Acta Med. Okayama, 2021
Vol. 75, No. 4, pp. 479-486

Acta Medica Okayama
http://escholarship.lib.okayama-u.ac.jp/amo/

Original Article

Long-term Multidisciplinary Rehabilitation Efficacy in Older Patients After Traumatic Brain Injury: Assessed by the Functional Independence Measure

Akio Harada[a], Nobuyuki Kawai[b]*, Tomoya Ogawa[a], Tetsuhiro Hatakeyama[a], and Takashi Tamiya[a]

[a]*Department of Neurological Surgery, Faculty of Medicine, Kagawa University, Miki-cho, Kagawa 761-0793, Japan,*
[b]*Department of Neurological Surgery, Kagawa Rehabilitation Hospital, Takamatsu 761-8057, Japan*

Instances of traumatic brain injury (TBI) in the elderly have been increasing along with the aging of populations. In the present study, we examined the effect of aging on long-term multidisciplinary in-patient rehabilitation efficacy after TBI. Sixty-three patients with physical and cognitive impairments after TBI were enrolled in this study. Patients were divided into 4 age groups (≤24, 25-44, 45-64, ≥65 years) and the clinical characteristics and rehabilitation efficacy of each age group were determined. Functional disability was evaluated using motor and cognitive Functional Independence Measure (FIM) scores. Rehabilitation efficacy was assessed by FIM gains during rehabilitation and compared among the groups. There were no statistically significant differences in motor and cognitive FIM gains among the age groups. However, cognitive FIM gain was limited in a subset of ≥65 patients, and initial cognitive measures could not predict cognitive FIM improvement. These results indicate that chronological age is insufficient to accurately predict rehabilitation efficacy in older TBI patients, and that such patients should be considered candidates for intensive rehabilitation programs based on these results. Accurate prognostication of rehabilitation efficacy with continuing data collection is important when using rehabilitation resources for older TBI patients.

Key words: aging, Functional Independence Measure, physical and cognitive impairments, traumatic brain injury, rehabilitation

The aged segments of populations are increasing globally, and this is especially the case in Japan. Recent population statistics revealed that about 28% of the Japanese population was comprised of adults aged 65 years or older in 2017, and it is estimated that the proportion will be about 32% by the year 2030. As the aged population increases, so to do instances of traumatic brain injury (TBI) in the elderly [1]. Generally, older patients experience higher morbidity and mortality after TBI, as well as slower recovery, and worse functional, cognitive, and psychosocial outcomes compared with younger patients [1].

TBI rehabilitation is a rapidly growing area of clinical and research interest [2]. Older age appears to negatively impact rehabilitation efficacy in patients after TBI [3,4]. Research on patients undergoing in-patient rehabilitation has frequently used the Functional Independence Measure (FIM) to assess a patient's physical and cognitive disability [5]. One study found that average total FIM scores at an in-patient rehabilitation facility on admission and at discharge, as well as the

Received November 17, 2020; accepted March 5, 2021.
*Corresponding author. Phone : +81-87-867-6008; Fax : +81-87-865-3915
E-mail : nobu@kagawa-reha.net (N. Kawai)

Conflict of Interest Disclosures: No potential conflict of interest relevant to this article was reported.

absolute change in FIM score during in-patient rehabilitation, were significantly lower in older patients than in younger patients after TBI [3]. Generally, the length of in-patient rehabilitation in the United States has been short, usually less than 30 days [6,7]. In addition, older TBI patients received less intensive rehabilitation services than younger patients, and regained less functional ability during in-patient rehabilitation [8]. Older TBI patients were less likely to be discharged to home from acute hospitalization and from in-patient rehabilitation [4]. Therefore, previous studies may not reflect the current rehabilitation situation for TBI patients in Japan, and the results may not apply to an estimation of the efficacy of long-term rehabilitation on functional recovery in older TBI patients.

In the present study, we clarified the effect of aging on long-term multidisciplinary rehabilitation efficacy in patients with post-TBI physical and cognitive impairments by comparing different age groups. We also examined whether rehabilitation efficacy could be predicted by cognitive measures on admission in older TBI patients. Information from this study could be useful for predicting the efficacy of multidisciplinary in-patient rehabilitation programs, and for decisions regarding how best to direct rehabilitation resources to older TBI patients.

Materials and Methods

Subjects. Patients who had a primary diagnosis of post-TBI physical and/or cognitive impairments and were admitted to Kagawa Rehabilitation Hospital between April 2013 and March 2020 were enrolled in this study. The patients were referred from seven acute care neurosurgical institutes and admitted to the rehabilitation hospital within two months of injury or surgical intervention. Exclusion criteria were (1) length of rehabilitation stay less than 30 days, (2) preexisting musculoskeletal and nervous system disease, and (3) severe physical impairment (essentially bed-ridden) during hospitalization. The ethical committee of Kagawa Rehabilitation Center approved the use of patient data for this retrospective analysis (approval number: 20004), and waived the need for individual consent.

Study design. Demographic information was obtained from patient referral documents, attached imaging findings, and telephone inquiries if necessary. Admission information, such as admission delay (time between injury onset and in-patient rehabilitation admission), and rehabilitation duration, initial cognitive measurement using the Mini-Mental State Examination (MMSE), functional disability as evaluated by the FIM instrument on admission and at discharge, use of antipsychotic drugs at discharge, and discharge destination (home or other facility), were obtained from in-patient medical and rehabilitation records and discharge reviews of individuals.

Patients were divided into 4 age groups (age ≤24, 25-44, 45-64, and ≥65 years) to clarify clinical characteristics and rehabilitation efficacy of each age group and allow between-age group comparisons of quantitative and qualitative variables.

In-patient rehabilitation program. Rehabilitation was provided as a multidisciplinary in-patient program based on a team approach developed within the framework of the International Classification of Functioning, Disability and Health (ICF) of the World Health Organization [9]. The following specific therapeutic objectives were set for TBI patients: gait and balance training; global strengthening; adaptation to orthoses and walking aids; fine use of upper limbs; safe swallowing; functional speech and advanced speech skill; independence in activities of daily living (ADL); and cognitive-behavioral interventions. Drugs to counter personality changes and behavioral problems were also tested, as necessary.

Functional Independence Measure (FIM). Functional disability was measured using the FIM, which assesses 6 domains and is comprised of 18 items grouped into 2 subscales, motor and cognition. The motor subscale is comprised of 13 items and assesses 4 motor domains: self-care (eating, grooming, upper body dressing, lower body dressing), sphincter control (toileting, bladder management, bowel management), transfers (bed/chair/wheelchair, toilet, bath/shower), and locomotion (walk/wheelchair, stairs). The cognition subscale is comprised of 5 items and assesses 2 cognitive domains: communication (comprehension, expression) and cognition (social interaction, problem solving, memory). Each of the motor and cognitive items is graded on a scale of 1-7 based on level of independence in terms of that item, so that total FIM scores range from 18 (total dependence) to 126 (complete independence). FIM scores were evaluated every month during in-patient rehabilitation. The difference between the admission and discharge scores constituted the FIM gain.

Statistical analysis. All statistical analyses were performed using EZR version 1.40 (Saitama Medical Center, Jichi Medical University, Saitama, Japan). Quantitative variables are presented as means and standard deviation, while qualitative variables are presented as numbers and proportions of each category. Quantitative variables, such as the initial Glasgow Coma Scale (GCS), initial cognitive measurement using MMSE, length of hospital stay, and FIM scores, were almost normally distributed and compared across the 4 age groups using one-way ANOVA and Tukey correction for multiple comparisons. Correlations between initial MMSE and cognitive FIM on admission were evaluated using linear regression analysis. Receiver operating characteristic (ROC) analysis was performed to examine the usefulness of the cognitive FIM score on admission and initial MMSE in predicting cognitive FIM gain during rehabilitation. Association between the qualitative variables, such as discharge destination (home vs. other facility) and use of antipsychotic drugs at discharge, was analyzed using the Chi-square (χ^2) test.

Results

During the data collection period, 70 patients with post-TBI physical and cognitive impairments were admitted for in-patient rehabilitation. Of these, 7 were excluded from the analysis due to a short length of stay (n=3), severe physical impairment (n=2), or preexisting musculoskeletal or nervous system disease (n=2, myotonic dystrophy and dentatorubropallidoluysial atrophy). Among the 3 patients who were excluded from the analysis due to a short length of stay, 1 patient showed severe psychotic symptoms, 1 patient refused rehabilitation, and 1 patient recovered soon after admission. Ultimately, 63 patients met the inclusion criteria for this study. Prior to injury, all patients had lived independently in their own homes.

The patients' demographics and clinical characteristics are presented in Table 1. Overall mean age was 47.1±22.7 years (range 9-87 years), and 55 patients (87.3%) were male. Fourteen patients were categorized into the ≤24 group (mean age: 16.6±3.7 years), 15 into the 25-44 group (34.5±7.0 years), 15 into the 45-64 group (54.9±6.6 years), and 19 into the ≥65 group (73.3±7.4 years). Fourteen patients (73.7%) in the ≥65

Table 1 Demographic data and clinical characteristics of the 4 age groups

	overall (n=63)	age ≤24 (n=14)	age 25–44 (n=15)	age 45–64 (n=15)	age ≥65 (n=19)
Age	47.1±22.7	16.6±3.7	34.5±7.0	54.9±6.6	73.3±7.4
Males	55 (87.3%)	13	13	14	15
Medical comorbidities	22 (34.9%)	1	0	7	14
MVAs*	35 (55.6%)	14	7	6	6
GCS*	8.9±3.1	7.9±2.7	7.8±2.9	9.0±3.5	12.4±2.2
TBI severity					
severe (GCS 3–8)	27 (42.9%)	8	10	7	2
moderate (GCS 9–12)	22 (34.9%)	6	5	5	6
mild (GCS 13–15)	14 (22.2%)	0	0	3	11
TCDB* classification (only severe TBI patients)					
diffuse injury	13	4	5	2	2
focal injury	14	4	5	5	0
Hematoma removal	23 (36.5%)	6	6	7	4
TTM*	10 (15.9%)	2	5	3	0
ICP* monitoring	10 (15.9%)	4	4	2	0
Admission delay (days)	43.1±12.6	45.6±11.7	47.7±10.1	41.3±11.7	38.9±14.8
Rehabilitation days	109.9±46.4	105.0±36.7	115.0±47.4	119.6±47.1	101.8±52.7
Antipsychotic drugs	18 (28.6%)	3 (21.4%)	5 (33.3%)	4 (26.7%)	6 (31.6%)
Home discharge	40 (82.5%)	14 (100%)	13 (86.7%)	12 (80%)	13 (68.4%)

MVAs, motor vehicle accidents; GCS, Glasgow Coma Scale; TCDB, Traumatic Coma Data Bank; TTM, targeted temperature management; ICP, intracranial pressure.

group had preexisting medical comorbidities, such as hypertension and diabetes mellitus. The cause of injury was motor vehicle accident in 35 patients (55.6%) and fall in 28 patients (44.4%). Motor vehicle accident was the cause of injury in all ≤24 patients, while fall was predominant in ≥65 patients (63.2%).

Information of acute care management. Information regarding acute care management is also listed in Table 1. The initial GCS scores were 7.9±2.7 in the ≤24 group, 7.8±2.9 in the 25-44 group, 9.0±3.5 in the 45-64 group, and 12.4±2.2 in the ≥65 group. Thus, initial GCS score in the ≥65 group was significantly higher compared with those in the non-senior groups ($p<0.001$).

In-patient rehabilitation. Information about in-patient rehabilitation is included in Table 1. There were no statistically significant differences in the mean admission delay (time from injury to admission) or mean rehabilitation duration between groups.

Initial cognitive measurements. The MMSE was conducted on all 63 patients on the day of admission. Initial MMSE scores were 26.1±4.3 in the ≤24 group, 27.4±3.2 in the 25-44 group, 24.8±4.7 in the 45-64 group, and 18.4±8.6 in the ≥65 group. The initial MMSE score in the ≥65 group was therefore significantly lower compared with those in the other groups (Fig. 1A). Initial MMSE scores were significantly correlated with the cognitive FIM scores on admission (Fig. 1B, $R^2=0.56$, $p<0.001$).

Changes in cognitive FIM scores. Table 2 lists the cognitive FIM scores on admission and at discharge, and the gain during rehabilitation in the 4 age groups. The cognitive FIM gains during rehabilitation were 5.6±5.3 in the ≤24 group, 5.7±4.4 in the 25-44 group, 6.2±4.9 in the 45-64 group, and 4.7±5.6 in the ≥65 group. There were no statistically significant differences between groups.

When we checked the cognitive FIM gains in individual patients, 9 of the 19 patients in the ≥65 group showed no or small improvement, while the other 10 patients exhibited significant improvement or maintained high cognitive FIM scores during rehabilitation (Fig. 2A). On the other hand, almost all non-senior patients showed significant improvement or maintained high cognitive FIM scores during rehabilitation (Fig. 2B).

In ≥65 patients, a cognitive FIM gain of more than 5 (≈ average cognitive FIM gain) during rehabilitation is considered a favorable gain; here, 7 patients exhibited a favorable gain, and 12 exhibited an unfavorable gain. ROC analysis showed that the cognitive FIM score on admission could not predict differentiation of patients with a favorable gain from those with an unfavorable gain (area under the curve 0.43, Fig. 3A). This was also the case with the initial MMSE score (area under the curve 0.57, Fig. 3B).

Changes in Motor FIM scores. Table 2 presents the motor FIM scores on admission and at discharge, and the gain during rehabilitation in the 4 age groups. Motor FIM gains during rehabilitation were 17.1±21.0 in the ≤24 group, 21.6±15.1 in the 25-44 group, 13.5±10.4 in the 45-64 group, and 20.7±13.4 in the

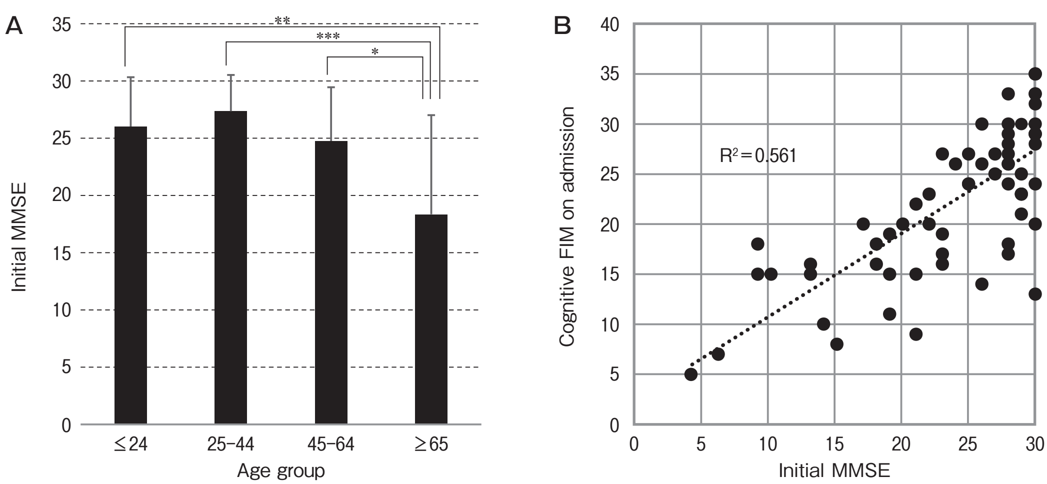

Fig. 1 (**A**) Initial MMSE in the 4 age groups. The initial MMSE score in the ≥65 group was significantly lower compared with those in the other groups (*$p<0.05$; **$p<0.01$; ***$p<0.001$). (**B**) Correlation between initial MMSE scores with cognitive FIM scores on admission. Initial MMSE scores were significantly correlated with cognitive FIM scores on admission ($R^2=0.56$, $p<0.001$).

Table 2 Cognitive and motor FIM scores on admission and at discharge, and the gain during in-patient rehabilitation in the 4 age groups

	age ≤24 (n=14)	age 25–44 (n=15)	age 45–64 (n=15)	age ≥65 (n=19)
Cognitive FIM score				
on admission	23.6±8.3	24.9±7.2	23.3±6.0	18.5±7.2
at discharge	29.1±5.0[a]	30.6±4.8[b]	29.3±3.0[a]	23.3±7.9*
gain	5.6±5.3	5.7±4.4	6.2±4.9	4.7±5.6
Motor FIM score				
on admission	69.5±25.3[c]	66.9±18.9[b]	71.8±15.6[c]	39.2±20.6**
at discharge	86.8±6.9[c]	88.5±5.4[c]	85.3±10.6[c]	60.7±25.7***
gain	17.1±21.0	21.6±15.1	13.5±10.4	20.4±13.4

* The cognitive FIM score at discharge in the ≥65 group was significantly lower compared with those in the other groups. ([a]$p<0.05$, [b]$p<0.01$)
** The motor FIM score on admission in the ≥65 group was significantly lower compared with those in the other groups. ([b]$p<0.01$, [c]$p<0.001$)
*** The motor FIM score at discharge in the ≥65 group was significantly lower compared with those in the other groups. ([c]$p<0.001$)

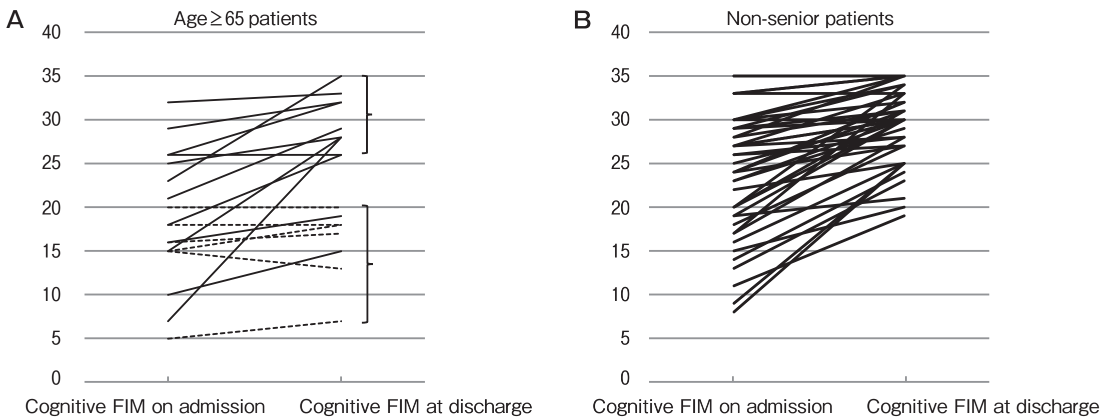

Fig. 2 (**A**) Individual changes in cognitive FIM score during rehabilitation in ≥65 patients. Of 19, 9 patients showed no or small improvement in cognitive FIM scores, while 10 patients exhibited significant improvement or maintained high cognitive FIM score during in-patient rehabilitation. Six of the 9 patients with unfavorable cognitive FIM gains were prescribed an antipsychotic drug for psychological symptoms (dotted lines). (**B**) Individual changes in cognitive FIM score during rehabilitation in non-senior patients. Almost all patients showed significant improvement or maintained high cognitive FIM score.

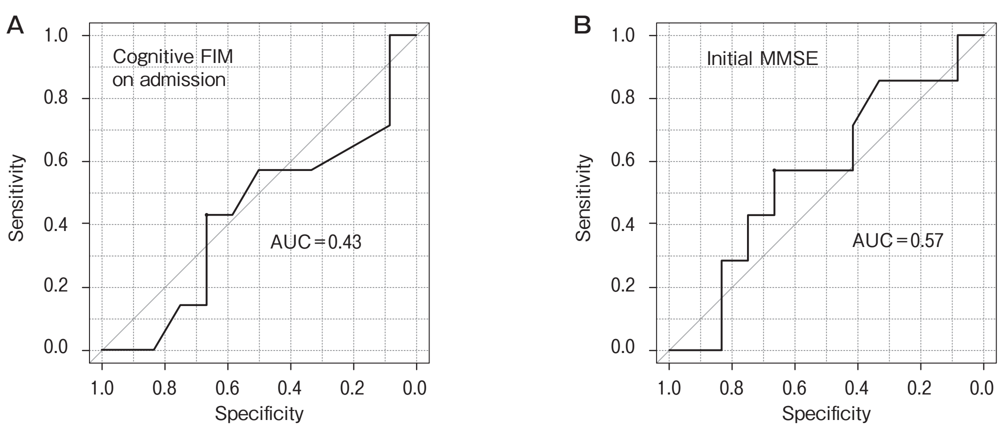

Fig. 3 ROC curve of cognitive FIM scores on admission (**A**), and initial MMSE score (**B**) for differentiating patients with favorable cognitive FIM gain (more than 5) from unfavorable cognitive FIM gain (less than 4). Neither the cognitive FIM on admission nor the initial MMSE score predicted cognitive FIM gain during rehabilitation.

≥65 group. There were no statistically significant differences between groups.

Discharge destination and use of antipsychotic drugs at discharge. All the patients in the ≤24 group, 13 of 15 patients (86.7%) in the 25-44 group, 12 of 15 patients (80%) in the 45-64 group, and 13 of 19 patients (68.4%) in the ≥65 group were discharged to their homes (Table 1). The other patients were discharged to a nursing hospital, nursing care facility, or geriatric health service facility. Age ≥65 patients tended to be discharged to non-home facilities more often than younger patients, but the difference was not statistically significant ($p=0.12$, Chi-square test).

Three of the 14 patients in the ≤24 group, 5 of 15 in the 25-44 group, 4 of 15 in the 45-64 group, and 6 of the 19 patients in the ≥65 group were prescribed antipsychotic drugs (mainly risperidone and/or quetiapine) to counter psychological symptoms such as agitation and aggressive behavior at discharge (in all, 18 of 63 patients, 28.6%; Table 1). There was no significant difference between age ≥65 patients and other (non-senior) patients in the prescription of antipsychotic drugs at discharge ($p=0.89$, Chi-square test). Surprisingly, all 6 patients who were prescribed antipsychotic drugs in the ≥65 group exhibited an unfavorable cognitive FIM gain (Fig. 2B, dotted lines).

Discussion

This study was conducted to clarify the effect of aging on physical and cognitive recovery in patients who receive long-term multidisciplinary in-patient rehabilitation after TBI. In the present study, we examined the rehabilitation efficacy as measured by the FIM. The FIM instrument is widely used in the field of rehabilitation; it covers several functional domains and is typically reported as a total score or subdivided into motor and cognitive subscores. Although previous studies have questioned the use of the total score for evaluating functional independence [10], the FIM score can be useful for setting rehabilitation program goals, evaluating the necessary amount of ADL assistance, and tracking progress during rehabilitation. Because cognitive impairment is a common consequence after TBI and can limit functional gains during in-patient rehabilitation, early assessment of cognitive skills is a crucial part of any routine evaluation of rehabilitation setting. Early evaluation of the cognitive aspects in TBI patients allows clinicians to identify patients' potential for rehabilitation and to set realistic plans for treatment. In the present study, we examined MMSE routinely, because it is brief and is the least difficult measure even in patients with severe cognitive impairment. The correlation coefficient between the cognitive FIM score on admission and initial MMSE was 0.56, which means they share a reasonable degree of resemblance and accounts for their construct validity.

Several studies have demonstrated that age is a strong indicator of long-term morbidity and negatively impacts rehabilitation efficacy after TBI. One showed that elderly patients (aged 55 and older) had lower rate of change in FIM [3]. A multicenter study of 1419 patients reported that patients aged 65 years or older had lower brain injury severity and shorter lengths of stay in acute care [8]. During rehabilitation, they received fewer hours of therapy and regained less functional ability during in-patient rehabilitation [8]. Graham *et al.* [4] also found that higher age (65-95 years) was associated with shorter length of stay, lower discharge FIM scores, and higher odds of home health service at discharge in a large prospective study. It is concerning that the results of these studies indicate older patients received less intensive rehabilitation services than younger patients and regained less functional ability by rehabilitation. However, there is conflicting evidence about the effect of age on rehabilitation efficacy.

Evidence has emerged indicating that intensive in-patient neurorehabilitation practices generally benefit older adults with acquired brain injury including TBI [11]. Although functional gains are often slower in older than in younger patients, necessitating longer lengths of stay in the former, the TBI Model System database found that overall net functional gains did not differ significantly between older and younger patients after accounting for TBI severity [12]. The findings of the present study were largely consistent with previous research showing that older TBI patients can achieve meaningful improvements in physical and cognitive function much like younger patients.

The present study showed that older TBI patients (age ≥65) had significantly higher initial GCS scores when admitted to acute care neurosurgical institutes, indicating that they suffered from less severe injuries than younger patients; this was because the most frequent mechanism of injury among the older patients was fall (63.2%), a non-high energy trauma. This is consistent with the increased frequency of TBI in older adults, for whom falls are by far the most common cause of TBI [13]. However, despite the less severe injury in the age ≥65 group, there was no significant difference in the admission delay between younger and older patients. This finding is important, since earlier rehabilitation admission was associated with greater recovery, lower costs, and shorter length of stay in TBI patients [14]. Elderly patients are more likely to have preexisting medical problems, and might have a higher incidence of concomitant medical complications during acute care management. These problems might prolong the time it takes to stabilize their general condition before starting in-patient rehabilitation even if their TBI severity is milder.

The present study demonstrated that older TBI patients showed significantly lower cognitive function as evaluated by the initial MMSE, but that cognitive FIM gain was not significantly different among age groups, suggesting that older TBI patients can be rehabilitated successfully with meaningful gains in cognitive function through in-patient rehabilitation. However, cognitive FIM gain was limited in a subset of older TBI patients. Neither the cognitive FIM score on admission nor initial MMSE could predict cognitive FIM gain during rehabilitation. In the present study, 14 of the 19 patients (73.7%) in the ≥65 group had preexisting medical comorbidities such as hypertension and diabetes mellitus. Greater disease comorbidity at the time of TBI has been associated with lower functional independence at rehabilitation admission and discharge [15]. Moreover, 6 of the 9 patients with unfavorable cognitive FIM gains in the ≥65 group were prescribed antipsychotic drugs for psychological symptoms. A previous study reported that antipsychotic drugs are prescribed to about 25% of TBI patients during in-patient rehabilitation [16]. These drugs reduce awareness and could negatively influence chance of recovery, especially in older TBI patients.

This study had several limitations. First, the total number of patients enrolled was small (n = 63) compared with previous multicenter prospective studies. Nonetheless, patients were referred from acute care neurosurgical institutes with full medical information, including type of TBI and acute care management. They received uniformly planned in-patient rehabilitation of significant duration at a single rehabilitation institute. The findings of the current study are largely consistent with previous research with large samples of TBI patients [11, 12]. Second, there is increasing recognition that the use of the FIM as the primary endpoint for TBI study does not adequately capture the complex, multidimensional, and evolving nature of TBI [10, 17]. To achieve a perfect cognitive FIM score, a patient need only communicate intelligibly and fluently, solve daily problems without help, and remember their daily routine. Thus, this instrument may suffer from substantial ceiling effects, especially in young TBI patients, resulting in a failure to demonstrate superiority in younger age groups. In fact, the maximum motor FIM score (91 points) was attained by 9 of 14 patients in the ≤24 group and 10 of 15 patients in the 25-44 group at the time of discharge. Third, our data indicated that the selection of subjects in the ≥65 group was affected by selection bias, as the number of TBI patients with low GCS scores was limited to those referred to our rehabilitation hospital. This selection bias could reflect the decisions of physicians at acute care hospitals regarding the indications for rehabilitation in older patients with severe TBI and low GCS scores.

In conclusion, older TBI patients can achieve meaningful improvements in physical and cognitive FIM scores much like younger patients, indicating that chronological age alone is insufficient to accurately predict rehabilitation response. Cognitive FIM gain was limited in a subset of older TBI patients, and initial cognitive measures could not predict the improvement of cognitive FIM. It is also crucial to control preexisting medical comorbidities and psychological symptoms, as they are significant inhibitors of recovery from post-TBI impairments.

Older adults are the fastest-growing segment of the population, and based on these results, they should be considered candidates for intensive in-patient rehabilitation after TBI. With further data collection, accurate prognostication of rehabilitation efficacy is important not only for avoiding less efficient treatments when poor outcome is inevitable, but also for avoiding inappropriate withdrawal of older TBI patients who might otherwise have a chance of achieving meaningful functional recovery.

Acknowledgements. We are sincerely grateful to all rehabilitation staff in the Department of Rehabilitation Medicine at Kagawa Rehabilitation Hospital.

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