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Association between National Institutes of Health Stroke Scale and Functional Independence Measure scores in patients with ischemic stroke from convalescent rehabilitation outcomes

Joe Senda[1,2], Keiichi Ito[2], Tomomitsu Kotake[2,3], Masanori Mizuno[2], Hideo Kishimoto[2], Keizo Yasui[4], Hiroko Nakagawa-Senda[5], Masahisa Katsuno[6], Yoshihiro Nishida[7,8] and Gen Sobue[9]

[1]*Department of Neurology and Rehabilitation, Komaki City Hospital, Komaki, Japan*
[2]*Division of Rehabilitation, Kami-iida Rehabilitation Hospital, Nagoya, Japan*
[3]*Department of Physiology, Graduate School of Health Sciences, Toyohashi Sozo University, Toyohashi, Japan*
[4]*Department of Neurology, Japanese Red Cross Aichi Medical Center Nagoya Second Hospital, Nagoya, Japan*
[5]*Department of Public Health, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan*
[6]*Department of Neurology, Nagoya University Graduate School of Medicine, Nagoya, Japan*
[7]*Division of Rehabilitation, Nagoya University Hospital, Nagoya, Japan*
[8]*Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan*
[9]*Graduate School of Medicine, Aichi Medical University, Nagakute, Japan*

ABSTRACT

We investigated the associations among neurological severity, activities of daily living (ADLs), and clinical factors in patients with ischemic stroke in convalescent rehabilitation outcome. The study sample included 723 patients with ischemic stroke (484 men and 239 women; mean age, 73.2 ± 8.5 years) for inpatient convalescent rehabilitation. National Institutes of Health Stroke Scale (NIHSS) was used to measure the neurological severity, and Functional Independence Measure (FIM) was used to assess ADLs at discharge. Leukoaraiosis was graded based on periventricular hyperintensity (PVH) and deep white matter hyperintensity (DWMH) on magnetic resonance imaging. The correlations between NIHSS scores and total FIM scores were significant but relatively mild (r = –0.684, $P < 0.001$). Multiple regression analysis revealed that age and PVH grade significantly decreased their total FIM scores and affected the discrepancies between NIHSS scores at discharge ($P < 0.001$), but DWMH scores did not affect these results. Factors such as positive history of heart disease ($P = 0.008$) and bilateral infarction ($P = 0.038$) additionally decreased their total FIM scores and affected the discrepancies between NIHSS scores. These findings suggest that age, PVH, history of heart disease positive, and bilateral infarction in patients with ischemic stroke affected their performance of ADLs and the discrepancies between their neurological severities in convalescent rehabilitation outcomes, probably because the pathophysiological background of leukoaraiosis and these factors strongly decrease their ADL performance in post-phase ischemic stroke.

Keywords: ischemic stroke, National Institutes of Health Stroke Scale, Functional Independence Measure, leukoaraiosis, convalescent rehabilitation

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Corresponding Author: Joe Senda, MD, PhD
Department of Neurology and Rehabilitation, Komaki City Hospital, 1-20 Jyoubushi, Komaki 485-8520, Japan
Tel: +81-568-76-4131, Fax: +81-568-76-4145, E-mail: joesenda@gmail.com

Abbreviations:
ADLs: activities of daily living
NIHSS: National Institutes of Health Stroke Scale
FIM: Functional Independence Measure
MRI: magnetic resonance imaging
MRA: magnetic resonance angiography
PVH: periventricular hyperintensity
DWMH: deep white matter hyperintensity

INTRODUCTION

In the post-acute stroke period, functional independence measures (FIMs)[1] are used to assess the patient's degree of functional independence in performing activities of daily living (ADLs), according to a 2016 mandate by the Japanese National Insurance System. However, the National Institutes of Health Stroke Scale (NIHSS) is also a well-validated instrument to assess the level of impaired neurological functions secondary to stroke.[2] While FIM measures the level of required physical and occupational assistance, which is non-specific to the neurological severities, the NIHSS instrument measures impairment rather than disability. Therefore, the discrepancies between the NIHSS and FIM become significant clinical issues upon use in the convalescent rehabilitation stages.[3]

We can precisely diagnose ischemic stroke, particularly in the acute stages, using magnetic resonance imaging (MRI) and magnetic resonance angiography (MRA). These imaging sequences have enabled more suitable therapies for each ischemic stroke subtype. Moreover, leukoaraiosis can be detected and assessed by MRI and is revealed as white matter hyperintensities to affect both cognitive and motor functions.[4] Furthermore, the relationship between convalescent rehabilitation outcomes and leukoaraiosis in post-ischemic stroke patients has been established.[5]

This study investigated the examinations that influence the discrepancies between the neurological severities and ADLs in patients with post-ischemic stroke regarding convalescent rehabilitation outcomes. Therefore, we investigated the associations between NIHSS and FIM scores with radiological diagnoses such as leukoaraiosis and arteriosclerosis using MRI, MRA, and various other clinical factors.

METHODS

Patients

This study included patients with post-acute ischemic stroke who were hospitalized and discharged from the convalescent rehabilitation ward at the Kami-iida Rehabilitation Hospital from 2007 to 2015. Overall, 723 patients (484 men, 239 women; mean age, 73.2 ± 8.5 years) who fulfilled the following inclusion criteria were enrolled in the study: (1) complete independence in performing ADLs, such that the patient could live alone prior to their most recent ischemic stroke based on the modified Rankin Scale (score of 0)[6] and Barthel Index (score of 100)[7]; (2) no dementia, including Alzheimer's disease or mild cognitive impairment, prior to the most recent ischemic stroke (this medical history was determined from the case files and interviews with patients and their families); (3) right-hand dominance; (4) underwent intracranial MRI/MRA to diagnose ischemic stroke; and (5) no cancellation during convalescent rehabilitation courses owing to changes in their conditions or other reasons. The total FIM and NIHSS scores were

measured in all patients at discharge from our hospital. Written informed consent was obtained before patient participation. This study was approved by the ethics committee of the Kami-iida Rehabilitation Hospital.

MRI/MRA assessments

Intracranial MRI/MRA assessments were conducted in all 723 patients. White matter lesions were classified using the Fazekas criteria for periventricular hyperintensity (PVH) and deep white matter hyperintensity (DWMH) using T2-weighted or fluid-attenuated inversion recovery images on admission to our hospital. PVH was graded from 0–3 as follows: grade 0, none or rim only; grade 1, localized lesion depicted as pencil-thin lining or caps; grade 2, irregular hyperintensity, a smooth halo; and grade 3, lesion spreading into the deep white matter and periventricular region.[8] DWMH was graded from 0–3 as follows: grade 0, none; grade 1, punctate hyperintensity; grade 2, punctate hyperintensity with fusion tendency; and grade 3, large fused punctate hyperintensity (Fig. 1).[9] On MRA, the presence of ≥ 50% stenosis or occlusion in the intracranial trunk arteries in the visible range was considered "stenosis positive".[10] (Fig. 1)

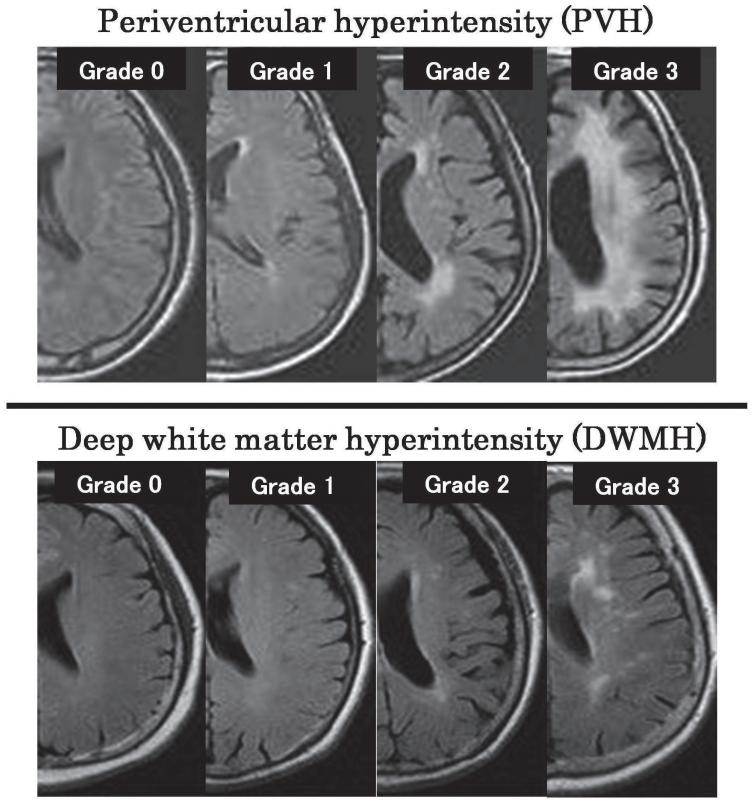

Fig. 1 Grading of PVH and DWMH was performed using axial T2-weighted or fluid-attenuated inversion recovery images according to the Fazekas scale
PVH: periventricular hyperintensity
DWMH: deep white matter hyperintensity

Ischemic stroke subtype classifications

Besides the National Institute of Neurological Disorders and Stroke-III classifications of lacunar infarction, atherothrombosis (AT), and cardiogenic embolism (CE),[11] we appended artery to artery embolism (A-to-A). Based on the Trial of ORG 10172 in Acute Stroke Treatment (TOAST) classification, A-to-A, which involves atherothrombotic mechanisms, can be distinguished from CE and AT. Embolic cases in which A-to-A and CE could not be diagnosed or the embolism source was unknown were classified as undetermined embolisms (UNs). Ischemic stroke due to a specific mechanism, such as vasculitis or postoperative ischemic stroke, was classified as "other".[12]

Statistical analyses

About the expressions for statistical analysis, quantitative variables were indicated as mean ± standard deviation. The chi-square test was selected to analyze multigroup qualitative variables, while the Kruskal–Wallis test (with the Scheffé method as a subtest) was selected for quantitative variables after excluding the UN and other ischemic stroke subtypes. A simple correlation analysis with Pearson's test and stepwise multiple regression were conducted to investigate the relationships between the NIHSS score vs the total FIM score. The dependent and primary independent variables were the total FIM and NIHSS scores at discharge, respectively. Other independent variables included: the use of medications for (a) hypertension, (b) hyperlipidemia, and (c) diabetes mellitus; (d) sex; (e) age; (f) history of stroke; (g) history of heart disease; (h) history of tobacco use; (i) lateralization of ischemic stroke lesion (right or left side); (j) whether the lesion was unilateral or bilateral; (k) presence of atrial fibrillation; (l) PVH grade; (m) DWMH grade; (n) presence of stenosis ≥ 50% or occlusion on MRA; and (o) average daily rehabilitation time. The history of stroke did not include the most recent ischemic stroke requiring convalescent rehabilitation. This history was also determined from case files and interviews with patients and their families, and the current diagnosis was not based on the information provided by the past attending neurologists or neurosurgeons. SPSS Version 24.0J (IBM SPSS Japan, Inc, Tokyo) was used for the statistical analyses. Additionally, these analyses were conducted separately for each male and female group.

RESULTS

The participants' demographics are summarized in Table 1-a. The average number of days from the onset of the most recent ischemic stroke to transfer to our hospital, including the period at the acute care hospital, was 31.6 ± 10.4 days. The daily rehabilitation time at our convalescent hospital was 115.0 ± 26.8 minutes/day. These results showed no significant differences between the male and female groups (Table 1-b, c).

Table 1-a Characteristics of patients with ischemic stroke in this study: All (n=723)

Parameter	All	LI	AT	A-to-A	CE	UN	Others
Number	723	54	305	105	129	93	37
Male/Female	444/279	31/23	176/129	73/32	80/49	63/30	21/16
Age (years)	73.2 ± 8.5	75.1 ± 8.7	72.6 ± 11.0	74.5 ± 7.7	75.5 ± 10.3	72.5 ± 10.1	67.6 ± 16.6
Hospital stay (days)	80.8 ± 35.4	75.1 ± 34.1	82.1 ± 34.9	77.9 ± 38.0	82.7 ± 36.5	81.6 ± 32.0	77.3 ± 38.6
Average daily rehabilitation time (minute)	115.0 ± 26.8	113.3 ± 12.2	114.0 ± 12.5	114.8 ± 22.0	116.8 ± 14.4	119.5 ± 22.2	116.5 ± 12.2
Hypertension	65.7%	80.5%	66.2%	69.5%	62.8%	60.2%	54.1%
Diabetes mellitus	27.9%	24.4%	29.8%	43.8%	21.7%	21.5%	10.8%
Hyperlipidemia	35.2%	39.0%	49.1%	37.1%	27.9%	33.3%	16.2%
Right	43.0%	51.9%	43.6%	41.9%	47.3%	39.8%	35.1%
Left	47.0%	49.1%	52.5%	41.0%	43.4%	34.4%	48.6%
Bilateral	10.0%	0%	3.9%	17.1%	9.3%	25.8%	16.2%
History of tobacco use	37.9%	35.1%	37.3%	38.1%	31.0%	52.6%	32.4%
History of stroke	23.4%	44.4%	16.1%	30.4%	27.1%	26.9%	10.8%
History of heart disease	10.2%	9.3%	7.2%	8.6%	17.0%	14.0%	8.1%
MRI-PVH	1.32 ± 0.96	1.93 ± 0.91	1.32 ± 0.94	1.37 ± 0.93	1.20 ± 0.91	1.19 ± 0.97	0.97 ± 1.01
MRI-DWMH	1.41 ± 0.90	1.98 ± 0.79	1.43 ± 0.86	1.50 ± 0.81	1.28 ± 0.94	1.24 ± 0.95	1.08 ± 1.01
MRA Stenosis ≥50% or occlusion (+)	40.8%	18.6%	31.8%	71.4%	41.1%	48.3%	40.5%
NIHSS at discharge	5.29 ± 5.38	3.07 ± 2.89	5.19 ± 4.98	5.13 ± 5.33	6.16 ± 5.94	7.26 ± 6.54	3.70 ± 4.41
Total-FIM at discharge	92.68 ± 26.39	98.41 ± 21.18	96.02 ± 24.13	93.27 ± 26.72	87.16 ± 28.98	82.19 ± 29.10	100.76 ± 23.96

Data shown as mean ± standard deviation or as percent of cases in the group.
LI: lacunar infarction
AT: atherothrombosis
A-to-A: artery-to-artery embolism
CE: cardiogenic embolism
UN: undetermined embolism, unable to differentiate A-to-A from CE
Others: other causes (dissection, vasculitis)
Right, Left, Bilateral: infarction in the right, left, or both sides, respectively
PVH: periventricular hyperintensity
DWMH: deep white matter hyperintensity
NIHSS: National Institutes of Health Stroke Scale
FIM: Functional Independence Measure

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Table 1-b Characteristics of patients with ischemic stroke in this study: Male (n=444)

Parameter	All	LI	AT	A-to-A	CE	UN	Others
Number	444	31	176	73	80	63	21
Age (years)	71.5 ± 10.3	74.8 ± 8.2	70.7 ± 9.9	72.1 ± 9.9	73.3 ± 10.2	70.9 ± 10.0	66.9 ± 16.2
Hospital stay (days)	80.2 ± 28.1	77.3 ± 23.7	81.4 ± 27.4	75.9 ± 30.9	82.7 ± 29.3	82.6 ± 26.4	72.4 ± 27.5
Average daily rehabilitation time (minute)	115.7 ± 45.9	111.4 ± 11.2	112.8 ± 12.0	115.0 ± 11.6	116.9 ± 12.4	124.6 ± 11.8	118.1 ± 15.6
Hypertension	65.8%	77.4%	69.3%	64.4%	58.8%	61.9%	61.9%
Diabetes mellitus	31.1%	25.8%	35.2%	43.8%	25.0%	20.6%	14.3%
Hyperlipidemia	39.4%	38.7%	50.0%	39.7%	28.8%	31.7%	14.3%
Right	44.1%	58.1%	41.5%	46.6%	51.3%	41.3%	19.0%
Left	45.7%	41.9%	54.0%	38.4%	40.0%	33.3%	66.7%
Bilateral	10.2%	0%	45.5%	15.0%	8.7%	25.4%	14.3%
History of tobacco use	56.0%	48.4%	60.2%	53.4%	46.3%	71.4%	52.4%
History of stroke	25.7%	45.2%	19.9%	30.1%	28.8%	27.0%	14.3%
History of heart disease	11.5%	9.7%	9.1%	8.2%	18.8%	14.3%	9.5%
MRI-PVH	1.23 ± 0.92	2.00 ± 0.89	1.22 ± 0.91	1.26 ± 0.85	1.08 ± 0.84	1.14 ± 0.96	0.90 ± 0.99
MRI-DWMH	1.34 ± 0.89	2.06 ± 0.77	1.35 ± 0.85	1.44 ± 0.78	1.19 ± 0.87	1.17 ± 0.96	1.05 ± 1.02
MRA Stenosis ≥50% or occlusion (+)	43.2%	19.4%	34.1%	69.9%	42.5%	49.2%	47.6%
NIHSS at discharge	5.34 ± 5.30	2.87 ± 2.83	5.17 ± 4.78	4.79 ± 4.90	5.73 ± 5.63	6.57 ± 5.70	4.19 ± 4.52
Total-FIM at discharge	94.57 ± 25.47	98.74 ± 19.59	98.17 ± 23.60	97.84 ± 24.45	90.43 ± 26.49	82.53 ± 29.26	100.2 ± 23.65

Data shown as mean ± standard deviation or as percent of cases in the group.
Study abbreviations are explained in a footnote to Table 1-a.

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Table 1-c Characteristics of patients with ischemic stroke in this study: Female (n=279)

Parameter	All	LI	AT	A-to-A	CE	UN	Others
Number	279	23	129	32	49	30	16
Age (years)	75.9 ± 11.3	75.6 ± 9.4	75.1 ± 11.9	78.2 ± 7.9	79.1 ± 9.5	75.7 ± 9.9	68.6 ± 17.5
Hospital stay (days)	81.7 ± 29.3	72.1 ± 30.6	83.2 ± 28.8	82.6 ± 35.5	82.6 ± 30.8	79.6 ± 24.8	83.6 ± 31.7
Average daily rehabilitation time (minute)	113.8 ± 13.1	116.0 ± 13.2	113.4 ± 14.3	114.3 ± 11.6	116.7 ± 10.9	108.8 ± 12.9	114.3 ± 9.9
Hypertension	65.6%	82.6%	62.0%	81.2%	69.3%	56.7%	43.8%
Diabetes mellitus	22.9%	21.7%	22.4%	43.8%	16.3%	23.3%	6.3%
Hyperlipidemia	39.8%	52.1%	48.1%	31.3%	26.5%	36.7%	18.8%
Right	41.2%	43.5%	46.5%	31.2%	30.6%	36.7%	56.3%
Left	49.1%	56.5%	50.4%	46.9%	59.2%	36.7%	25.0%
Bilateral	9.7%	0%	3.1%	21.9%	10.2%	26.6%	18.7%
History of tobacco use	7.5%	17.4%	6.2%	3.1%	6.1%	13.3%	6.3%
History of stroke	19.7%	43.5%	10.9%	31.3%	24.5%	26.6%	6.3%
History of heart disease	8.2%	8.7%	4.7%	9.4%	14.3%	13.3%	6.3%
MRI-PVH	1.46 ± 0.99	1.83 ± 0.94	1.46 ± 0.95	1.63 ± 1.07	1.41 ± 1.00	1.30 ± 0.99	1.06 ± 1.06
MRI-DWMH	1.52 ± 0.91	1.87 ± 0.81	1.53 ± 0.86	1.66 ± 0.86	1.43 ± 1.02	1.37 ± 0.93	1.13 ± 1.02
MRA Stenosis ≥50% or occlusion (+)	36.9%	17.4%	28.7%	75.0%	38.8%	46.7%	31.3%
NIHSS at discharge	5.46 ± 5.52	3.35 ± 2.95	5.22 ± 5.96	5.91 ± 6.22	6.88 ± 6.41	6.57 ± 5.70	3.06 ± 4.31
Total-FIM at discharge	89.68 ± 27.59	97.96 ± 23.36	93.09 ± 24.64	82.81 ± 29.07	81.82 ± 32.21	82.53 ± 29.26	101.40 ± 25.12

Data shown as mean ± standard deviation or as percent of cases in the group.
Study abbreviations are explained in a footnote to Table 1-a.

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In the correlation analysis, there was a mild correlation between the NIHSS and total FIM scores at discharge (r = –0.684, P < 0.001). In brief, a considerable number of patients had decreased FIM scores despite their low NIHSS scores, and discrepancies between their neurological severities and ADL performance were observed (Fig. 2).

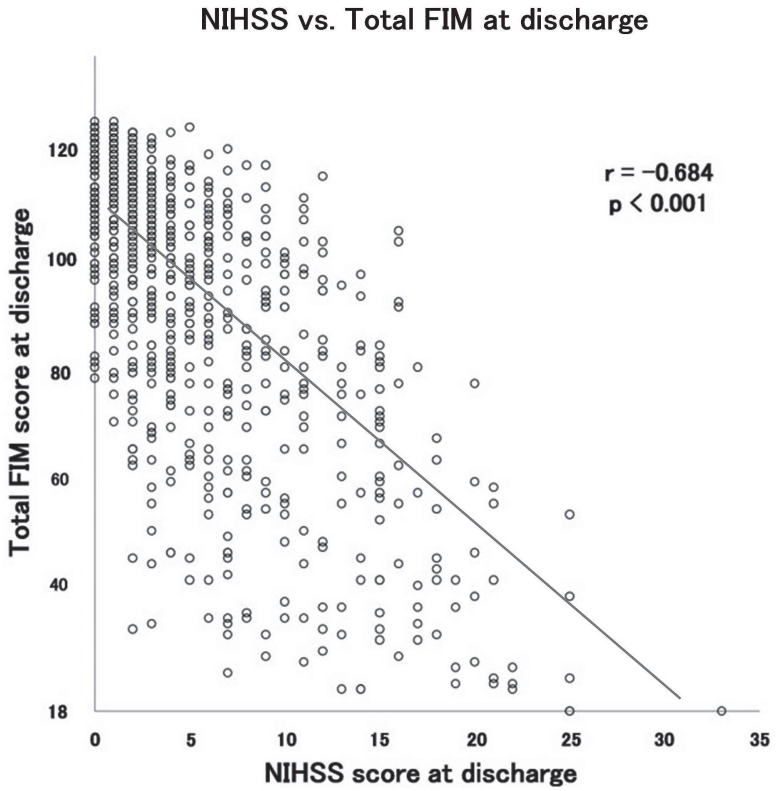

Fig. 2 Scatter diagrams of correlation analysis using Pearson's test between NIHSS score vs total FIM score at discharge
FIM: Functional Independence Measure
NIHSS: National Institutes of Health Stroke Scale

Next, we examined how patients' clinical factors affected the discrepancies between their neurological severities and ADLs a stepwise multiple regression analysis was conducted.

When the relationships between the NIHSS and FIM scores at discharge were considered for all patients, age, PVH grade, positive history of heart disease, and bilateral ischemic stroke lesions were significant deviating factors (Table 2-a). In the analysis according to the subtypes, the history of stroke positivity was a significant factor that affected the discrepancies between the NIHSS and FIM scores in the AT group. In the analysis according to sex, hypertension was a significantly affected factor in the male group (Table 2-b). Otherwise, PVH grade was a significantly affected factor in the female group (Table 2-c).

Table 2 Multiple linear regression analysis of associations between NIHSS and total FIM with clinical factors

(a) All (n=723)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.657	–3.222	<0.001	
Age	–0.270	–0.654	<0.001	
PVH grade	–0.145	–3.999	<0.001	0.602
History of heart disease positive	–0.063	–5.498	0.008	
Bilateral infarction	–0.049	–1.975	0.038	
(b) Male (n=444)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.684	–3.287	<0.001	
Age	–0.225	–0.555	<0.001	0.594
PVH grade	–0.188	–5.190	<0.001	
Hypertension	–0.063	–3.401	0.040	
(c) Female (n=279)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.639	–3.195	<0.001	
Age	–0.344	–0.842	<0.001	0.615
Bilateral infarction	–0.102	–4.392	0.007	
History of heart disease positive	–0.082	–8.202	0.032	

FIM: Functional Independence Measure
NIHSS: National Institutes of Health Stroke Scale
PVH: periventricular hyperintensity
β: standardized regression coefficient
B: unstandardized coefficient
R^2: coefficient of determination

Hypertension significantly affected the discrepancies in the A-to-A and CE groups (Table 3). Significant but mild correlations between age and PVH grade ($r = 0.290$, $P < 0.001$), and age and DWMH grade ($r = 0.287$, $P < 0.001$) were estimated from the viewpoint of multicollinearity. However, the variance inflation factor values of PVH or DWMH were relatively low in each stepwise multiple regression analysis (< 1.1 in each analysis). Therefore, we directly used each independent variable factor as PVH and DWMH grades in this study.

Table 3-a Multiple linear regression analysis of associations between NIHSS and total FIM with clinical factors according to each type of ischemic stroke: All (n=723)

(1) Lacunar (n=54)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.521	–3.811	<0.001	0.340
Age	–0.327	–0.799	0.005	
(2) Atherothrombosis (n=305)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.591	–2.863	<0.001	0.559
Age	–0.316	–0.693	<0.001	
PVH grade	–0.139	–3.582	0.001	
History of stroke positive	–0.091	–5.969	0.019	
(3) Artery-to-artery embolism (n=105)				
Influencing factors	β	B	*P* value	R^2
NIHSS score on admission	–0.688	–0.364	<0.001	0.600
Age	–0.188	–3.450	<0.001	
Hypertension	–1.000	–10.850	0.003	
(4) Cardiogenic embolism (n=151)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.720	–0.365	<0.001	0.712
Age	–0.100	–3.515	<0.001	
Hypertension	–1.028	–5.949	0.038	

Study abbreviations are explained in a footnote to Table 2.

Table 3-b Multiple linear regression analysis of associations between NIHSS and total FIM with clinical factors according to each type of ischemic stroke: Male (n=444)

(1) Lacunar (n=31)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.564	–3.829	<0.001	0.488
DWMH grade	–0.434	–11.014	0.003	
(2) Atherothrombosis (n=176)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.645	–3.184	<0.001	0.551
PVH grade	–0.189	–4.884	0.001	
Age	–0.193	–0.459	0.001	
History of stroke positive	–0.140	–8.230	0.007	

(3) Artery-to-artery embolism (n=73)				
Influencing factors	β	B	*P* value	R^2
NIHSS score on admission	–0.679	–3.386	<0.001	0.584
Age	–0.378	–0.931	<0.001	
Hypertension	–0.219	–11.079	0.006	
(4) Cardiogenic embolism (n=80)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.769	–3.868	<0.001	0.747
Hypertension	–0.248	–0.841	0.002	

Study abbreviations are explained in a footnote to Table 2.

Table 3-c Multiple linear regression analysis of associations between NIHSS and total FIM with clinical factors according to each type of ischemic stroke: Female (n=279)

(1) Lacunar (n=23)				
Influencing factors	β	B	*P* value	R^2
History of heart disease positive	–0.535	–43.812	0.020	0.539
NIHSS score at discharge	–0.495	–3.965	0.030	
(2) Atherothrombosis (n=129)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.552	–2.584	<0.001	0.578
Age	–0.454	–0.941	<0.001	
(3) Artery-to-artery embolism (n=32)				
Influencing factors	β	B	*P* value	R^2
NIHSS score on admission	–0.794	–3.709	<0.001	0.531
Age	–0.292	–1.076	0.033	
(4) Cardiogenic embolism (n=49)				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.769	–3.868	<0.001	0.747
Age	–0.249	–0.841	0.002	

Study abbreviations are explained in a footnote to Table 2.

DISCUSSION

Our results revealed that the outcomes of convalescent rehabilitation following ischemic stroke showed discrepancies between patients' NIHSS and Total FIM scores were influenced by several factors, particularly the presence of leukoaraiosis on MRI. In our previous study, the participants' total and motor FIM scores correlated with PVH, and the cognitive FIM score correlated with DWMH in patients with ischemic stroke during convalescent rehabilitation.[5] To the best of our knowledge, the discrepancies between the NIHSS and total FIM in patients with ischemic stroke who were affected by the degree of leukoaraiosis had not been clearly described, especially about

using PVH or DWMH grades.

Recently, imaging biomarkers have gained particular interest, given that neuroimaging is a prerequisite to patient selection for acute therapy. Leukoaraiosis may be a viable biomarker because it can be determined by standard neuroimaging and has been a consistent predictor of poor post-stroke outcomes, even though it is administered after endovascular stroke therapy.[8,10,13] Pathologically, the dilation of the perivascular space and the clarification of the myelin sheath are ordinary in leukoaraiosis. However, PVH is worsened by factors such as age and hypertension, otherwise, DWMH is worsened by vascular risk factors such as thrombosis.[8,9]

The degree of PVH or DWMH assessed using MRI is not necessarily congruous with the pathological severity of white matter lesions.[14] However, an increase in white matter hyperintensities on MRI has been associated with decreased motor and cognitive functions in non-disabled patients.[4] Pathologically, in lesions where PVH borders the lateral ventricle, long association and projection fibers that connect brain lobes exist in large numbers, and reduced motor function may result from disturbances to these fibers.[15] Abnormal white matter lesions indicated as PVH can impair walking and balance because the lower extremities' sensory, motor, and balance functions decrease following disturbances to the superior longitudinal fasciculus fibers, which connect the sensorimotor areas from the frontal lobes.[16,17]

This study revealed that PVH, not DWMH, affected the discrepancies between the NIHSS and total FIM scores. We believe that this is primarily because the NIHSS is a 15-item neurologic examination stroke scale used to evaluate the effect of acute cerebral infarction on consciousness, language, neglect, visual-field loss, extraocular movement, motor strength, ataxia, dysarthria, and sensory loss. In other words, the sections pertaining to cognitive function contained only the following four items: (1a) level of consciousness, (1b) questions, (1c) commands, and (9) language functions. This highlights a limited cognitive function-related assessments using simple questionnaires, and the neurological severities as motor functions are emphasized in the NIHSS.[2]

Furthermore, previous studies indicate that the right-hemisphere lesion volumes have less effect on NIHSS scores, especially on the cognitive function-related assessments, than left-hemisphere lesion volumes.[18,19] However, the FIM scale is based on independence in ADLs. It includes 13 motor and six cognitive items that rate patients' ability to independently perform ADLs using a seven-level scale. Though it is also dominated by motor functions, it has more cognitive components and less laterality of hemispheres than the NIHSS.[1,20] Thus, PVH, the predictor of motor function recovery, was closely related to the discrepancies between NIHSS and total FIM scores.

Additionally, the degree of white matter lesions indicated by PVH may influence the presence of foci size, spatial neglect, and lesion site, which decreases their ADLs.[21-23] Therefore, intracranial MRI assessments are also necessary for patients undergoing convalescent rehabilitation.

Another important finding was the influence of positive histories of heart disease and hypertension medication on the discrepancies between NIHSS and total FIM scores in some sub-analyses. Histories of heart disease and hypertension are important factors associated with reduced ADL performance.[24,25] Thus, we must focus on the possibility that histories of heart disease may result in discrepancies between neurological severities and ADL performance.

In accordance with previous studies, we found that factors such as age[26,27] and bilateralism of the ischemic stroke lesions[28] were associated with functional decline in ischemic stroke patients from the analysis of the NIHSS and total FIM scores at discharge.

This study has some significant limitations. First, this was not a population-based study (patients were referred by acute care hospitals or stroke units), and not all patients who survived strokes were enrolled. Furthermore, the study was performed on a population admitted to rehabilitation hospitals requiring physical rehabilitation. Therefore, it does not reflect the actual functional disability of stroke patients in general. Second, the participants' ADLs before their

participation in our convalescent rehabilitation programs were assessed only from medical history interviews; more accurate compilations and assessments using cognitive function scales, such as the Montreal Cognitive Assessment,[29] were not performed. Carotid artery echograms and cervical MRA were also not performed, and we only assessed the condition of the intracranial, not extracranial, arteries. Third, as mentioned before, the NIHSS and FIM have fundamentally different assessment structures, making it difficult to evaluate the relationships between them directly; this methodology remains controversial. However, the most important of this study's objectives was the investigation of the direct associations between these two clinical assessments. Fourth, some independent variables that may affect FIM scores were not assessed in this study, such as sarcopenia and frailty,[30,31] nutritional conditions,[32] and living environment.[33,34] Future research must address these aspects. Fifth, multiple linear regression analysis with a stepwise approach was performed in this study using variable factors from our data directly, but this methodology increases the possibility of type 1 errors.

Alternately, we investigated the factors that might affect the associations between neurological severities and ADL performance assessments in ischemic stroke patients' convalescent rehabilitation outcomes by combining diagnostic elements mainly used in the acute care stage. We demonstrated that the degree of leukoaraiosis estimated on MRI influenced the rehabilitation outcomes and induced discrepancies between neurological severities and ADL performance. This study revealed that MRI/MRA could be used to detect and diagnose ischemic stroke regions and understand the influences of white matter abnormalities such as leukoaraiosis in the convalescent rehabilitation stage. Overall, the neuroimaging finding as PVH and clinical factors are associated with ADL independently of neurological severity among patients with ischemic stroke.

This study also reveals that post-ischemic stroke patients with relatively mild sequelae characterized by low NIHSS or high FIM scores were admitted to the convalescent rehabilitation hospital to improve their ADL performance. Japan has recently become a super-aged society, and age has a significant and negative effect on the neurological severities and ADL performance of ischemic stroke. Thus, although the conditions of ischemic stroke are mild, the discrepancies between the condition's neurological severity and ADL performance in post-stroke patients may be greater in this super-aged society.

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CONFLICTS OF INTEREST

The authors state that they have no conflicts of interest.

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SUPPLEMENTAL TABLES

Multiple linear regression analysis of associations between NIHSS and total FIM with clinical factors according to the classifications of total FIM score

(a) FIM scores from 18 to 55, n=84 (Male=46, Female=38, Age 79.1±8.7) Pearson correlation coefficient: *r*= –0.427, *P* value <0.001				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.460	–0.718	<0.001	0.238
PVH grade	–0.238	–2.441	0.017	
(b) FIM scores from 56 to 99, n=257 (Male=152, Female=105, Age 76.4±9.4) Pearson correlation coefficient: *r*= –0.324, *P* value <0.001				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.420	–1.079	<0.001	
Age	–0.386	–0.517	<0.001	0.249
Hypertension	–0.112	–2.814	0.048	
(c) FIM scores from 100 to 126, n=382 (Male=247, Female=135, Age 70.0±11.1) Pearson correlation coefficient: *r*=–0.371, *P* value <0.001				
Influencing factors	β	B	*P* value	R^2
NIHSS score at discharge	–0.418	–1.047	<0.001	
Age	–0.253	–0.158	<0.001	0.278
PVH grade	–0.178	–1.352	<0.001	
History of heart disease positive	–0.105	–2.889	0.032	

FIM: Functional Independence Measure
NIHSS: National Institutes of Health Stroke Scale
PVH: periventricular hyperintensity
β: standardized regression coefficient
B: unstandardized coefficient
R^2: coefficient of determination