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Association between baseline cognitive function and motor improvement in subacute hemiplegic stroke patients after 4 weeks of rehabilitation

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Abstract

Background & Objectives: Motor function and cognition are crucial for performing daily activities in patients with stroke. However, it remains unclear whether measures of motor function in patients with subacute hemiplegic stroke are related to baseline overall cognitive domains or to specific domains. The aim of this study is to determine which baseline cognitive domains are associated with improvements in motor function in patients with subacute hemiplegic stroke after 4 weeks of rehabilitation. *Method:* We retrospectively analyzed data of 129 hemiplegic patients with a first-ever stroke, who were admitted or transferred to the rehabilitation department within 3 months of stroke onset. We assessed patient demographics, baseline cognitive function using Mini-Mental Status Examination (MMSE), Wechsler Adult Intelligence Scale-IV, and Motor-Free Visual Perceptual Test-Revised (MVPT-R). Motor function was evaluated using the Berg Balance Scale, Timed Up and Go Test (TUG), 10 m gait time, and functional reach at baseline and after 4 weeks of rehabilitation. Pearson's correlation coefficient was used to analyze the correlation between improvements in motor and cognitive functions. *Results:* No significant correlation was observed between improvements in motor function and baseline MMSE, full-scale IQ, and MVPT total scores. However, subscale analysis of baseline MVPT demonstrated significant correlations between visual discrimination and all outcome effects. Additionally, visual closure and visual-spatial relationship exhibited significant correlation with TUG and 10 m gait velocity. *Conclusions:* This study highlighted the association between improvement in motor function, including balance and gait speed, and initial visual perception skills. Thus, evaluating and enhancing visual perception skills are essential for improving motor function in patients with subacute hemiplegic stroke.

Keywords: Stroke; motor function; cognition; visual perception; rehabilitation

INTRODUCTION

Stroke is the second-leading cause of death and disability worldwide.[1,2] Individuals often experience impairments in motor control, strength, and spasticity following stroke. Additionally, impairment with trunk control and balance function can occur because of paralysis of the limb and trunk muscles and impairment of proprioception after stroke.[3,4] Approximately 60–80% of patients after stroke cannot ambulate independently following rehabilitation, often resulting in a hemiplegic gait, which limits motor function.[5] Motor and balance impairments increase the risk of falls in these patients, leading to a decline in activities of daily life (ADL).[6] To overcome these problems, exercise therapy is administered to patients with subacute stroke.

However, patients with stroke develop motor as well as cognitive impairments. Approximately 60% of stroke survivors exhibit some degree of cognitive decline, and approximately one-third

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develop dementia within 1 year.[7,8] Impaired gait and balance are significant risk factors for cognitive impairment in patients with stroke.[9,10] Motor function has been reported to be a significant predictor of cognitive decline after stroke.[10] Additionally, patients with stroke who experience cognitive impairment tend to have poor balance function and exhibit a high risk of falls.[11] In other words, cognitive and motor functions in patients with stroke have reciprocal influence on each other. The theory suggesting that concurrent impairment in cognition and motor function shares underlying pathologies is gaining support from accumulating evidence.[12] However, to the best of our knowledge, the association between specific domains of cognitive function and motor function improvements in patients with subacute hemiplegic stroke has not been fully investigated.

To improve the effectiveness of rehabilitation therapy, identification of the cognitive domains associated with motor-skill recovery is crucial in patients with hemiplegic stroke. Once these cognitive domains related to motor skill recovery are identified, enhancing them can maximize the effectiveness of exercise therapy. In this study, we aimed to examine the relationship between baseline cognitive function and motor improvement in patients with subacute hemiplegic stroke after 4 weeks of rehabilitation.

METHODS

Subjects

We retrospectively analyzed the clinical data of consecutive patients admitted to our general hospital between March 2017 and June 2021. The inclusion criteria for this study were as follows: (1) first-ever stroke (cerebral infarction or hemorrhage), (2) hemiplegia, (3) transfer to the rehabilitation department within 3 months of the onset of stroke, (4) age >20 years, and (5) medical and neurological stability. In this study, the following patients were excluded: (1) those with missing data at the time of admission, (2) those discharged within 4 weeks, (3) those with pre-stroke cognitive impairment, and (4) those with conditions that could affect gait, such as fractures or nerve injuries. This study was approved by the institutional review board (IRB No. 2021-08-002). Patient data were de-identified before analysis by removing their name and address. The requirement for informed consent was waived due to the retrospective design of the study.

Data collection

Stroke was defined as the sudden onset of acute neurological deficits along with evidence of acute brain lesions, as evaluated through computed tomography or magnetic resonance imaging. Disease severity was assessed by using the National Institutes of Health Stroke Scale (NIHSS) score. Age at the time of admission, sex, and number of days since the onset of stroke were recorded for all patients. Information regarding functional assessment upon admission to the rehabilitation department after acute management of stroke and at discharge was retrieved from electronic medical records.

Rehabilitation therapy

All participants received rehabilitation treatment for five times per week for 4 weeks. Each day, the participants engaged in two sessions consisting of 1 h of physical therapy, 30 min of occupational therapy, and 30 min of daily ADL training. During physical therapy, range of motion (ROM) exercises for both lower extremities, strengthening exercises for the hemiplegic lower extremities, sitting balance training, sit-to-stand training, and gait training were performed. Occupational therapy included ROM exercises for both upper extremities, strengthening exercises for the hemiplegic upper extremities, and bimanual hand-activity training. ADL training included tasks necessary for activities of daily living, such as eating, grooming, and dressing; however, specific cognitive training was not included.

Assessment of cognitive variables

To examine the association between initial cognitive function and motor improvement, cognitive function was measured once at baseline, while mobility variables were measured twice—at baseline and reassessed before discharge, approximately 4 weeks after the initial assessment.

Baseline cognitive function was assessed at the time of admission using the Korean version of the Mini-mental Status Examination (K-MMSE), Korean Wechsler Adult Intelligence Scale-IV (K-WAIS-IV), and Motor-free Visual Perceptual Test-Revised (MVPT-R).

The MMSE is the most widely used screening tool for dementia and is often employed in studies concerning post-stroke cognitive function.[13] It comprises 19 items (orientation, verbal memory, concentration, calculation, language, praxis, and visuospatial construction).[14]

The WAIS-fourth edition is a cognitive function test for adults and adolescents. It includes a four-factor index score: verbal comprehension [VC], perceptual reasoning [PR], working memory [WM], and processing speed [PS], in addition to a higher-order Full-Scale Intelligence Quotient score (FSIQ).[15]

The MVPT-R is a valid test for measuring global visual perception. In contrast to conventional visual perception assessments, it focuses on evaluating visual perception while excluding the influence of motor skills. It assesses five sub-skills of visual perception, including visual discrimination, visual figure ground, visual short term memory, visual closure, and visual-spatial relationships.[16]

Assessment of mobility variables

Clinical assessments were performed to evaluate impairments in patients following a stroke. Initial assessments were conducted when patients were admitted to the rehabilitation department after acute stroke management, and a follow-up assessment was performed before discharge, approximately 4 weeks after the initial assessment. Postural balance was measured using the Berg Balance Scale (BBS) and functional reach test (FRT). The BBS reflects performance-oriented balance and includes simple mobility tasks (e.g., transfers, standing unsupported, and sit-to-stand) as well as difficult tasks (e.g., tandem standing, turning 360°, and single-leg stance).[17] It is used to assess balance function for activity limitations.[18] It is a consensus measurement of the international classification functioning activity and uses a five-point scale, ranging from 0 to 4, with a total score of 56. The FRT is a clinically accepted tool for measuring static balance.[19]

Gait was assessed using the Timed Up & Go Test (TUG) and 10m walking test (10MWT).[20,21] The TUG test consists of five stages: getting up, walking, turning around, walking, and sitting down. Patients are asked to stand up from an armchair, walk 3 m, turn around the cone, and sit down safely on the armchair. The 10 MWT is used to assess gait function as patients walk along a tapered line on the floor for a distance of 10 m. An experienced physical therapist measured the time taken for the TUG test and 10 MWT using a stopwatch.

Clinical assessments, including BBS, TUG, 10 m gait time, and FRT, were conducted at admission and before discharge, approximately 4 weeks after the initial assessment by an experienced physical therapist. Outcome effectiveness was calculated as the difference in scores taken at the time of admission and 4 weeks follow up.

Statistical analysis

Data were reported as means and standard deviations for continuous variables and as percentages for categorical variables. Pearson's correlation analysis was used to assess the relationship between improvements in mobility, balance, gait, and baseline cognitive function. Before performing Pearson's correlation analysis, multiple linear regression was conducted to adjust for the confounding variables. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS Statistics for Windows, version 21.0; IBM, Armonk, NY, US). Statistical significance was defined as $p < 0.05$.

RESULTS

Clinical characteristics of the participants

The study population consisted of 129 patients with hemiplegic stroke who were admitted to inpatient rehabilitation facilities within 90 days of stroke occurrence. Among them, 24 patients with missing data and 15 patients who were discharged within 4 weeks were excluded from the study. Of the remaining 90 patients, 37 with other neurological or orthopedic conditions (e.g., Parkinson's disease, fracture) that could affect rehabilitation functions were excluded. Consequently, 53 patients with stroke were included in the final analysis (Figure 1).

The participants included 45.2% men with a mean age of 61.00±14.25 years. The etiologies of brain injury were cerebral infarction (35.8%) and cerebral hemorrhage (64.20%). The mean duration since stroke onset was 18.42±14.19 days. The mean initial K-MMSE score, FSIQ, and MVPT score at the time of admission to the rehabilitation unit was 16.85±7.93, 64.65±16.5, and 19.89±10.05, respectively. The mean initial BBS score, TUG, 10m gait time, and FR at the time of admission to the rehabilitation department were 16.00±18.92, 58.43±29.12, 90.20±47.08 and 8.31±14.67, respectively. The demographic characteristics of the 53 participants are summarized in Table 1.

Correlation analysis of the improvement in mobility and initial comprehensive cognition

After adjusting for age, NIHSS score, and

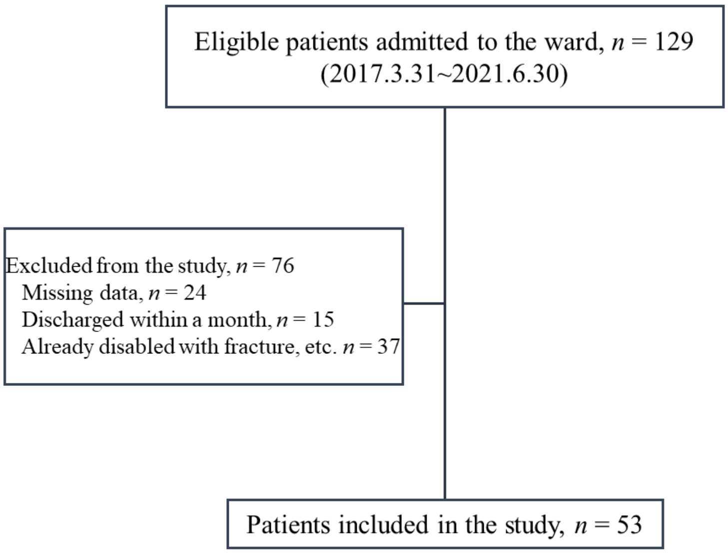

Figure 1. Flowchart of the study population

Table 1: Baseline characteristics stratified by outcome

Variables	N=53
Age (years)	61.00±14.25
Male (%)	45.2
Stroke type, n (%)	
Infarction	35.8
Hemorrhage	64.2
Side of impairment (%)	
Right	54.7
Left	45.3
NIHSS	4.36±3.89
Time to rehabilitation admission (days)	18.42±14.19
BBS score	16.00±18.92
TUG	58.43±29.12
10m gait time	90.20±47.08
FR	8.31±14.67
MMSE (score)	16.85±7.93
FSIQ	64.65±16.50
MVPT (score)	19.89±10.05

Values are mean ± standard deviation
NIHSS, National Institutes of Health Stroke Severity ; BBS, Berg balance scale ; TUG, Timed Up & Go Test ; FR, functional reach ; MMSE, Mini-Mental State Examination ; FSIQ, Full Scale Intelligence Quotient ; MVPT, Motor-Free Visual Perceptual Test

the time to rehabilitation admission, no significant association was observed between the improvement in mobility and the initial comprehensive cognitive scores, including MMSE, full-scale IQ, and MVPT total scores (Table 2).

Correlation analysis of the improvement in mobility and initial cognitive subscale scores

We also analyzed the association between improvement in mobility and initial cognitive subscale scores. In the correlation analysis, MVPT subscale for visual discrimination demonstrated a significant correlation with △BBS (r = 0.326, p = 0.025), △TUG (r = −0.320, p = 0.028), △10m gait time (r = −0.322, p = 0.027), and △FRT (r = 0.313, p = 0.032). Visual closure demonstrated a significant correlation with △TUG (r = −0.307, p = 0.036) (Table 2). Additionally, visual-spatial relationship demonstrated a significant correlation with △TUG (r = −0.502, p < 0.001) and △10m gait time (r = −0.460, p = 0.001) (Table 2).

DISCUSSION

In this study, we identified an association between initial impairments in visual perception skills, such as visual discrimination, visual closure, and spatial orientation, and an increased risk of falls during turning or sitting down among patients with subacute hemiplegia. Additionally, these impairments had a notable impact on walking speed in these patients. For patients recovering

Table 2: Pearson's correlation coefficient (*r*) between outcome effectiveness and the cognitive function adjusted for age, NIHSS, and time to rehabilitation admission (n=53)

		Pearson's correlation							
	Variables	**△BBS**		**△TUG**		**△10m gait time**		**△FR**	
		r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
MMSE score		0.079	0.599	-0.129	0.386	-0.161	0.279	0.049	0.743
WAIS									
FSIQ		0.188	0.207	-0.192	0.197	-0.183	0.219	0.254	0.085
Index scores	Verbal Comprehension	0.046	0.761	-0.094	0.531	-0.109	0.466	0.042	0.779
	Perceptual Reasoning	0.155	0.299	-0.292	0.046	-0.223	0.132	0.328	0.024
	Working Memory	0.215	0.146	-0.131	0.381	-0.129	0.387	0.172	0.247
	Processing Speed	0.281	0.056	-0.208	0.160	-0.186	0.211	**0.433**	**0.002***
MVPT									
Total Scores		0.127	0.395	-0.270	0.066	-0.246	0.096	0.194	0.192
Subscale scores	Visual Discrimination	**0.326**	**0.025***	**-0.320**	**0.028***	**-0.322**	**0.027***	**0.313**	**0.032***
	Figure ground	-0.026	0.863	-0.082	0.585	-0.070	0.640	0.027	0.855
	Visual Short Term Memory	0.068	0.652	-0.197	0.184	-0.168	0.260	0.214	0.148
	Visual Closure	0.161	0.279	**-0.307**	**0.036***	-0.251	0.088	0.090	0.545
	Visual-Spatial Relationship	0.243	0.100	**-0.502**	**<0.001***	**-0.460**	**0.001***	0.108	0.471

NIHSS, National Institutes of Health Stroke Severity ; BBS, Berg balance scale ; TUG, Timed Up & Go Test ; FR, functional reach ; MMSE, Mini-Mental State Examination ; WAIS, Wechsler Adult Intelligence Scale ; FSIQ, Full Scale Intelligence Quotient ; MVPT, Motor-Free Visual Perceptual Test
*P** <0.05 is significant. △== Value after 4 weeks of rehabilitation - Initial value

from stroke, activities of daily living, such as walking, can be quite challenging. Therefore, improving visual perception skills in patients with subacute hemiplegic stroke may lead to improved balance and gait speed, potentially reducing the occurrence of falls. This, in turn, could lead to an improvement in patients' activities of daily living and a reduction in social costs. This study suggests that the higher baseline visual perception skills might be associated with greater motor improvement after 4 weeks of rehabilitation.

Furthermore, this study highlighted the interdependence of cognition and motor functions, including balance and gait velocity. In earlier studies, the predominant belief among researchers was that human actions are solely regulated by the motor system. Nevertheless, recently, researchers have identified the essential role of a sensory-cognitive-motor network system in ensuring the precision of an action.[22,23] The sensory-cognitive-motor neural circuits encompass regions, including the frontal cortex, subcortical structures, basal ganglia, brainstem, and cerebellum,[24] all of which play a crucial role in ensuring safe and efficient postural control and enabling individuals to safely and effectively adapt to intricate home or community environments. Furthermore, cognitive function is associated with gait velocity.[25] Moreover, the simultaneous decline in cognitive function and motor skills may be linked to common underlying factors, a concept gaining increasing support in academic discourse.[12] These impairments could potentially stem from the stroke lesion itself or from structural and functional abnormalities that manifest at a distance from the lesion, a phenomenon known as diaschisis.[26] Previous studies have demonstrated that stroke survivors often exhibit focal stroke lesions, concomitant small-vessel disease, and neurodegeneration[2], all of which are associated with deficits in gait, balance, and cognitive abilities.[27] Through these mechanisms, a close association between baseline cognition and the improvements of motor function possibly exists in patients with subacute hemiplegic stroke.

Cognition encompasses various domains, including verbal and visual memory, perceptual, frontal executive, and speed and attention. Therefore, it is essential to use diverse tools for conducting cognitive assessment. In this study, cognitive assessment was performed using MMSE, WAIS, and MVPT-R. The MMSE assessed orientation, verbal memory, concentration, calculation ability, language, praxis and visuospatial construction; WAIS assessed VC, PR, WM, and PS; and MVPT-R measured global visual perception. Among various cognitive domains, visual perception exhibited a correlation with motor recovery. Visual perception is a highly complex integrative activity that can affect a patients' perception of their spatial orientation in the surrounding environment, the identification of figure-ground relationships, and discrimination of the dominant features of objects in moving environments. Visual perceptual disorders often manifest as clinical outcomes following stroke, leading to alterations in the processing and integration of visual information into other cognitive systems. Such alterations can impair a patient's ability to meet the fundamental demands of daily life. Previous studies have shown that patients with stroke rely excessively on visual input to compensate for poor postural and balance control.[28]

Motor skills, including balance and agility, develop harmoniously through various abilities. Exercise therapies, such as balance training, are often implemented to enhance motor skills. However, in this study, it was evident that to improve balance, training should encompass aspects, such as visual perception. Furthermore, this study suggested that comprehensive cognitive assessments, including evaluations of visual perception skills, such as in MVPT-R, should be conducted in patients with hemiplegic stroke. This approach enables the development of suitable rehabilitation treatments and the ability to predict patient outcomes.

This study had several limitations related to its retrospective design. First, the study included a small number of participants, which precluded the use of a multivariate logistic regression analysis. Second, although we aimed to identify the baseline cognitive domains affecting motor recovery, we assessed motor functions initially and reassessed before discharge (approximately 4 weeks later). However, since cognitive function was only evaluated at baseline, the direct relationship between cognitive changes and motor improvement could not be determined. Future studies should incorporate cognitive assessments both at baseline and after rehabilitation to clarify this relationship. Third, MMSE was used in this study instead of Montreal Cognitive Assessment (MoCA) for cognitive function assessment. Given that MoCA is more sensitive in detecting milder cognitive impairments, particularly in domains such as executive function and visuospatial abilities, future studies should consider incorporating cognitive assessments using MoCA in addition to MMSE.

In conclusion, the patients with hemiplegic stroke exhibited a significant independent correlation between initial visual perception skills and improvements in balance and gait speed. Thus, evaluating and enhancing visual perception skills is necessary for improving motor function in patients with subacute hemiplegic stroke.

DISCLOSURES

Ethics: The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Data availability: The corresponding authors take responsibility for the integrity of the data and the accuracy of the data analysis. The datasets generated during and/or analyzed during the current study are available from the corresponding authors on reasonable request.

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Conflict of interest. None

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