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Clinical profiles and functional outcomes in elderly stroke survivors undergoing neurorehabilitation: a retrospective cohort study

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Abstract

Background This retrospective study characterizes clinical profiles and evolution of elderly stroke patients undergoing neurorehabilitation. Additionally, it identifies predictors of functional outcomes and hospital length of stay (LOS). For this purpose, patients aged ≥ 60 years admitted for neurorehabilitation within 6 months post-stroke, were recruited between January 2015 and August 2022. Rehabilitation profiles were identified using two-step clustering analysis, including the Modified Rankin Score (mRS), the National Institutes of Health Stroke Scale (NIHSS) and the motor and cognitive Functional Independence Measure (m-FIM and c-FIM) upon admission. FIM-effectiveness was calculated as (FIM-discharge–FIM-admission)/(maximum FIM–FIM-admission). Linear regression analyses were conducted to identify predictors of functional outcomes and LOS (days).

Results The study enrolled 104 patients (68 male; mean age = 69.45 ± 6.5 years). Three clusters were identified: "Moderate" [NIHSS = 7.70 ± 3.21, motor-FIM = 59.42 ± 12.24, cognitive-FIM = 26.96 ± 4.69, mRS = 4 (4–4), aphasia = 41.7%, severe dysphagia = 4.2%, LOS = 45 (33.25–59) days]; "Moderate-severe" [NIHS = 10.40 ± 3.23, motor-FIM = 28.00 ± 7.74, cognitive-FIM = 25.92 ± 6.55, mRS = 4 (4–5), aphasia = 13%, severe dysphagia = 6.4%, LOS = 61 (45–92) days]; and "Severe" group [NIHS = 18.76 ± 4.19, motor-FIM = 16.12 ± 6.69, cognitive-FIM = 10.58 ± 4.14, mRS = 5 (5–5), aphasia = 60.6%, severe dysphagia = 42.4%, LOS = 71 (60.5–97.5) days]. The motor and cognitive FIM effectiveness significantly improved in the "Moderate" (m-FIM-effectiveness = 33.70 [12.16–53.54]; c-FIM-effectiveness = 33.3 [0–50.0]) and "Moderate-severe" cluster (m-FIM-effectiveness = 31.15 [10.34–46.55]; c-FIM-effectiveness = 33.3[0–63.16]) compared to the "Severe" cluster (m-FIM-effectiveness = 5.77 [0–18.77]; c-FIM-effectiveness = 4.65 [0–22.30]) ($p = 0.001$ and $p = 0.025$), whereas aphasia and dysphagia improved in all groups ($p > 0.1$). Severe stroke (NIHSS) ($\beta = 0.33$, $p < 0.001$), greater functional dependence (mRS) ($\beta = 0.24$, $p = 0.013$), presenting dysphagia ($\beta = 0.30$, $p = 0.002$), neuropathic pain ($\beta = 0.22$, $p = 0.02$), depression ($\beta = 0.29$, $p = 0.003$) or in-hospital infections ($\beta = 0.23$, $p = 0.02$) predicted higher LOS.

Conclusions Patient clustering proves valuable in identifying distinct stroke rehabilitation profiles. Low FIM on admission, severe dysphagia, in-hospital infections, and psychotropic medication use, predicted poor functional outcomes and longer hospitalization.

Keywords Stroke, Elderly, Rehabilitation, Functional outcomes, Hospital length of stay

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Background

Stroke is the second leading cause of death worldwide and the third-leading cause of death and disability combined, as well as an increased economic burden [1]. The number of stroke survivors in Europe is expected to increase by 27% in the next 3 decades, mainly due to population aging and improved acute stroke care [2]. Advancing age in patients admitted to rehabilitation is associated with reduced effectiveness of intervention on functional outcomes, higher rate of infection and pressure sores, and higher mortality rates [3]. However, the evidence regarding the effectiveness of rehabilitation in elderly stroke survivors is limited.

Stroke recovery and functional independence at 5 years is significantly less favorable in older patients with multiple comorbidities and those with pre-stroke functional dependence [4, 5]. Other factors, such as cognitive impairment, aphasia, and dysphagia, are associated with more severe stroke, higher rehabilitation complexity, and negative prognosis of recovery in patients over 65 years old [6, 7]. According to the Cerebrovascular Diseases Master Plans of the Health Department of Catalonia, stroke patients with moderate to severe functional impairment able to participate in intensive rehabilitation programs (at least 3 h of daily activities) are candidates for admission to specialized rehabilitation hospitals [8]. Elderly stroke patients who are unable to participate in an intensive rehabilitation program, due to associated medical conditions and premorbid functional status, have limited therapeutic objectives and potential for recovery. Therefore, they are mainly candidates for rehabilitation in an extended care facility [6]. However, other studies have shown that intensive rehabilitation can produce significant functional improvements at all ages [3]. Therefore, identifying socio-demographic and clinically relevant factors associated with positive prognostic for stroke recovery in older adult patients could be useful to set realistic goals, tailor therapeutic intervention, to optimize healthcare resources, and to facilitate early planning for discharge destinations.

The current retrospective longitudinal study aims to characterize the clinical profiles and functional outcomes in elderly stroke patients undergoing neurorehabilitation. The analytical framework integrates cluster analysis, with a particular emphasis on stroke severity and functional status at the time of admission. The secondary objective is to identify the sociodemographic and clinical predictors of functional status at discharge, as well as the duration of hospitalization.

Methods

We conducted a retrospective observational study in old stroke patients who underwent inpatient rehabilitation at Institute Guttmann between January 2015 and August 2022.

Eligible participants were adult patients over the age of 60 with ischemic or hemorrhagic stroke, who underwent at least 4 weeks of inpatient multidisciplinary neurorehabilitation within the first 6 months following a stroke. Patients presenting stroke secondary to traumatic brain injury, brain tumors or infections were excluded from the study.

Data of eligible patients were collected through the Comprehensive Information System of Institute Guttmann (SIIG) [9]. Missing data were collected from clinical records.

The Research Ethics Committee of the Fundacio La Unió approved the request to waive the documentation of informed consent. The study has been carried out in accordance with the recommendations of the Declaration of Helsinki. The study conforms to the STROBE standards for observational studies (www.strobe-statement.org).

The Institute Guttmann is a tertiary healthcare center in Barcelona (Spain) specializing in intensive rehabilitation of patients with neurological diseases. Older stroke patients have access to the rehabilitation programs through private health insurance or privately.

We collected the following variables: demographic data [age and sex], stroke type [ischemic or hemorrhagic], stroke location [right, left or bilateral], territory of ischemic stroke [total anterior circulation infarcts (TACI), partial anterior circulation infarcts (PACI), lacunar circulation infarcts (LACI), and posterior circulation infarcts (POCI)] according to the Oxfordshire Community Stroke Project (OCSP) [10], revascularization treatment for ischemic stroke (intravenous thrombolysis; mechanical thrombectomy; or both), complications of revascularization treatment [hemorrhagic transformation], type of hemorrhagic stroke [intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH)], complications of hemorrhagic stroke [subarachnoid extension of ICH, intraventricular extension or hydrocephalus], surgical treatment of hemorrhagic stroke [decompressive craniectomy or ventricular drainage].

Clinical scales have been used to assess: stroke severity on admission using the National Institute of Health Stroke Scale (NIHSS) [11]; functionality on admission and discharge based on the motor and cognitive domains of the Functional Independence Measure (FIM) scale [12]; the degree of independence using the Modified Rankin Scale (mRS) [13]; and dysphagia severity was assessed on the Functional Oral Intake Scale (FOIS) [14].

Language was evaluated by speech therapists and neuropsychologists using the Test Barcelona [15] and the PMR test, which evaluates the phonological verbal fluency for the letters P, M, R and represents the Spanish version of the FAS letter fluency task [16]. For the current study, three subtest were employed as screening tools for impaired verbal repetition, naming, and comprehension, whereas the PMR test was used to evaluate verbal fluency.

Obesity was defined as Body Mass Index (BMI) > 30 kg/m^2 according to the WHO criteria.

Cardiovascular risk factors: diabetes mellitus, dyslipidemia, hypertension, atrial fibrillation, ischemic heart disease, previous stroke, obesity, current smoking or alcohol consumption were recorded as binary variables ("yes" = 1; "no" = 0).

Medication use during hospitalization: antidepressants, antipsychotics, antiepileptics for seizure treatment, antiepileptics for neuropathic pain (gabapentin, pregabalin), and benzodiazepines were recorded as binary variables ("yes" = 1; "no" = 0).

Patient safety-related complications during hospitalization: pressure ulcers, falls, hospital acquired infections (respiratory, urologic, skin and soft tissues), presence of multi resistant infections were recorded as binary variables ("yes" = 1; "no" = 0).

All patients underwent rehabilitation tailored to their neurological sequelae, according to their functional state and tolerance, guided by goals set by the rehabilitation team. Patients underwent two to four daily sessions of physiotherapy and occupational therapy (60 min) 6 days/week, one daily session of individualized speech and swallowing therapy (30 min) 3 times/week, and one daily session of neuropsychological training (60 min) 3 times/week. It is important to note that this description does not constitute an intervention study.

Outcome variables were m-FIM, c-FIM, FOIS at discharge and the hospital length of stay.

Aphasia improvement at discharge was recorded as binary variable for specific domains (expression, comprehension, repetition and naming) ("improvement" = 1; "no improvement" = 0).

We calculated functional gain, efficiency, and effectiveness, which allow evaluating the absolute change in functional scores as well as the time-dependent and the state-dependent improvement in functional scores. FIM gain = FIM at admission-FIM at discharge. FIM efficiency = FIM gain/LOS. FIM effectiveness = FIM gain/(maximum FIM score- FIM score on admission). FIM gain, efficiency and effectiveness were calculated for the motor and cognitive sub-scores [3]. Similarly, FOIS gain = FOIS on admission-FOIS at discharge. FOIS efficiency = FOIS gain/LOS. FOIS effectiveness = FOIS gain/(maximum FOIS score−FOIS score on admission). Dysphagia at discharge was recorded as binary variable.

Statistical analyses were conducted with a commercial Statistical Package for Social Sciences version 16.0.1 (SPSS Inc., Chicago, IL, USA, 2007).

Descriptive statistics were used for demographic and clinical characteristics. Continuous parametric variables are presented as Mean ± SD or median [25th–75th percentile], whereas categorical variables are presented as numbers and percents. Shapiro–Wilk's test was used to examine the normality of distribution. To identify possible rehabilitation profiles, we conducted two step clustering analysis including standardized m-FIM, c-FIM, NIHSS and mRS on admission, which were reported as predictors of rehabilitation outcomes in multiple studies and are considered relevant functional and independence measures for admission decision-making process. We explored possible grouping of patients into two, three or four clusters. The three clusters model was the optimal number of clusters with a silhouette coefficient 0.5 (good quality). To validate the clusters, we compared the dependent variables between cluster using general linear models for parametric data (m-FIM, c-FIM, NIHSS) or the Kruskal–Wallis test for nonparametric data (mRS) (Fig. 1). A General linear models with Bonferroni post hoc analyses were used to compare baseline parametric variables (age and BMI) as well as to compare rehabilitation outcomes between clusters (m-FIM and c-FIM at discharge with admission score as covariate). We used the Kruskal–Wallis test with the Mann–Whitney *U* test as post hoc to compare nonparametric variables (mRS and time since stroke to admission) and outcomes (gain, efficiency and effectiveness of m-FIM, c-FIM and FOIS) between groups. The χ^2 test was applied to test relationships between categorical variables and clusters.

We performed simple regression analyses to study the relationship between functional outcomes (m-FIM, c-FIM) and the LOS (days) and dependent variables and sociodemographic (age, gender) and clinical characteristics (stroke characteristics and severity, functional variables on admission, associated comorbid conditions, inhospital complications or medication use) as independent variables.

Results

A total of 169 patients were identified throughout the database of which 65 patients were excluded: 12 patients presented with severe comorbidity (traumatic brain injury, hypoxic brain injury, cancer or other

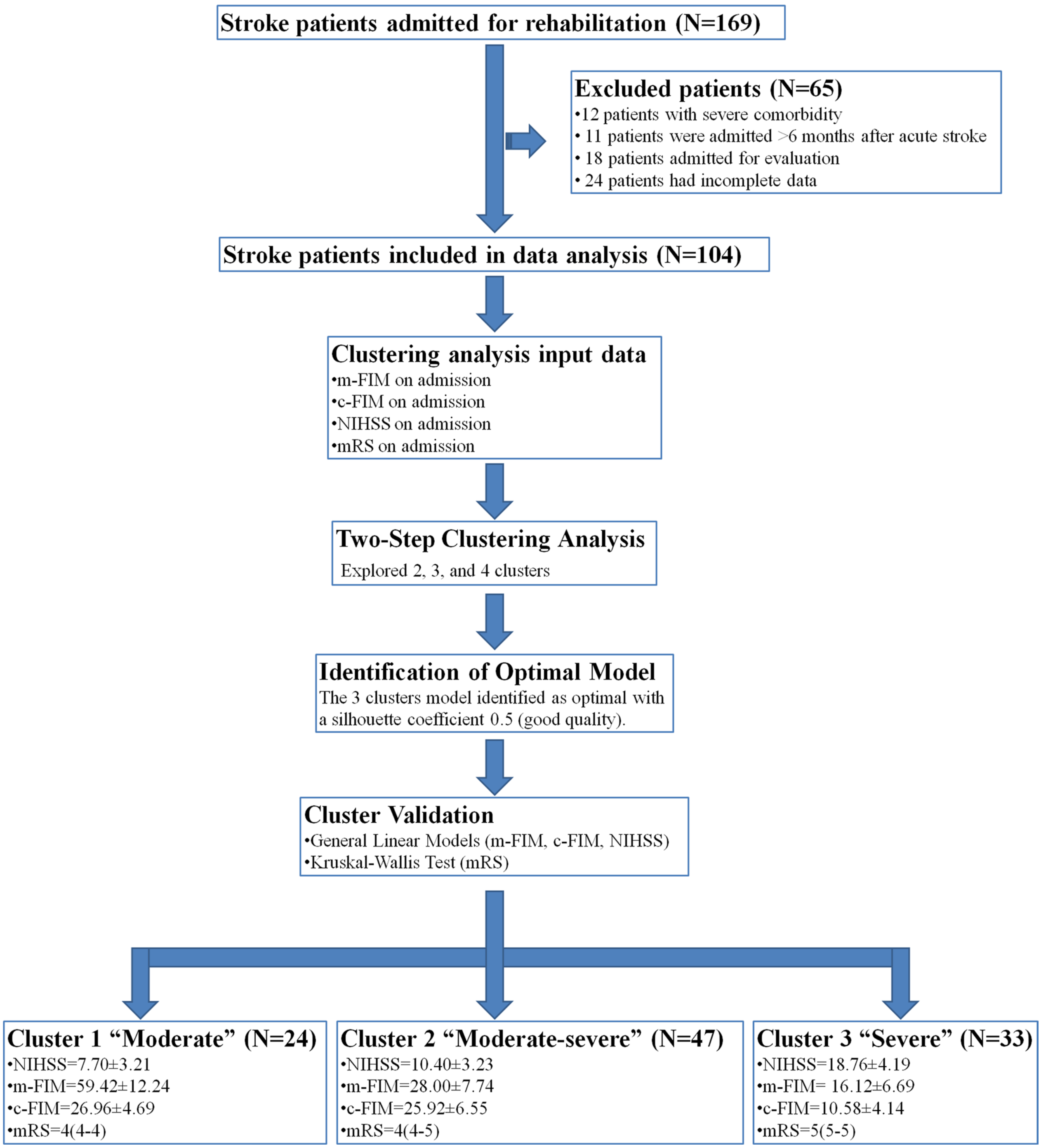

Fig. 1 Methodological approach: clustering analysis to identify rehabilitation profiles. m-FIM: the motor Functional Independence Measure; c-FIM: the cognitive Functional Independence Measure; NIHSS: the National Institutes of Health Stroke Scale; mRS: Modified Rankin Score

severe disease), 11 patients were admitted later than 6 months after acute stroke; 18 patients were admitted for evaluation or rehabilitation for less than 4 weeks; 24 patients had incomplete data regarding stroke-related severity and independence measures on admission, which did not allow clustering. A total of 104 patients were eligible for the study: 68/36 (65.4/34.6%) males/females; mean age 69.45 ± 6.5 years; 59/45 (56.7/43.3%) patients had ischemic/or hemorrhagic stroke.

Considering stroke severity, functional and independence measures on admission we identify three clusters. The validated clusters had the following characteristics (Table 1):

Cluster 1, defined as "Moderate": NIHSS = 7.70 ± 3.21, m-FIM = 59.42 ± 12.24, c-FIM = 26.96 ± 4.69 and mRS = 4 (4–4);

Cluster 2 defined as "Moderate-severe": NIHSS = 10.40 ± 3.23, m-FIM = 28.00 ± 7.74, c-FIM = 25.92 ± 6.55 and mRS = 4 (4–5);

Cluster 3 defined as "Severe": NIHSS = 18.76 ± 4.19, m-FIM = 16.12 ± 6.69, c-FIM = 10.58 ± 4.14 and mRS = 5 (5–5).

The demographic and stroke characteristics of the clusters are reported in Table 1.

According to the OCSP classification of ischemic stroke, POCI was more prevalent in the moderate group, whereas TACI was more prevalent in the moderate–severe group ($p = 0.007$). Right-side location of stroke was more common in the moderate–severe group ($p = 0.001$) which also had higher prevalence of hemineglect compared to the other groups ($p = 0.025$). The severe group more frequently presented with aphasia and dysphagia on admission ($p = 0.001$) with need for feeding through a nasogastric tube or percutaneous gastrostomy in 42.4% of patients (FOIS = 1–3) ($p = 0.001$). There were no significant differences in age, gender, stroke type, time since stroke to admission or the prevalence of cardiovascular risk factors between groups ($p > 0.05$ for all comparisons) (Table 1).

Functional outcomes are reported in the Table 2.

The patients in the moderate and moderate–severe groups experienced significantly greater motor improvement compared to the severe group with higher m-FIM gain and effectiveness ($p < 0.001$ for all comparisons). The c-FIM effectiveness significantly improved in the moderate and moderate–severe group as compared to severe group ($p = 0.025$). In contrast, the c-FIM gain and efficiency were not significantly different between groups ($p = 0.60$ and $p = 0.21$, respectively), probably due to a saturation effect related to almost normal range of c-FIM score on admission in the moderate and moderate–severe groups (Table 2).

Dysphagia improved in all groups with no significant differences in the FOIS gain, efficiency, and effectiveness. However, in the severe group, the prevalence of severe dysphagia at discharge significantly decreased from 42.4 to 21.2% ($p = 0.001$). Similarly, significant improvement of aphasia was detected across all groups ($p = 0.55$), specifically in naming abilities in the moderate group ($p = 0.03$) and comprehension abilities in the severe group ($p = 0.03$) (Table 2).

Hospital-related complications and the use of psychotropic medication are reported in the Table 2.

The proportion of patients who presented at least one fall during hospitalization was higher in the moderate and moderate–severe group compared to the Severe group ($p = 0.02$). On the other hand, severe patients presented higher rates of infections during hospitalizations ($p = 0.001$), provoked by multi-drug-resistant bacteria (86.36%), of which 54.5% were urologic infections. We found no significant difference in the prevalence of pressure ulcers among groups ($p = 0.15$).

Patients in the severe group were more frequently taking antidepressant medication (81.8%) compared to the moderate and moderate–severe group (45.8% and 53.2%, respectively) ($p = 0.01$).

The LOS varied among groups with longer hospitalization in the severe group compared to the moderate and moderate–severe groups ($p = 0.001$) (Table 2).

At the cohort level, more severe stroke, higher level of dependence, lower functionality on admission, more severe dysphagia, having an infection during hospitalization or taking antiepileptic drugs predicted lower motor and cognitive FIM at discharge. In addition, older age was a negative predictor for m-FIM, whereas presence of aphasia on admission and the use of antidepressants during hospitalization were negative predictors for c-FIM (Table 3).

At the cohort level, younger age, more severe stroke, higher level of dependence, lower functionality on admission, more severe dysphagia, having an infection during hospitalization or taking antidepressants or antiepileptic drugs predicted longer hospital stay. Cardiovascular risk factors did not predict functional outcomes or LOS (Table 3).

Discussion

The current study employed cluster analysis, based on stroke severity and functionality upon admission, to identify clinical profiles, and describes group changes following rehabilitation. Our primary findings revealed the presence of three distinct clusters, which presented diverse evolution during rehabilitation and distinctive rates of in-hospital complications, medication utilization, and length of hospitalization. Patients with moderate and moderate–severe stroke achieved significant motor and cognitive improvement over a shorter hospitalization period compared to patients with severe stroke, whereas aphasia and dysphagia improved in all groups regardless of stroke severity. Stroke severity, as well as the level of independence and functionality on admission, were major determinants of functional outcomes at discharge. Furthermore, younger age, stroke severity, and low

Table 1 Sociodemographic and clinical characteristics on admission

Variable	Total (n = 104)	Moderate (n = 24)	Moderate–severe (n = 47)	Severe (n = 33)	p value
Age (years)	69.45 ± 6.50	68.56 ± 6.80	70.06 ± 6.37	69.30 ± 6.53	0.61
Sex, male (%)	68 (65.4)	19 (79.2)	31 (66)	18 (54.4)	0.15
Type of stroke					0.86
Ischemic (%)	59 (56.7%)	13 (54.2%)	26 (55.3%)	20 (60.6%)	
Hemorrhagic (%)	45 (43.3%)	11 (45.8%)	21 (4.7%)	13 (39.4%)	
Laterality					0.001
Right (%)	52 (50%)	9 (37.5%)	34 (72.3%)	9 (27.3%)	
Left (%)	44 (42.3%)	14 (58.3%)	11 (23.4%)	19 (57.6%)	
Bilateral (%)	8 (7.7%)	1 (4.2%)	2 (4.3%)	5 (15.2%)	
OCSP					0.007
TACI (%)	43 (72.9%)	7 (53.8%)	23 (88.5%)	13 (65%)	
PACI (%)	4 (6.8%)	0 (0%)	0 (0%)	4 (20%)	
POCI (%)	8 (13.6%)	5 (38.5%)	1 (3.8%)	2 (10%)	
LACI (%)	4 (6.8%)	1 (7.7%)	2 (7.7%)	1 (5%)	
Revascularization treatment in ischemic stroke (%)					0.51
Intravenous thrombolysis	7 (11.9%)	2 (15.4%)	3 (11.5%)	2 (10%)	
Mechanical thrombectomy	10 (16.9%)	2 (15.4%)	3 (11.5%)	5 (25%)	
Both	3 (5.1%)	0 (0%)	3 (11.5%)	0 (0%)	
None	39 (66.1%)	9 (69.2%)	17 (65.4%)	13 (65%)	
Hemorrhagic transformation (%)	9 (8.7%)	2 (8.3%)	3 (6.4%)	4 (12.1%)	0.61
Type of hemorrhagic stroke					0.20
ICH (%)	37 (35.6%)	8 (33.3%)	20 (42.6%)	9 (27.3%)	
SAH (%)	8 (7.7%)	3 (12.5%)	1 (2.1%)	4 (12.1%)	
Complications of hemorrhagic stroke (%)					0.41
Subarachnoid extension (%)	1 (1%)	0 (0%)	1 (2.1%)	0 (0%)	
Intraventricular extension (%)	4 (3.8%)	1 (4.2%)	1 (2.1%)	2 (6.1%)	
Hydrocephalus (%)	1 (1%)	0 (0%)	0 (0%)	1 (3%)	
Intraventricular extension + Hydrocephalus (%)	9 (8.7%)	3 (12.5%)	2 (4.3%)	4 (12.1%)	
Surgical treatment of hemorrhagic stroke (DC or VD) (%)	17 (16.3%)	4 (16.7%)	5 (10.6%)	8 (24.2%)	0.09
Time since stroke to admission (days)	47.5 [27–77.5]	40.5 [16.5–87.5]	42 [24–70]	56 [37.5–84.5]	0.17
Functional status on admission					
mRS on admission	4 [4, 5]	4 [4–4][ab]	4 [4–5][c]	5 [5–5]	0.001
NIHSS on admission	12.48 ± 5.69	7.70 ± 3.21[ab]	10.40 ± 3.23[c]	18.76 ± 4.19	0.001
m-FIM on admission	31.48 ± 18.36	59.42 ± 12.24[ab]	28.00 ± 7.74[c]	16.12 ± 6.69	0.001
c-FIM on admission	21.29 ± 9.13	26.96 ± 4.69[b]	25.92 ± 6.55[c]	10.58 ± 4.14	0.001
Aphasia on admission	36 (35%)	10 (41.7%)	6 (13%)	20 (60.6%)	0.001
Hemineglect on admission	38 (36.5%)	4 (16.7%)	23 (48.9%)	11 (33.3%)	0.025
Dysphagia on admission	62 (59.6%)	4 (16.7%)	27 (57.4%)	31 (93.9%)	0.001
FOIS on admission	5 [4–7]	6 [7–7][ab]	5 [5–7][c]	4 [1–5]	0.001
Severe dysphagia at admission (no oral feeding, FOIS 1–3)	18 (17.3%)	1 (4.2%)	3 (6.4%)	14 (42.4%)	0.001
Cardiovascular risk factors on admission					
Diabetes (%)	30 (28.8%)	6 (25%)	10 (21.3%)	14 (42.4%)	0.11
Dyslipidemia (%)	48 (46.2%)	12 (50%)	22 (46.8%)	14 (42.4%)	0.85
Hypertension (%)	78 (75%)	21 (87.5%)	34 (72.3%)	23 (69.7%)	0.26
Atrial fibrillation (%)	24 (23.1%)	4 (16.7%)	11 (23.4%)	9 (27.3%)	0.64
Ischemic heart disease (%)	8 (7.7%)	1 (4.2%)	4 (8.5%)	3 (9.1%)	0.76
Previous stroke (%)	12 (11.5%)	3 (12.5%)	5 (10.6%)	4 (12.1%)	0.97
Number of comorbidities	1.9 ± 1.1	2.0 ± 1.0	1.8 ± 1.0	2.0 ± 1.5	0.74
BMI on admission	24.76 ± 3.88	25.05 ± 3.84	24.81 ± 4.26	24.48 ± 3.39	0.85

Table 1 (continued)

Variable	Total ($n=104$)	Moderate ($n=24$)	Moderate–severe ($n=47$)	Severe ($n=33$)	p value
Obese (%)	8 (7.7%)	1 (4.2%)	5 (10.6%)	2 (6.1%)	0.61
Current smoking	15 (14.4%)	5 (20.8%)	7 (14.9%)	3 (9.1%)	0.75
Current alcohol consumption	19 (18.3%)	4 (16.7%)	11 (23.4%)	4 (12.1%)	0.44

OCSP: Oxfordshire Community Stroke Project; TACI: Total anterior circulation infarcts; PACI: Partial anterior circulation infarcts; LACI: Lacunar circulation infarcts; POCI: Posterior circulation infarcts; ICH: Intracerebral hemorrhage; SAH: Subarachnoid hemorrhage; NIHSS: National institute of Health Stroke Scale; DC: Decompressive craniectomy; VD: Ventricular drainage; mRS: Modified Rankin Scale; m-FIM: motor Functional Independence Measure; c-FIM: cognitive Functional Independence Measure; FOIS: Functional Oral Intake Scale

[a] Moderate vs Moderate–severe

[b] Moderate vs Severe

[c] Moderate–severe vs Severe. (General linear models with Bonferroni post hoc analyses for parametric variables; the Mann–Whitney U test as post hoc for nonparametric variables; and the χ^2 test for categorical variables)

functionality/high dependence at admission, along with severe dysphagia, hospital-acquired infections, and the use of antidepressants or antiepileptic drugs predicted longer hospital stay.

Previous research has aimed to identify predictors for functional outcomes in elderly stroke patients or mixed-age groups employing different clinical measures such as: FIM score at discharge or FIM gain [17–19], Barthel Index and mRS gain [20] or Fugl-Meyer gain [21]. The results of these studies highlighted the important predictive value of functional status on admission for functional outcomes at discharge, which is in line with our results. However, unlike these studies that characterized the functional evolution of stroke patients at the cohort level [17, 20, 21], or through age-subgroup comparisons [18, 19], often marked by large functional heterogeneity, our study distinguishes itself by employing clustering analysis based on stroke severity and functionality upon admission. Rather than assigning patients to a specific group based on a single criterion, this approach enables us to identify clinical phenotypes using information available on admission. A similar approach was conducted in a recent study in older adult stroke survivors admitted to intermediate care geriatric rehabilitation units in Catalonia [6]. This study revealed that patients with more severe stroke, higher post-stroke disability and those with associated cognitive impairment, showed lower rehabilitation efficiency and limited functional improvement compared to patients with less severe stroke who had a similar age and duration of hospitalization. However, our study distinguishes itself from the study by Perez et al. (2016) by incorporating a younger population (69.45 versus 79.6 years) and later hospital admission (47.5 days versus 13 days after stroke onset).

Early admission to rehabilitation units after a stroke is also emphasized as a positive predictor of functional recovery [17, 22]. However, the time from stroke onset to admission was not found to be significant either by Li et al. [18] or our study.

On the other hand, advanced age was reported as a negative predictor of functional recovery [3, 18, 19, 23], a finding consistent with our study, which may be explained by age-related decrease in rehabilitation effectiveness in patient with severe stroke [3, 23]. However, it is worth noting that this association did not achieve significance in Yavuzer's study [17], possibly attributed to the relatively young and homogeneous nature of the population under investigation. Other factors, such as the intensity and the total amount of rehabilitation, emerged as strong determinants of functional gains, which was not quantified in our study but should be considered in future research [21, 23, 24].

Our study introduces novelty as it is the only one to analyze predictors of hospital length of stay while encompassing a broader spectrum of clinical variables. Although age was negatively related to the length of hospitalization in our study, patients with severe stroke and associated conditions such as severe dysphagia; those who develop in-hospital infections; or have higher use of psychotropic medication, had significantly poorer functional outcomes and longer hospital stays. Overall, stroke severity, as well as respiratory and urinary tract infections, may have contributed to interruptions or reduced participation in rehabilitation, which is in line with a previous study [3].

The prevalence of dysphagia and severe dysphagia that require feeding through nasogastric tube or gastrostomy in our cohort is similar to a previous report in older adults with stroke admitted to early post-acute care [20] and early intermediate care units [6]. However, feeding function and FOIS similarly improved across all groups and the rate of severe dysphagia decreased from 42.4 to 21.2% in patients with severe stroke, suggesting that dysphagia treatment and feeding

Table 2 Functional outcomes and complications during hospitalization

Variable	Total (*n* = 104)	Moderate (*n* = 24)	Moderate-severe (*n* = 47)	Severe (*n* = 33)	*p* value
m-FIM at discharge	45.77 ± 21.62	70.08 ± 10.99	47.53 ± 15.14[c]	24.04 ± 14.05	0.001
m-FIM gain	11 [3–22]	11 [4.3–18.5][a]	19 (7.0–30.0][c]	4.5 (0–12.5]	0.001
m-FIM efficiency	0.19 [0.04–0.39]	0.22 [0.08–0.41][b]	0.31 [0.08–0.45][c]	0.05 [0–0.19]	0.001
m-FIM effectiveness	23.80 [4.29–41.49]	33.70 [12.16–53.54][b]	31.15 [10.34–46.55][c]	5.77 [0–18.77]	0.001
c-FIM at discharge	24.75 ± 9.10	30.42 ± 3.65[b]	29.19 ± 5.72[c]	13.97 ± 6.27	0.004
c-FIM gain	2 [0–5]	3 [0–4.75]	3 [0–6]	1 [0–5]	0.60
c-FIM efficiency	0.03 [0–0.09]	0.05 [0–0.10]	0.04 [0–0.09]	0.02 [0–0.06]	0.21
c-FIM effectiveness	20 [0–50]	33.3 [0–50.0][b]	33.3 [0–63.16][c]	4.65 [0–22.30]	0.025
Aphasia improvement (%)	33 (91.7%)	9 (90%)	6 (100%)	18 (90%)	0.55
Expression (%)	15 (41.7%)	4 (40%)	2 (33.3%)	9 (45%)	
Comprehension (%)	22 (61.1%)	2 (20%)	4 (66.7%)	16 (80%)	
Repetition (%)	18 (50.0%)	3 (30%)	3 (50%)	12 (60%)	
Naming (%)	18(50.0%)	8 (80%)	3 (50%)	7 (35%)	
FOIS at discharge	7 [5–7]	7 [7–7][ab]	7 [6–7][c]	6 [4–7]	0.001
FOIS gain	2 [1–2)	1[1–1)	1 [0.5–2)	2 [1–2)	0.12
FOIS efficiency	0.02 [0.01–0.03]	0.02 [0.01–0.04]	0.02 [0–0.03]	0.03 [0.01–0.04]	0.47
FOIS effectiveness	50 [0–100]	58.33 [25.0–100]	50 [0–100]	66.67 [25.0–100]	0.95
Severe dysphagia at discharge	7 [6.7%]	0 [0%]	0 [0%]	7 [21.2%]	0.001
Medication use					
Antipsycotic	27 (26%)	4 (16.7%)	11 (23.4%)	12 (36.4%)	0.21
Antidepressants	63 (60.6%)	11 (45.8%)	25 (53.2%)	27 (81.8%)	0.01
Benzodiazepines	55(52.9%)	11(45.8%)	26(55.3%)	18(54.4%)	0.73
Antiepileptics	20(19.2%)	2(8.3%)	8(17%)	10(30.3%)	0.10
Antiepileptics for NP	36(34.6%)	6(25.0%)	17(36.2%)	13(39.4%)	0.51
Pressure ulcers	8(7.7%)	1(4.2%)	2(4.3%)	5(15.2%)	0.15
Falls during hospitalization	24(23.1%)	8(33.3%)	14(29.8%)	2(6.1%)	0.02
Infections during hospitalization					0.001
Respiratory	6(5.8%)	0(0%)	3(6.4%)	3(9.1%)	
Urologic	27(26%)	1(4.2%)	8(17.0%)	18(54.5%)	
Skin and soft tissues	2(1.9%)	0(0%)	1(2.1%)	1(3.0%)	
MR infections (%)	29(27.9%)	1(100%)	9(75%)	19(86.36%)	0.001
Length of stay (days)	60.5[45–83]	45[33.25–59][ab]	61[45–92]	71[60.5–97.5]	0.001

mRS: Modified Rankin Scale; m-FIM: motor Functional Independence Measure; c-FIM: cognitive Functional Independence Measure; FOIS: Functional Oral Intake Scale; NP: Neuropathic Pain; MR infections: Multi-drug resistant infection

[a] Moderate vs Moderate–severe

[b] Moderate vs Severe

[c] Moderate–severe vs Severe. (General linear models with Bonferroni post hoc analyses for parametric variables; the Mann–Whitney *U* test as post hoc for nonparametric variables; and the χ^2 test for categorical variables.)

independence should be a realistic goal of rehabilitation [7, 20, 24].

Post stroke aphasia and hemineglect may have negative impacts on motor and cognitive recovery [25]. Compared to patients without aphasia, patients with aphasia present higher rates of long-term disability, use rehabilitation services for longer periods of time, and less frequently return home [26]. In our study, symptoms of hemineglect were more prevalent in the moderate–severe group whereas aphasia was more prevalent in the severe group. However, although presence of aphasia negatively predicted cognitive FIM score at discharge only, neither aphasia nor hemineglect predicted functional motor outcomes or the length of stay.

Depression is estimated to affect 33% of stroke survivors (18–85 years) [27], and predict poor rehabilitation efficiency in stroke patients [28]. Although we did not directly evaluate the prevalence of affective disorders, the use of antidepressants at the cohort level was generally higher (60.6%), with significantly higher

Table 3 Prediction of functional outcomes and the length of hospital stay

Variable	m-FIM at discharge		c-FIM at discharge		Length of stay	
	Beta	Sig.	Beta	Sig.	Beta	Sig.
Age	− 0.224	*0.023*	− 0.085	0.396	− 0.239	*0.019*
Sex	0.148	0.137	0.170	0.086	− 0.079	0.426
Type of stroke	0.102	0.308	0.065	0.513	− 0.163	0.098
Time after stroke to admission	− 0.114	0.251	− 0.115	0.249	0.114	0.248
mRS on admission	− 0.622	*0.000*	− 0.463	*0.000*	0.243	*0.013*
NIHSS on admission	− 0.651	*0.000*	− 0.664	*0.000*	0.331	*0.001*
m-FIM on admission	0.806	*0.000*	0.524	*0.000*	− 0.381	*0.000*
c-FIM on admission	0.591	*0.000*	0.886	*0.000*	− 0.298	*0.002*
FOIS on admission	0.538	*0.000*	0.533	*0.000*	− 0.299	*0.002*
Aphasia on admission	*− 0.152*	*0.128*	− 0.527	*0.000*	− 0.064	*0.520*
Hemineglect	− 0.173	0.080	0.115	0.249	0.047	0.637
Diabetes	− 0.159	0.109	− 0.152	0.125	0.101	0.307
Dyslipidemia	− 0.022	0.827	0.082	0.413	0.030	0.759
Hypertension	0.009	0.926	0.060	0.545	− 0.137	0.167
Obesity	− 0.007	0.946	0.021	0.833	− 0.012	0.905
Previous stroke	0.030	0.763	− 0.011	0.911	− 0.118	0.235
Antipsychotics	− 0.153	0.124	− 0.147	0.139	0.160	0.104
Antidepressives	− 0.138	0.165	− 0.272	*0.005*	0.290	*0.003*
Antiepileptics	− 0.251	*0.011*	− 0.258	*0.009*	− 0.082	0.934
Benzodiazepines	− 0.001	0.990	0.115	0.247	0.165	0.095
Gaba/Lyrica	− 0.071	0.474	− 0.016	0.871	0.224	*0.023*
Infections	− 0.499	*0.000*	− 0.394	*0.000*	0.225	*0.022*
Length of stay	− 0.316	*0.001*	− 0.339	*0.000*	–	–

Linear regression analysis to predict functional outcomes (m-FIM, c-FIM) and LOS (days). Statistically significant predictors of the regression model, defined by p<0.05, are highlighted in italics

use among patients in the Severe group. This suggests higher rates of depression, which predicted lower cognitive FIM score at discharge and longer hospital stay. Similarly, use of antiepileptic drugs for post-stroke epilepsy predicted lower motor and cognitive FIM score at discharge, whereas the use of Gabapentin and Pregabalin for neuropathic pain treatment was associated with longer hospitalization. This is in line with findings that antiepileptic and GABA-mimetic drugs could impair stroke recovery [29]. Therefore, we can speculate that presence of post-stroke seizure and use of antiepileptic drugs are negative predictors for motor and cognitive outcomes.

There are several limitations of the study. We designed a retrospective cohort study on older adult patients admitted to in-hospital rehabilitation privately or through private health insurance; therefore, current results may not be representative of the general older adult population with stroke. We could not evaluate the effects of rehabilitation intensity on functional outcomes, therefore, we can only speculate that more impaired patients and those who develop in-hospital infections underwent less intensive rehabilitation programs.

Conclusions

The application of cluster analysis, based on stroke severity and functional status upon admission, proved valuable in identifying distinct clinical profiles with different functional outcomes in rehabilitation programs. Factors such as severe stroke, poor functional status at admission, presence of severe dysphagia, higher rates of in-hospital infections, and the use of psychotropic medication, emerge as primary predictors of unfavorable rehabilitation outcomes and extended hospitalization duration. This information could be useful for setting rehabilitation goals upon admission and facilitating early planning for discharge destinations.

Abbreviations

BMI Body mass index
DC Decompressive craniectomy
FIM Functional independence measure
FOIS Functional oral intake scale
ICH Intracerebral hemorrhage
LACI Lacunar circulation infarcts
LOS Length of stay

mRS Modified Rankin Score
NIHSS National Institutes of Health Stroke Scale
NP Neuropathic pain
OCSP Oxfordshire Community Stroke Project
PACI Partial anterior circulation infarcts
PACI Posterior circulation infarcts
SAH Subarachnoid hemorrhage
TACI Total anterior circulation infarcts
VD Ventricular drainage

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Author contributions
SA, MSE, AJC and HK conceived the study. SA, MSE, EILM and AJC were involved in protocol development. SA was responsible for obtaining ethical approval. SA, EILM and MSE conducted the data collection and analysis. SA, MSE and HK interpreted the data. SA and HK wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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Declarations

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The authors report there are no competing interests to declare.

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References

1. Collaborators GBDS. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol. 2021;20(10):795–820.
2. Wafa HA, Wolfe CDA, Emmett E, Roth GA, Johnson CO, Wang Y. Burden of stroke in Europe: thirty-year projections of incidence, prevalence, deaths, and disability-adjusted life years. Stroke. 2020;51(8):2418–27.
3. Zucchella C, Consilvio M, Iacoviello L, Intiso D, Tamburin S, Casale R, et al. Rehabilitation in oldest-old stroke patients: a comparison within over 65 population. Eur J Phys Rehabil Med. 2019;55(2):148–55.
4. Sennfalt S, Norrving B, Petersson J, Ullberg T. Long-term survival and function after stroke: a longitudinal observational study from the Swedish Stroke Register. Stroke. 2019;50(1):53–61.
5. Sennfalt S, Pihlsgard M, Petersson J, Norrving B, Ullberg T. Long-term outcome after ischemic stroke in relation to comorbidity—an observational study from the Swedish Stroke Register (Riksstroke). Eur Stroke J. 2020;5(1):36–46.
6. Perez LM, Inzitari M, Quinn TJ, Montaner J, Gavalda R, Duarte E, et al. Rehabilitation profiles of older adult stroke survivors admitted to intermediate care units: a multi-centre study. PLoS ONE. 2016;11(11):e0166304.
7. Castagna A, Ferrara L, Asnaghi E, Colombo V, Rega V, Fiorini G. Post-stroke dysphagia rehabilitation in the old and oldest old: outcome and relevance for discharge home. Int J Rehabil Res. 2020;43(1):55–61.
8. Duarte E, Alonso B, Fernández MJ, Fernández JM, Flórez M, García-Montes I, et al. Rehabilitación del ictus: modelo asistencial: Recomendaciones de la Sociedad Española de Rehabilitación y Medicina Física, 2009. Rehabilitacion. 2010;44(1):60–8.
9. Secanell M, López J, López R, Sánchez D, Ferrer V, Amargós MV. Automatització dels indicadors de seguretat del pacient: avançant cap a un sistema de gestió de la qualitat eficient i integrat. An Med. 2018;101:22–6.
10. Bamford J, Sandercock P, Dennis M, Burn J, Warlow C. Classification and natural history of clinically identifiable subtypes of cerebral infarction. Lancet. 1991;337(8756):1521–6.
11. Duncan PW, Zorowitz R, Bates B, Choi JY, Glasberg JJ, Graham GD, et al. Management of adult stroke rehabilitation care: a clinical practice guideline. Stroke. 2005;36(9):e100–43.
12. Stineman MG, Shea JA, Jette A, Tassoni CJ, Ottenbacher KJ, Fiedler R, et al. The functional independence measure: tests of scaling assumptions, structure, and reliability across 20 diverse impairment categories. Arch Phys Med Rehabil. 1996;77(11):1101–8.
13. Banks JL, Marotta CA. Outcomes validity and reliability of the modified Rankin scale: implications for stroke clinical trials: a literature review and synthesis. Stroke. 2007;38(3):1091–6.
14. Crary MA, Mann GD, Groher ME. Initial psychometric assessment of a functional oral intake scale for dysphagia in stroke patients. Arch Phys Med Rehabil. 2005;86(8):1516–20.
15 Peña-Casanova J, JarneEsparciaEsparcia A, Guardia Olmos J. Programa integrado de exploración neuropsicológica—test barcelona: validez de contenidos. Rev Logop Foniatr Audiol. 1991;11(2):96–107.
16. ArtiolaiFortuny L, Hermosillo Romo D, Heaton RK, Pardee R. Manual de Normas y Procedimientos para la Batería Neuropsicológica en Español. Tucson: mPress; 1999.
17. Yavuzer G, Kucukdeveci A, Arasil T, Elhan A. Rehabilitation of stroke patients: clinical profile and functional outcome. Am J Phys Med Rehabil. 2001;80(4):250–5.
18. Li TK, Ng BH, Chan DY, Chung RS, Yu KK. Factors predicting clinically significant functional gain and discharge to home in stroke in-patients after rehabilitation—a retrospective cohort study. Hong Kong J Occup Ther. 2020;33(2):63–72.
19. Bagg S, Pombo AP, Hopman W. Effect of age on functional outcomes after stroke rehabilitation. Stroke. 2002;33(1):179–85.
20. Chien SH, Sung PY, Liao WL, Tsai SW. A functional recovery profile for patients with stroke following post-acute rehabilitation care in Taiwan. J Formos Med Assoc. 2020;119(1 Pt 2):254–9.
21. Salvalaggio S, Cacciante L, Maistrello L, Turolla A. Clinical predictors for upper limb recovery after stroke rehabilitation: retrospective cohort study. Healthcare. 2023;11(3):335.
22. Salter K, Jutai J, Hartley M, Foley N, Bhogal S, Bayona N, et al. Impact of early vs delayed admission to rehabilitation on functional outcomes in persons with stroke. J Rehabil Med. 2006;38(2):113–7.
23. Wattanapan P, Lukkanapichonchut P, Massakulpan P, Suethanapornkul S, Kuptniratsaikul V. Effectiveness of stroke rehabilitation compared between intensive and nonintensive rehabilitation protocol: a multicenter study. J Stroke Cerebrovasc Dis. 2020;29(6):104809.
24. Knecht S, Rossmuller J, Unrath M, Stephan KM, Berger K, Studer B. Old benefit as much as young patients with stroke from high-intensity neurorehabilitation: cohort analysis. J Neurol Neurosurg Psychiatry. 2016;87(5):526–30.
25. Gialanella B, Ferlucci C. Functional outcome after stroke in patients with aphasia and neglect: assessment by the motor and cognitive functional independence measure instrument. Cerebrovasc Dis. 2010;30(5):440–7.
26 Flowers HL, Skoretz SA, Silver FL, Rochon E, Fang J, Flamand-Roze C, et al. Poststroke aphasia frequency, recovery, and outcomes: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2016;97(12):2188-201.e8.

27. Hackett ML, Yapa C, Parag V, Anderson CS. Frequency of depression after stroke: a systematic review of observational studies. Stroke. 2005;36(6):1330–40.
28. Gillen R, Tennen H, McKee TE, Gernert-Dott P, Affleck G. Depressive symptoms and history of depression predict rehabilitation efficiency in stroke patients. Arch Phys Med Rehabil. 2001;82(12):1645–9.
29. Viale L, Catoira NP, Di Girolamo G, Gonzalez CD. Pharmacotherapy and motor recovery after stroke. Expert Rev Neurother. 2018;18(1):65–82.

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