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Original Article

The relationship between measured values and values predicted using multiple regression analysis for mean motor FIM at discharge – A study at 13 *Kaifukuki* rehabilitation hospitals for stroke patients in the Japan Rehabilitation Database

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ABSTRACT

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Objective: The purpose of this study was to predict mean Functional Independence Measure (FIM) at discharge in patients with stroke from *Kaifukuki* rehabilitation wards using multiple regression analysis, and to clarify the measured values and predicted values at each hospital.

Methods: The subjects were 2,320 stroke patients of 13 *Kaifukuki* rehabilitation wards registered in the 2014 Japan Rehabilitation Database. For each patient, we found a "measurement/prediction ratio" by dividing the "measured value for motor FIM at discharge" by the "predicted value for motor FIM at discharge obtained by multiple regression analysis", and compared the mean values among hospitals.

Results: The 13 hospitals had significant differences in the measurement/prediction ratio for the motor FIM at discharge, ranging from 0.91 to 1.09.

Conclusion: The technique of using multiple regression analysis to predict FIM at discharge and comparing the measurement/prediction ratio between hospitals is advantageous in that it can correct the effects of various factors and enables statistical comparisons.

Key words: Functional Independence Measure, multiple regression analysis, inter-hospital comparison.

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Introduction

One approach to assess the rehabilitation performance at different hospitals is to compare the outcome in terms of the improvement in activities of daily living (ADL). However, the improvement in the Functional Independence Measure (FIM), a method of assessing ADL, varies depending on the FIM at admission, which is a major problem. The total-assistance level includes many patients whose FIM is difficult to improve, while the light-assistance level has a ceiling effect that ends with little improvement in FIM. In contrast, moderate-assistance patients often show considerable improvement in their FIM [1]. For this reason, it is not possible to make simple comparisons in the mean improvement in FIM (FIM gain) between hospitals that have different proportions of patients' severity (i.e., different severity distributions).

Reports that corrected the differences in severity distribution between hospitals before comparing the ADL gain between hospitals include: (1) the technique of using the severity distribution of all hospitals as a "standard severity distribution" and correcting the mean FIM gain at each hospital to a numerical value that assumes that patients are admitted at each individual hospital with the same severity as all the hospitals [2−7]; (2) the technique of limiting patients based on their ADL at admission [7, 8]; (3) the technique of using the corrected FIM effectiveness [7, 9, 10]; (4) a case-control study that matched basic attributes [11]; and (5) the technique of using multiple regression analysis to predict FIM at discharge, and clarifying which hospitals had measured values that were higher than the predicted values [12]. The techniques in (1) to (4) are either corrections only based on the ADL at admission or corrections only based on age and the ADL at admission, whereas (5) has the advantage of being able to correct the effects of various factors.

Jeong et al. [12], who used the technique in (5), predicted FIM at discharge by using five items: the ages of stroke patients in rehabilitation hospitals, the pre-onset modified Rankin Scale (mRS), number of days from onset to admission, the sum of 13-item scores for motor FIM at admission (motor FIM at admission), and the sum of 5-item scores for cognitive FIM at admission (cognitive FIM at admission), as explanatory variables. “Good” was defined as patients whose measured FIM at discharge was +6 or more points than predicted, “fair” as patients where it was from − 4 points to + 5 points, and “poor” as patients where it was − 5 or less, and the proportions of good/fair/poor patients were compared between 12 hospitals (basic attribute data are not shown in this study). However, the hospital ranking with a large “good” proportion and the hospital ranking with a low “poor” proportion did not coincide, and a statistical comparison was not performed. We chose not to categorize quantitative variables into qualitative variables, but to statistically compare the ratios between the measured FIM values at discharge and the predicted values among hospitals.

The purpose of this study was to predict hospitals’ mean FIM at discharge for stroke patients in *Kaifukuki* rehabilitation wards using multiple regression analysis, and to clarify the measured values and predicted values at each hospital.

Subjects and Methods

We used patient data from the Japan Rehabilitation Database. The goal behind the creation of the Japan Association of Rehabilitation Database, which was established in September 2012, is to construct and use a rehabilitation database to help improve rehabilitation medicine and care [13]. The groups which comprise the Japan Association of Rehabilitation Database are: the Japanese Association of Rehabilitation Medicine, the Japanese Physical Therapy Association, the Japanese Association of Occupational Therapists, and the Japanese Association of Speech-Language-Hearing Therapists. Data on patients who have suffered stroke, hip fracture, or spinal cord injury are collected from participating institutions throughout Japan.

The present epidemiologic study is a retrospective design. The number of patients registered in the May 2015 Japan Rehabilitation Database (stroke in *Kaifukuki* rehabilitation wards) [13] was 6,322. The number was narrowed down to 2,735 patients by applying the following conditions: number of days from onset to admission: 5 to 80; length of hospital stay in *Kaifukuki* rehabilitation wards: 10 to 240; motor FIM score at admission: 13 to 90 points; the sum of the number of units of physical therapy, occupational therapy, and speech-language-hearing therapy during hospital stay (total training units): 10 or more units; and pre-onset mRS has been entered. Of these, 2,320 patients from 13 hospitals (Hospital A to Hospital M) which registered 50 or more cases, were used as the subjects of this study.

1. Basic attributes data

At the 13 hospitals A to M, we investigated the means for age, pre-onset mRS, number of days from onset to admission, motor FIM score at admission, cognitive FIM score at admission, length of hospital stay, number of training units per day, total number of training units, and motor FIM score at discharge. The presence or absence of significant differences between the 13 hospitals was tested with the Kruskal-Wallis test (significance level of less than 5%).

2. Multiple regression analysis using motor FIM at discharge as a dependent variable

Multiple regression analysis was performed with all patients using five items: age, pre-onset mRS, number of days from onset to admission, motor FIM score at admission, and cognitive FIM score at admission, as explanatory variables, and using motor FIM score at discharge as a dependent variable.

3. Measurement/prediction ratio of motor FIM at discharge

For each patient, we found the measurement/prediction ratio by dividing the measured value for motor FIM score at discharge by the predicted value for motor FIM score at discharge obtained by multiple regression analysis. Then, whether or not hospitals had significantly different mean measurement/prediction ratios was tested with the Kruskal-Wallis test (significance level of less than 5%). If there was a significant difference, multiple comparison was subsequently performed with Scheffé’s method.

In the Japan Rehabilitation Database, all personal information is converted to data to prevent identification of individuals. The present epidemiologic study was conducted based on the regulations of the institutional review board of the hospital to which the first author belongs and with the permission of an employee designated in advance by the institutional review board.

Results

Table 1 shows the mean values for basic attribute data at Hospitals A to M. The mean motor FIM (measured value) at discharge was in the range of 59.2 points (Hospital A) to 76.8 points (Hospital M), and there were significant differences among the 13 hospitals (Kruskal-Wallis test, $p<0.001$). There were also significant differences among the 13 hospitals in

Table 1. Clinical characteristics in each hospital.

	A	B	C	D	E	F	G	H	I	J	K	L	M	Significance
Number of patients	456	331	319	272	221	209	123	75	74	71	60	55	54	$p < 0.001$
Age	71.9	71.4	69.7	70.6	**63.2**	67.2	**74.1**	63.3	67.5	72.1	68.4	70.7	64.0	$p < 0.001$
Pre-stroke modified Rankin Scale	1.1	0.4	0.6	0.9	**0.1**	0.3	0.9	0.1	0.6	0.8	0.3	1.1	0.2	$p < 0.001$
Number of days from onset to admission	32.9	36.6	**44.6**	**23.3**	29.7	36.9	36.1	32.9	32.5	37.5	27.4	39.9	31.9	$p < 0.001$
Motor FIM score at admission	**34.8**	43.0	52.3	43.6	49.2	**59.0**	47.1	53.3	51.1	55.7	43.4	44.3	49.3	$p < 0.001$
Cognitive FIM score at admission	21.2	19.7	22.9	20.4	21.7	23.7	21.7	25.0	24.6	23.5	**25.1**	**19.1**	24.3	$p < 0.001$
Length of stay	90.9	108.4	112.1	100.3	**115.9**	78.2	84.4	104.0	103.6	89.2	**62.2**	106.3	80.5	$p < 0.001$
Training dose per day	**2.9**	6.3	5.8	6.9	5.9	4.8	4.7	6.6	7.1	**7.3**	4.5	4.9	3.2	$p < 0.001$
Total training dose	270	695	655	705	695	392	405	691	**748**	664	281	529	**256**	$p < 0.001$
Measured value of motor FIM at discharge	**59.2**	60.8	65.9	64.8	64.5	76.6	61.1	73.9	72.0	67.4	63.8	61.5	**76.8**	$p < 0.001$
Predicted value of motor FIM at discharge	**56.5**	61.6	67.6	63.4	69.7	**74.2**	63.5	73.4	70.0	70.2	67.2	60.3	70.5	$p < 0.001$
Measured/predicted	1.04	0.96	0.96	1.01	**0.91**	1.05	0.93	1.00	1.04	0.94	0.93	1.01	**1.09**	$p < 0.001$

Numerical values other than number of patients and measured/predicted, mean value;
Underlined, Maximum and minimum values; Significance, significance among 13 hospitals (Kruskal-Wallis test);
A−M, each hospital; Measured/predicted, "measured motor FIM at discharge" divided by "predicted motor FIM at discharge".

age, pre-onset mRS, number of days from onset to admission, motor FIM at admission, cognitive FIM at admission, length of hospital stay, number of training units per day, and total training units.

Table 2 shows the results of multiple regression analysis using the motor FIM at discharge as the dependent variable. The prediction formula was significant (p<0.001), and the coefficient of determination adjusted for degree of freedom (R^{*2}), which is indicative of the extent to which the dependent variable can be explained by the explanatory variables, was 0.690. All five items were significant explanatory variables. The regression coefficient was negative with pre-onset mRS, age, and number of days from onset to admission (the greater these were, the lower the motor FIM at discharge was), and positive with motor FIM at admission and cognitive FIM at admission (the greater these were, the higher the motor FIM at discharge was).

Predicted values for motor FIM at discharge as obtained by multiple regression analysis ranged from 56.5 points (Hospital A) to 74.2 points (Hospital F) (Table 1). The “measurement/prediction ratio”, found by dividing the measured values by the predicted values, ranged from 0.91 (Hospital E) to 1.09 (Hospital M). Measurement/prediction ratios were significantly different among the 13 hospitals (Kruskal-Wallis test, p<0.001). In multiple comparison, Hospital A and Hospital F had significantly higher measurement/prediction ratios than Hospital E (Scheffé’s method, p<0.05).

Figure 1 shows the relationships between predicted values and measured values. Hospital M had the

Table 2. Multiple regression analysis to predict motor FIM at discharge.

Number of patients	2,320
Explanatory variables	
Motor FIM at admission	0.583 (0.575), $p < 0.001$
Cognitive FIM at admission	0.569 (0.217), $p < 0.001$
Pre-stroke modified Rankin Scale	− 2.174 (− 0.111), $p < 0.001$
Age	− 0.203 (− 0.109), $p < 0.001$
Number of days from onset to admission	− 0.147 (− 0.089), $p < 0.001$
Constant	46.104
P value	$p < 0.001$
Adjusted coefficient of determination R^{*2}	0.690

FIM, Functional Independence Measure;
Numerical value for explanatory variables, coefficient of regression (standardized partial regression coefficient).

highest measurement/prediction ratio, and Hospital E had the lowest measurement/prediction ratio. The other hospitals had predicted and measured values that were substantially equivalent to each other.

Discussion

The present study shows that the "measurement/prediction ratio" of motor FIM at discharge varied, from 0.91 to 1.09, among the 13 hospitals studied.

Hospitals with a higher "measurement/prediction ratio" for motor FIM at discharge are regarded as having better quantities or qualities of rehabilitation, but Hospital M, which had the highest measurement/prediction ratio, had the least total rehabilitation units. The question of whether the quality of rehabilitation at Hospital M is high will need to be clarified in the future.

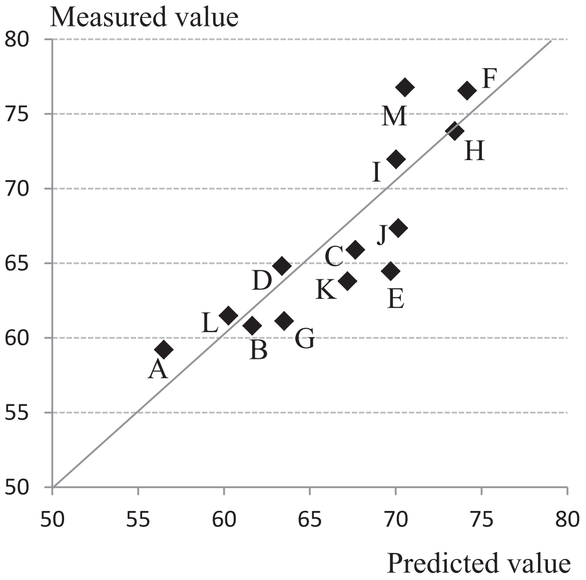

Figure 1. Relationship between predicted value and measured value of motor FIM at discharge.
A−M: each hospital.

Though quite a few reports have used multiple regression analysis to predict FIM at discharge in stroke patients, the purpose of these reports was to predict individual outcomes, with the exception of the report from Jeong et al. [12].

Table 3 shows a comparison of the five kinds of techniques for comparing the improvement in ADL between hospitals with different ADL at admission. The technique of using multiple regression analysis to predict FIM at discharge and comparing the measurement/prediction ratios between hospitals is advantageous in that it can correct the effects of various factors and enables statistical comparisons.

Limitations of the present study include the following. First, the question of whether the results of inter-hospital comparison using multiple regression analysis are reliable depends on the prediction accuracy of the multiple regression analysis. The adjusted coefficient of determination (indicative of the extent to which the dependent variable can be explained by the explanatory variables) was 0.690, which is not necessarily satisfactory. But this figure is similar to other reports using multiple regression analyses. In the review of Heinemann et al. [14], the coefficient of determination for multiple regression analysis was on the order of 0.46 to 0.73. At this level,

Table 3. Methods to compare ADL improvements among hospitals with different mean ADL at admission.

Methods	Standard severity distribution	Limiting patients	Corrected FIM effectiveness	Case-control study	Multiple regression analysis
References	2−7	7, 8	7, 9, 10	11	12, this study
Comparison among many hospitals	**possible**	**possible**	**possible**	impossible (two hospital comparison)	**possible**
Subjects	**all patients**	some patients	full score of FIM at admission and negative FIM gain are excluded	some patients	**all patients**
Number of patients needed	many are needed to stratify	many are needed to limit patients	many are desirable	one hospital needs several times more patients than the other hospital	many are desirable
Simultaneous correction of age and ADL at admission	**possible**	difficult	impossible	**possible**	**possible**
Correction of numerous factors	impossible	impossible	impossible	impossible	**possible**
Usage for other than ADL improvement comparison	**possible**	**possible**	impossible	**possible**	impossible
Is correction always possible?	**possible**	impossible	**possible**	**possible**	**possible**
Statistical comparison	impossible	**possible**	**possible**	**possible**	**possible**

Usage for other than ADL improvement, mean length of stay and mean discharge rate can be compared among hospitals; bold figure, the merit of the method.

population trends can be predicted, but it is not enough to make precise predictions for individual cases [15]. Predicting a hospital's mean FIM at discharge would be a population prediction, but more accurate multiple regression analysis remains an issue for future research. Possible approaches for this include using an index for co-morbidities and dysfunction, in addition to the five items used here, as explanatory variables [16−18], or creating multiple prediction formulae if it is difficult to fit all patients into one prediction formula [19−21]. Second, because we used division to find the measurement/prediction ratio, differences in outcome in patients with lower FIM at discharge were emphasized. Third, it is not clear that a hospital with a high measurement/prediction ratio has high-quality rehabilitation. In the future, it will be necessary to investigate whether indices of rehabilitation quality are higher in hospitals with a high measurement/prediction ratio. Fourth, patients are registered into the Japan Rehabilitation Database only from particular hospitals, and results may differ from those of the national average of *Kaifukuki* rehabilitation hospitals.

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