in stroke patients with a nondominant hemisphere lesion is temporary, which would require a longitudinal study controlling for the time elapsed since the onset of the stroke.

Also, the patients' core problem may not be identified solely based on the results of this study. It cannot be clarified whether patients' cognitive ability deteriorated due to linguistic deficits, or their linguistic ability deteriorated due to cognitive deficits, or both. To clarify this, more diverse tests should be undertaken, including a language-based cognition test, nonlinguistic cognitive tests, language tests, and cognitive-communicative tests, and the results compiled to produce a conclusion.

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References

Aerden, L., Luijckx, G. J., Ricci, S., Hilton, A., Kessels, F., & Lodder, J. (2004). Validation of the Oxfordshire Community Stroke Project syndrome diagnosis derived from a standard symptom list in acute stroke. *Journal of the Neurological Sciences, 220*, 55–58.

Al-Khawaja, I., Wade, D. T., & Collin, C. F. (1996). Bedside screening for aphasia: A comparison of two methods. *Journal of Neurology, 243*, 201–204.

Amarenco, P., Bogousslavsky, J., Caplan, L. R., Donnan, G. A., & Hennerici, M. G. (2009). Classification of stroke subtypes. *Cerebrovascular Disease, 27*, 493–501.

Benton, E., & Bryan, M. T. (1996). Incidence of language disorder after right hemisphere CVA. *International Journal of Rehabilitation Research, 19*, 47–54.

Cappa, S. F., Papagno, C., & Vallar, G. (1990). Language and verbal memory after right hemispheric stroke: A clinical-CT scan study. *Neuropsychologia, 28*, 503–509.

Carter, B. S., Buckley, D., Ferraro, R., Rordorf, G., & Ogilvy, C. S. (2000). Factors associated with reintegration to normal living after subarachnoid hemorrhage. *Neurosurgery, 46*, 1326–1333.

Démonet, J. F., Thierry, G., & Cardebat, D. (2005). Renewal of the neurophysiology of language: Functional neuroimaging. *Physiological Review, 85*, 49–95.

Enderby, P., Wood, V., Wade, D., & Hewer, R. (1987). The Frenchay Aphasia screening test: A short, simple test for aphasia appropriate for non-specialists. *International Journal of Rehabilitation Medicine, 8*, 166–170.

Ha, J. W., Pyun, S. B., Lee, H. Y., Hwang, Y. M., & Nam, K. C. (2009). Reliability and validity analyses of Korean version of Frenchay Aphasia Screening Test in brain-damaged patients. *Communication Sciences and Disorders, 14*, 46–57.

Helm-Estabrooks, N. (2002). Cognition and aphasia: A discussion and a study. *Journal of Communication Disorders, 35*, 171–186.

Hunt, W. E., & Hess, R. M. (1968). Surgical risk as related to time of intervention in the repair of intracranial aneurysms. *Journal of Neurosurgery, 28*, 14–20.

Joanette, Y., Lecours, A. R., Lepage, Y., & Lamoureux, M. (1983). Language in right-handers with right-hemisphere lesions: A preliminary study including anatomical, genetic, and social factors. *Brain and Language, 20*, 217–248.

Kang, Y., Na, D. L., & Hahn, S. (1997). A validity study on the Korean mini-mental state examination (K-MMSE) in dementia patients. *Journal of the Korean Neurological Association, 15*, 300–308.

Kim, H. H., & Na, D. L. (2001). *Korean-version Western Aphasia battery (K-WAB).* Seoul: Paradise Welfare Foundation.

Le Roux, P. D., Elliott, J. P., Newell, D. W., Grady, M. S., & Winn, H. R. (1996). Predicting outcome in poor-grade patients with subarachnoid hemorrhage: A retrospective review of 159 aggressively managed cases. *Journal of Neurosurgery, 85*, 39–49.

Lindberg, M., Angquist, K. A., Fodstad, H., Fugl-Meyer, K., & Fugl-Meyer, A. R. (1992). Self-reported prevalence of disability after subarachnoid haemorrhage, with special emphasis on return to leisure and work. *British Journal of Neurosurgery, 6*, 297–304.

Lindell, A. K. (2006). In your right mind: Right hemisphere contributions to language processing and production. *Neuropsychological Review, 16*, 131–148.

Miller, R. M., Groher, M. E., Yorkston, K. M., Rees, T. S., & Palmer, J. B. (1998). Speech, language, swallowing, and auditory rehabilitation. In J. A. Delisa, B. M. Gans, & W. L. Bockenek (Eds.), *Rehabilitation medicine: Principles and practice* (3rd ed., pp. 239–268). Philadelphia: Lippincott-Raven.

Nickels, L. (2002). Therapy for naming disorders: Revisiting, revising, and reviewing. *Aphasiology, 16*, 935–979.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*, 97–113.

Purpura, J. E. (1997). An analysis of the relationships between test takers' cognitive and metacognitive strategy use and second language test performance. *Language Learning, 47*, 289–325.

Pyun, S. B. (2013). Re: Lateralization of cognitive functions in aphasia after right brain damage. *Yonsei Medical Journal, 54*, 1072–1073.

Ross, E. D., & Monnot, M. (2008). Neurology of affective prosody and its functional-anatomic organization in right hemisphere. *Brain and Language, 104*, 51–74.

Rovira, A., Grive, E., Rovira, A., & Alvarez-Sabin, J. (2005). Distribution territories and causative mechanisms of ischemic stroke. *European Radiology, 15*, 416–426.

Schmidt, G. L., DeBuse, C. J., & Seger, C. A. (2007). Right hemisphere metaphor processing? Characterizing the lateralization of semantic processes. *Brain and Language, 100*, 127–141.

Warrington, E. K., Logue, V., & Pratt, R. T. (1971). The anatomical localisation of selective impairment of auditory verbal short-term memory. *Neuropsychologia, 9*, 377–387.