Age-related differences in the effectiveness of rehabilitation to improve activities of daily living in patients with stroke: A cross-sectional study

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Takuaki Tani: Conceptualization, Writing–original draft, Writing–review & editing

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Abstract

Background: This study aimed to reveal differences in the effectiveness of rehabilitation in improving activities of daily living (ADL) in patients with acute stroke across age groups and propose age-appropriate rehabilitation strategies.

Methods: This observational study analyzed nationwide administrative data of inpatients admitted to hospitals with acute stroke between April 1, 2018, and March 31, 2020. The data included the average length of daily rehabilitation sessions, weekly frequency of rehabilitation sessions, and initiation of rehabilitation within three days. The primary outcome was the improvement in the Barthel Index (BI) score from admission to discharge. We classified the patients based on age and analyzed improvements in ADL according to rehabilitation characteristics.

Results: An increased daily rehabilitation dose was associated with improved ADL, except in patients aged <65 years (risk ratios and 95% confidence intervals [CIs] in the 65–74, 75–85, and ≥85 age groups: 1.20 [1.14–1.27], 1.21 [1.15–1.27], and 1.43 [1.34–1.53], respectively; all p <0.001 vs. <65 years: 1.05 [0.98–1.12]; p=0.18). A rehabilitation frequency of seven sessions per week was associated with improved ADL in the 75–85-year and ≥85-year age groups (1.06 [1.02–1.10] and 1.08 [1.03–1.13], respectively; both p <0.001). The effects of
initiating rehabilitation within three days on ADL post-admission did not differ across age groups.

Conclusions: Increasing the daily dose of rehabilitation was significantly associated with improved ADL in all age groups while increasing the frequency of rehabilitation per week improved ADL in older and very old patients.

Keywords: rehabilitation, age, stroke, hospital care, activities of daily living
An increase in the aging global population has led to a demographic shift in patients with stroke (1). This trend is anticipated to increase the demand for rehabilitation, potentially impacting rehabilitation delivery systems owing to factors such as staff shortages (2).

Age is a significant factor in the recovery of activities of daily living (ADL) after stroke (2, 3). Additionally, patients' outcomes are influenced by age-specific characteristics (4). Physical and cognitive impairments are common after stroke, and the effectiveness of recovery is closely linked to the treatment received during the early acute phase (5).

Post-stroke rehabilitation is crucial for patient treatment (6), and rehabilitation methods tailored to each age group are particularly important to ensure the appropriate use of healthcare resources.

The provision of stroke rehabilitation should consider the timing of initiation (7), daily dose (8), and frequency (9, 10) as they influence ADL improvement. Various impacts of these factors on different age groups have been reported, highlighting the need for age-specific rehabilitation approaches (11) (12).

Previous research has explored the association between rehabilitation and improved ADL in acute stroke hospitals for older age groups; however, none have simultaneously analyzed the timing of initiation, daily dose, and number of rehabilitation sessions per week. Furthermore, few studies have addressed the impact of age on rehabilitation timing, dose, and frequency.
Therefore, this study investigated the relationship between rehabilitation dose, frequency, and timing and ADL in patients of various ages with acute stroke to determine age-appropriate rehabilitation strategies.
Material and Methods

Study design

This cross-sectional observational study analyzed nationwide administrative data from Japan.

Ethical approval and consent to participate.

The Institutional Review Board of Tokyo Medical and Dental University approved this study (M2000-788-27), which complied with the Declaration of Helsinki and the ethical guidelines for medical and health science research involving human participants in Japan. The Institutional Board waived the requirement for informed consent because we analyzed secondary innominate data.

Data source

The Diagnosis Procedure Combination (DPC) Per-Diem Payment System is a Japanese national acute care inpatient database that provides administrative claims data for a fixed payment system for medical expenses (13). The 2020 DPC data include information derived from 1,757 hospitals, comprising 89% of the total number of beds in acute care hospitals throughout Japan. The database includes information on patient demographics, namely age, sex, weight, height, main diagnoses, comorbidities, disease complications (coded according
to the International Classification of Diseases 10th Revision [ICD-10]), and hospitalization length of stay (LOS). Highly sensitive and specific disease diagnoses in this database have been validated (14, 15).

The database also includes prescription information and medical procedures coded according to the original Japanese system, and patient status information, including ADL based on the Barthel Index (BI) scale (16), modified Rankin Scale (mRS) (17), and Japan Coma Scale (JCS) (commonly used to measure coma status upon admission in Japan (18)). Additionally, the database includes information regarding discharge destination, such as transfer to another hospital or discharge to a nursing home. Further details regarding the database are described elsewhere (19).

Patient selection

This study analyzed the data of patients with ischemic stroke admitted to acute care facilities between April 1, 2018, and March 31, 2020. Rehabilitation was initiated within three days of admission and continued for 14 days. The inclusion criteria were patients aged ≥20 years diagnosed with ischemic stroke (ICD-10 I63) within three days of onset. The Japanese insurance system imposes a time limit of 60 days for transferring patients from acute care hospitals to subacute facilities. Thus, patients who had been in acute care hospitals for >60 days might not have received a standard course of treatment. Therefore, patients hospitalized
for >60 days and those who died at discharge were excluded.

Outcomes

The primary outcome was ADL improvement according to BI and the difference in BI scores between admission and discharge. We defined ADL improvement as an increase of >1 point at discharge compared with that at admission. The BI scores at the time of admission and discharge from the hospital are measured on a 20-point scale, summing the items of eating, transferring, dressing, toileting, bathing, walking, stair climbing, dressing, and control of defecation and urination.

Rehabilitation

Rehabilitation initiation within three days was defined as rehabilitation starting on days one, two, or three after admission. We categorized the daily dose of rehabilitation, calculated from the total dose of rehabilitation while hospitalized divided by the number of rehabilitation days, as ≤1.0 h, 1.1–2.0 h, and ≥2.1–3.0 h. Similarly, we categorized the weekly frequency of rehabilitation, calculated from the total number of days per week when rehabilitation sessions occurred, as <5, 6, or 7 days. Stroke rehabilitation in Japan is standardized by guidelines (20), and rehabilitation services for inpatients are covered by universal health insurance. Owing to the nature of the Japanese healthcare system, the amount of rehabilitation is constrained by
insurance coverage, and a maximum of 3 h of rehabilitation per day is covered. During the
rehabilitation session, patients received physical, occupational, and speech and hearing
therapies based on their individual needs. The program can be implemented for up to 180 days
after stroke onset. However, patients must be transferred from an acute care hospital to a
specialized rehabilitation hospital within 60 days.

Age groups

Most Japanese workers retire at 65 years, and those aged 75 are insured by the healthcare
system for older individuals. Thus, we divided age distribution data using 65, 75, and 85 years
as cutoffs and stratified the patients into <65-year, 65–74-year, 75–85-year, and ≥85-year age
groups.

Other variables

Information on sex, readmission, emergency transport, LOS, and discharge destination was
extracted from the DPC data. We calculated the body mass index (BMI) as weight (kg) divided
by height squared (m$^2$) and categorized it according to the modified World Health Organization
classifications of <18.5, 18.5–24.9, 25.0–29.9, 30.0–34.9 and ≥35 kg/m$^2$ (21). We calculated
the Charlson Comorbidity Index based on Quan's protocol using the ICD-10 (22).

Comorbidities were coded according to the ICD-10 as diabetes mellitus (E10–15),
hypertension (I10–15), dyslipidemia (E78), coronary artery disease (I20–25), atrial fibrillation
We converted JCS scores of 0, 1–3, 10–30, and 100–300 into categories of 0 (fully alert), 1 (awake without stimuli), 2 (awake with stimuli), and 3 (comatose), respectively. The mRS scores at discharge were categorized as good (0–2) or poor (3–5). The ADL category at admission was included in the BI category, with BI scores of 20 and <20 considered dependent and independent, respectively.

We extracted medication information, including the use of tissue plasminogen activator and neuroprotection (from the prescription information), mechanical thrombectomy, and admission to stroke, high, and intensive care units. Information on the nutritional team support was also extracted. Hospital volume was defined as the total number of patients per hospital. Data are expressed according to the number of patients in each hospital. We divided the cases into quartiles according to the number of patients per hospital over a 2-year period: first (394), median (1,105), and third (2,302).

Statistical analyses

We estimated the effectiveness of the interval related to initiating rehabilitation within three days, weekly rehabilitation frequency, and daily dose of rehabilitation on ADL using a generalized linear model with a log-link function and quasi-Poisson distribution to estimate improvement (23). Other variables included in the model were rehabilitation type, age, sex, BMI, JCS, Charlson Comorbidity Index, diabetes mellitus, hypertension, dyslipidemia,
coronary artery disease, atrial fibrillation, dementia, readmission, emergency transport, mRS score before admission, nutrition team support, tissue plasminogen activator use, mechanical thrombectomy, all care units, and the three rehabilitation intervals.

Missing values were handled by multiple imputations using chained equations (24). We conducted the main analysis using 20 multiple imputation datasets. We combined the results using Rubin’s rule to obtain final estimates and 95% confidence intervals (CIs). A two-sided p-value of <0.05 with a standardized mean difference of <0.1 was considered statistically significant. All analyses were performed using R software (version 4.2.2).

Sensitivity analyses

To assess sensitivity, we changed the cutoff value for ADL improvement to >1.0, >2.0, and >3.0. We determined whether a change in score represented a true and meaningful change for the patients according to the minimal clinically important difference (MCID). The mean MCID of the BI for stroke rehabilitation was 1.85 (95%CI, 0.89–2.81) (25). Therefore, analyses with outcome differences of up to three covered the 95%CI of the MCID. Stratified analysis according to LOS >30 and <30 days was conducted to investigate if rehabilitation was more effective with a longer LOS and more sessions and if a longer LOS was associated with more spontaneous post-onset ADL recovery.
Results

We extracted data from 84,823 patients aged ≥20 years with ischemic stroke who started rehabilitation during hospitalization within three days of stroke onset. After excluding patients hospitalized for >60 days and those who died, the remaining 66,122 eligible patients were classified into <65-year (n = 7,677), 65–74-year (n = 14,328), 75–85-year (n = 23,622), and ≥85-year (n = 20,485) age groups.

Table 1 summarizes the patient characteristics. The proportions of women and BMI values (range, 18.5–24.9 kg/m²) increased and decreased, respectively, with advancing age (<65-year, 65–74-year, 75–85-year, and ≥85-year age groups: 25.9%, 30.7%, 43.9%, and 65.1%, respectively, and 29.1%, 22.7%, 18.5% and 11.3%, respectively). In addition, pre-admission mRS tended to decrease, while ADL at admission (dependent) tended to increase with advancing age (pre-admission mRS [0]: (<65-year, 65–74-year, 75–85-year, and ≥85-year age groups: 66.1% and 64.5%, 55.0% and 68.4%; 41.9%, 72.6%, 25.5% and 78.2%, respectively). Moreover, the proportion of patients with disturbed consciousness based on the JCS at admission increased with age (<65-year, 65–74-year, 75–85-year, and ≥85-year age groups with JCS 1: 36.2%, 43.3%, 50.0%, and 55.6%, respectively).

Table 2 presents the rehabilitation implementation status for each age group. Initiating
rehabilitation within three days and frequency within one week did not significantly differ among the age groups. In contrast, the daily dose of rehabilitation sessions decreased with age \([2.1–3]\): (<65-year, 65–74-year, 75–85-year, and ≥85-year age groups: 13.6%, 12.1%, 9.8%, and 6.9%, respectively).

Table 3 shows the outcomes at the time of discharge and LOS. As age advanced, the mean (SD) improvement in ADL values—6.27 (7.65), 5.1 (7.58), 3.96 (7.37), and 2.08 (6.36) for the <65-year, 65–74-year, 75–85-year, and ≥85-year age groups, respectively—and the proportion of good mRS scores at discharge—4,543 [59.2%], 6,813 [47.6%], 8,582 [36.3%], and 4,183 [20.4%], respectively—decreased. The mean LOS (SD) increased with age, at 31.73 [10.58], 32.23 [10.80], 33.05 [10.94], and 33.78 [11.07], respectively, in the <65-year, 65–74-year, 75–85-year, and ≥85-year age groups.

The proportion of patients discharged to home decreased in older age groups (<65-year, 65–74-year, 75–85-year, and ≥85-year age groups: 43.0%, 38.9%, 32.0%, and 23.0%, respectively).

Table 4 shows the results of Poisson regression analysis of ADL improvement. Increasing the frequency of rehabilitation to seven sessions per week was associated with improved ADL in old and very old patients (7 days, risk ratio [95%CI]: 1.06 [1.02–1.10] and 1.08 [1.03–1.13], respectively; both \(p <0.001\)). The length of daily rehabilitation was significantly associated with improved ADL, except for the <65-year age group, for 2.1 and 3.0 h of daily rehabilitation (risk
Supplemental Table 1 shows that a shift from one to two points indicated ADL improvement. Rehabilitation within three days tended to reduce ADL improvement in the 65–74-year and 75–85-year age groups.

Analysis after stratifying LOS into ≤30 and 31–60-day segments (Supplemental Table 2) revealed that hospitalization for ≤30 days and an increased frequency of rehabilitation per week, as well as longer daily sessions, were associated with improved ADL among very old patients (risk ratio [95%CI] 1.08, 1.02–1.15, p = 0.008 and 2.1–3 h: 1.24, 1.13–1.36, p <0.001).

Longer daily sessions and hospitalization for 31–60 days were associated with improved ADL in the middle-aged, old, and very old age groups (2.1–3.0 h: 1.34; 95%CI [1.24–1.46]; 1.38, 95%CI, 1.28–1.47; and 1.66, 95%CI, 1.50–1.84, respectively; all p <0.001).

Analysis after stratifying LOS revealed that increasing the daily dose of rehabilitation was associated with improvement in ADL in the very old group with LOS of ≤30 days (2.1–3.0 h, risk ratio [95%CI]: 1.24 [1.13–1.36], p <0.001). In contrast, increasing the daily dose of rehabilitation was associated with improved ADL in the 65–74-year, 75–85-year, and ≥85-year age groups with a LOS of 31–60 days (2.1–3.0 h, risk ratio [95%CI]: 65–74-years, 1.34 [1.24–1.46], p <0.001; older, 1.38 [1.28–1.47], p < 0.001; 75-85, 1.66 [1.50–1.84], p < 0.001). In the ≥85-year age group with LOS ≤30 days, an increased frequency of rehabilitation per week was
associated with improvement in ADL (risk ratio [95%CI]: 1.08 [1.02–1.15], p = 0.008).

Regardless of LOS stratification (≤30 or >30 days), the improvement in ADL did not differ significantly between initiating rehabilitation within three days and on the first day across all four age groups (Supplemental Table 2).

Discussion

The findings of the present study underscore the importance of providing appropriate rehabilitation services within the healthcare system for individuals of all ages. As age increased, increased doses of rehabilitation had a positive effect on ADL, even in the presence of various background factors. However, increasing the daily dose to >2.1 h did not result in a significant difference compared with ≤1.0 h in patients aged <65 years. For patients aged <65 years with relatively minor stroke severity, >2.1 h of rehabilitation per day may not be necessary, consistent with previous findings. A systematic review showed that increasing the amount of rehabilitation improves body function (8). Another study investigating the effect of the daily dose of rehabilitation on improvement in ADL in patients with subacute stroke stratified by age (≤59, 60–69, 70–79, and ≥80 years) reported that increasing the dose was not associated with improved ADL in patients aged <70 years (26). Therefore, when allocating rehabilitation resources, we recommend prioritizing other age groups over younger patients in terms of rehabilitation per day.
Increasing the number of rehabilitation days per week may benefit ADL improvement in old and very old patients with poor ADL performance at admission. The results of the present study showed that increasing the frequency of rehabilitation per week was associated with an improvement in ADL in old and very old individuals and that the ADL scores at admission in these groups were lower than those in the other groups. Previous research has shown that rehabilitation for seven days per week can improve the ADL of patients with acute stroke (27). In contrast, another study reported that rehabilitation for seven days per week did not significantly increase walking ability at four weeks compared with usual care (28). These conflicting results may be attributed to differences in the measured outcomes; one study assessed ADL, whereas the other focused on walking ability. Increasing the frequency of rehabilitation per week may influence ADLs that are less complex than walking, such as transfer and toilet use, in the 75–85-year and >85-year age groups. Therefore, if rehabilitation resources must be allocated effectively, weekend rehabilitation may be provided to older patients with an expected short hospital stay. Improvement in ADL did not differ significantly between initiating rehabilitation within three days and on the first day across all four age groups, which is inconsistent with previous findings. For example, a previous study showed that early rehabilitation within 24–48 h of stroke onset was beneficial for patients with stroke (29) (30). However, these studies did not adjust for the number of rehabilitation days per week or the daily dose. Rehabilitation parameters may
influence each other, and the association between initiating rehabilitation within three days and improvement in ADL may change after adjusting for rehabilitation days per week and dose per day. We observed in the present study that the stroke severity and dependency rate before admission increased with age. Moreover, the proportion of individuals with normal BMI (18.5–24.9 kg/m²) decreased with age. Previous studies have not examined the differences in dependency or BMI in different age groups; thus, the effectiveness of initiating rehabilitation within three days might have been distorted by age interactions. These baseline differences vary according to age group and affect stroke recovery (31). Therefore, when allocating rehabilitation resources, a faster initiation time of rehabilitation may not be beneficial compared with a higher frequency or increased dose of rehabilitation in older age groups.

With increasing age, the BMI shows a decreasing trend, indicating a potential increase in frailty or malnutrition risk among older patients; hence, specialized nutritional support and more condition-specific rehabilitation sessions are required (32). Additionally, older patients often present with higher dependency and worse functional status upon admission, suggesting the need for a higher dose of rehabilitation to improve ADL. The increase in disturbed consciousness among this group further complicates their rehabilitation requirements, necessitating more specialized and potentially longer rehabilitation periods. These observations suggest that older patients, particularly those aged >75 years, can benefit from more frequent rehabilitation sessions to address high initial dependency and poor functional
status. However, the dose of rehabilitation must be balanced as older patients may not be able to withstand intense sessions.

This study had several limitations. First, this was a retrospective cohort study that analyzed claims data; therefore, some unmeasured confounding factors may have been present, such as imaging studies, medication administration time, socioeconomic status, and environmental factors. Second, our adjustment for stroke severity might not have been sufficient owing to a lack of information, such as the stroke site or onset time of cerebral infarction (only daily data were available). Third, initiating rehabilitation within three days might have been misclassified in this study, as our definition was based on claim information within three days. To account for selection bias due to adaptation, we targeted patients who started rehabilitation within three days of hospitalization. Fourth, we did not specify the rehabilitation content. However, the rehabilitation is standardized according to guidelines in Japan (33). Lastly, we did not assess the long-term outcomes. The follow-up period in this study was approximately 20 days, based on the period from admission to discharge from the acute care hospital.

Conclusion

Our results suggest that increasing the daily dose of rehabilitation is significantly associated with improved ADL in all age groups and that increasing the frequency of rehabilitation per week affects the improvement in ADL in old and very old patients. When allocating rehabilitation resources, we recommend considering age-specific rehabilitation strategies,
both daily and weekly, to optimize outcomes.

359 Declarations

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361 The funding sources did not influence the study design; data collection, analysis, and interpretation; publication of the results, or the writing of the manuscript.

364 Declaration of interests

365 The authors declare no competing interests.

366 Grammarly was used to collect grammar data during the preparation of this work. After using this tool/service, we reviewed and edited the content as needed. The authors take full responsibility for the publication of this content.
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Availability of data and materials

The datasets supporting the conclusions of this study are available from the corresponding author upon request.

List of abbreviations

ADL, activities of daily living; BMI, body mass index; BI, Barthel Index; CI, confidence interval; DPC, diagnostic procedure combination; ICD-10, International Classification of Diseases 10th Revision; JCS, Japan Coma Scale; LOS, length of hospital stay; MCID, minimal clinically important difference; mRS, modified Rankin Scale; SD, standard deviation.