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Attempt to Raise the Predictive Accuracy in Binary Logistic Regression Analysis

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Abstract

Objective: It is necessary to improve the predictive accuracy of binary logistic regression analysis. This study aimed to clarify whether binary logistic regression analysis using Functional Independence Measure (FIM) gain (a 0/1 binary value) as a dependent variable increases the predictive accuracy when FIM at admission (FIMa) is categorized or when multiple predictive formulae are created.

Methods: The study population consisted of 2,542 stroke patients admitted to convalescent rehabilitation wards in Japan. We compared the predictive accuracy of FIM gain between a formula using FIMa as quantitative data (A), a formula that categorized FIMa into 4 groups (B), and two predictive formulae (C).

Result: The predictive accuracy of these formulae, in descending order, was found to be C (76.3%), B (76.0%), and A (68. 4%).

Conclusion: Even more than using FIMa as quantitative data, the predictive accuracy of FIM gain was heightened by either categorizing FIMa into 4 groups or by creating two predictive formulae.

Keywords: Binary logistic regression analysis; Categorization; Stratification; FIM gain; Predictive accuracy

Introduction

Many reports have used Functional Independence Measure (FIM) [1] gain (FIM at discharge minus FIM at admission) as the dependent variable in multiple linear regression analysis [2]. Binary logistic regression analyses have also been carried out using 1 for FIM gains equal to or greater than the median value and 0 for FIM gains less than the median value [3-11]. The deliberate conversion of quantitative FIM gains into 0/1 binary data is thought to be advantageous in that this does not require as much rigor in terms of the type or distribution of data [12].

While multiple regression analysis envisions a linear relationship between independent variables and dependent variable, there are in fact many cases where no such linear relationship exists. Especially, there is no linear relationship found between FIM at admission and FIM gain [13]. Accordingly, it has been reported that, rather than relying on a single predictive formula, the predictive accuracy of motor FIM (mFIM) gain will be increased by creating two predictive formulae by stratifying mFIM scores at the time of admission (mFIMa) into two groups [14].

In binary logistic regression analysis, as well, stratifying mFIMa to create two predictive formulae may improve the predictive accuracy of mFIM gain. In addition, because it is possible to categorize independent variables in binary logistic regression analysis [12], it may also be possible to heighten the predictive accuracy of mFIM gain by categorizing mFIMa.

This study conducted binary logistic regression analysis with mFIM gain as dependent variable among stroke patients admitted to convalescent rehabilitation wards in Japan. The aim of this study was to compare the predictive accuracy of mFIM gain (a 0/1 binary value) between "mFIMa used as quantitative data", "categorized mFIMa into 4 groups, and "creation of two predictive formulae".

Subjects and Methods

We used patient data from the Japan Rehabilitation Database (JRD) [15]. The subjects were selected from 6,322 stroke patients hospitalized in convalescent rehabilitation wards and registered with the JRD in April 2015. To reduce the influence of exceptional cases that could be seen as outliers, the subjects were limited to patients who fulfilled the following inclusion criteria: age 15 to 99 years, duration from onset to hospital admission of 5 to 90 days, admitted to convalescent rehabilitation wards for 21 to 210 days, total score of 13 to 90 for mFIMa, FIM gain of 0 or higher, and having entries for all items to be examined. The remaining 2,542 patients were included in this study (Figure 1).

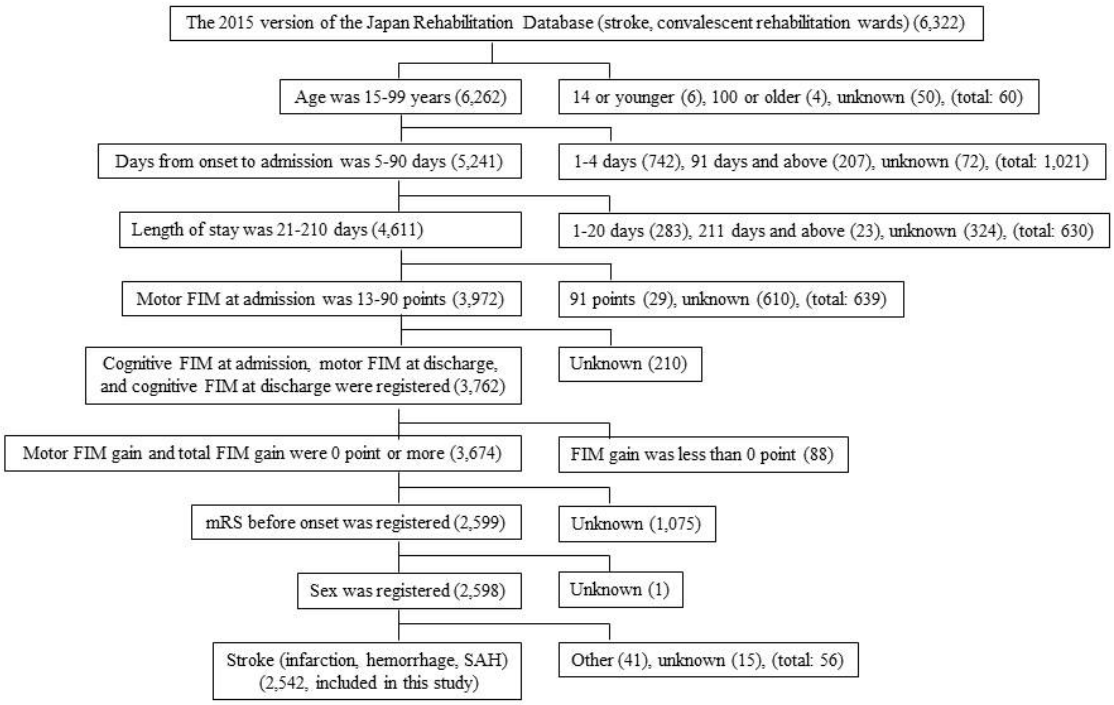

Figure 1: Inclusion and exclusion criteria (FIM, Functional Independence Measure; mRS, modified Rankin Scale; Numerical value, number of patients).

Study 1: Predictive formula using mFIMa as quantitative data

Binary logistic regression analysis with mFIM gain as dependent variable and the six independent variables consisting of age modified Rankin Scale before onset, days from onset to admission, mFIMa (quantitative data), cognitive FIMa, and length of stay in hospital. The dependent variable of mFIM gain, as in previous studies [3-11], was input as 1 for scores equal to or greater than the median value and 0 for scores less than the median value. Specifically, as the median value for mFIM gain was 18 points, mFIM gains of equal to or greater than 18 points were entered as 1, while those from 0 to 17 points were entered as 0.

Study 2: Categorization of mFIMa into 2 groups or 4 groups

mFIMa (independent variable) was categorized into four groups; 13-21 points, 22-30 points, 31-60 points, and 61-90 points. A predictive formula was created using the same independent variables and dependent variable as in study 1. The difference was while mFIMa was quantitative data in study 1, it was categorized in study 2.

Study 3: Two predictive formulae using stratified mFIMa scores

mFIMa was divided into two groups of 13-30 and 31-90 points. And two predictive formulae were created. The predictive accuracy of the predicted values for mFIM gain (a 0/1 binary value) obtained in studies 1, 2, and 3 were then compared.

Results

Table 1 shows the basic characteristics of this study. The median value for mFIMa was 46 points and the median value for mFIM gain was 18 points.

Number of patients	2542
Sex	Male 1492, female 1050
Stroke type	Infarction 1613, hemorrhage 772, SAH 157
Age	69.3 ± 12.9 (71)
mRS before onset	0.7 ± 1.4 (0)
Days from onset to admission	36.3 ± 15.2 (33)

Length of stay in hospital	101.6 ± 44.8 (100)
Motor FIM score at admission	45.7 ± 23.2 (46)
Cognitive FIM score at admission	21.9 ± 9.0 (23)
Total FIM score at admission	67.6 ± 29.9 (69)
Motor FIM score at discharge	65.7 ± 23.1 (74)
Cognitive FIM score at discharge	25.7 ± 8.3 (28)
Total FIM score at discharge	91.4 ± 29.9 (101)
Motor FIM gain	20.0 ± 14.8 (18)

Table 1: Basic characteristics of the subjects (SAH: Subarachnoid Hemorrhage; FIM: Functional Independence Measure; mRS: modified Rankin Scale; Numerical value: mean ± standard deviation or number of patients).

The results of binary logistic regression analysis are shown in Table 2.

	Coeff (B)	Significance (p)	OR	95% CI of OR	
				Lower	Upper
Age	-0.023	<0.001	0.977	0.970	0.984
mRS before onset	-0.167	<0.001	0.846	0.792	0.904
Days from onset to admission	-0.018	<0.001	0.983	0.977	0.988
Motor FIM at admission	-0.050	<0.001	0.951	0.945	0.957
Cognitive FIM at admission	0.080	<0.001	1.083	1.068	1.099
Length of stay in hospital	0.006	<0.001	1.006	1.004	1.008

Table 2a: Predictive formula using mFIM at admission as quantitative data.

	Coeff (B)	Significance (p)	OR	95% CI of OR	
				Lower	Upper
Age	-0.028	<0.001	0.972	0.965	0.980
mRS before onset	-0.174	<0.001	0.840	0.784	0.900
Days from onset to admission	-0.018	<0.001	0.982	0.976	0.988
Cognitive FIM at admission	0.041	<0.001	1.042	1.028	1.057
Length of stay in hospital	0.006	<0.001	1.006	1.004	1.008
Motor FIM at admission (22-30 points)	1.273	<0.001	3.570	2.544	5.018
Motor FIM at admission (31-60 points)	0.826	<0.001	2.285	1.733	3.013
Motor FIM at admission (61-90 points)	-1.957	<0.001	0.141	0.098	0.204
Constants: 1.376; predictive accuracy: 0.760; p values: <0.001. Motor FIM at admission (61-90 points), 1 for motor FIM at admission of 61-90 points and 0 for 13-21 points.					

Table 2b: Predictive formula using mFIM at admission as categorized into four groups.

Table 3 shows a 2 × 2 grid of predicted values and actual values. The predictive accuracy of the formula using FIMa as quantitative data was 68.4% ((834+905)/2,542)) (Table 3a). It was 76.0% ((921+1.011)/2.542) when mFIMa was categorized into 4 groups (Table 3b). And it was 76.3% ((936+1.003)/2.542) when two predictive formulae were created (Table 3c).

	Coeff (B)	Significance (p)	OR	95% CI of OR	
				Lower	Upper
Age	-0.044	<0.001	0.957	0.942	0.971

mRS before onset	-0.172	0.001	0.842	0.760	0.932
Days from onset to admission	-0.026	<0.001	0.974	0.964	0.985
Motor FIM at admission	0.131	<0.001	1.140	1.103	1.179
Cognitive FIM at admission	0.058	<0.001	1.060	1.034	1.086
Length of stay in hospital	0.007	<0.001	1.007	1.003	1.011
Constants: 0.448; predictive accuracy: 0.739; p values: <0.001.					

Table 2C: Predictive formula with patients whose motor FIM at admission was 13-30 points.

	Coeff (B)	Significance (p)	OR	95% CI of OR	
				Lower	Upper
Age	-0.031	<0.001	0.970	0.960	0.979
mRS before onset	-0.242	<0.001	0.785	0.706	0.873
Days from onset to admission	-0.014	0.001	0.986	0.977	0.994
Motor FIM at admission	-0.119	<0.001	0.888	0.877	0.899
Cognitive FIM at admission	0.051	<0.001	1.052	1.032	1.073
Length of stay in hospital	0.000	0.908	1.000	0.997	1.003
Constants: 8.379; predictive accuracy: 0.775; p values: <0.001.					

Table 2d: Predictive formula with patients whose motor FIM at admission was 31-90 points.

Discussion

Predictive accuracy was found to be highest in (1) creation of two predictive formulae (76.3%), followed in descending order by (2) the formula in which mFIMa was categorized into 4 groups (76.0%), and (3) the ordinary formula using mFIMa as quantitative data (68.4%).

		Predicted value	
		0	1
Actual value	0	834	414
	1	389	905
"Predictive accuracy 68.4% (Sensitivity 66.8%, specificity 69.9%)"			

Table 3a: Prediction using mFIM at admission as quantitative data.

		Predicted value	
		0	1
Actual value	0	921	327
	1	283	1011

Table 3b: Prediction using mFIM at admission as categorized into four groups.

Motor FIM at admission 13-30 points		Predicted value		Motor FIM at admission 31-90 points		Predicted value		Total		Predicted value	
		0	1	0	1	0	1				
Actual value	0	271	120	Actual value	0	665	192	Actual value	0	936	312
	1	103	359		1	188	644		1	291	1003

Table 3c: Two predictive formulae using stratified motor FIM at admission scores.

In reports of binary logistic regression analyses with FIM gain as dependent variable, FIMa was always used as quantitative data (Table

4) [3-11]. The only exception [4] produced a predictive formula using patients with mFIMa scores of less than 50 points. However, we were unable to find any reports comparing the predictive accuracy of the respective techniques of using FIMa as quantitative data, FIMa, as categorized data, and creating two predictive formulae by stratifying FIMa.

Reports	Disease	Number of patients	Favourable outcome	FIM at admission	Predictive accuracy
Shiraishi et al. [3]	Stroke	2,148	mFIM efficiency 1.18	Quantitative data	
Matsuo et al. [4]	Brain infarction mFIM at admission<50	331	mFIM gain 27	Quantitative data	Sensitivity 0.79 Specificity 0.77
Tokunaga et al. [5]	Stroke	155	mFIM gain 13	Quantitative data	Predictive accuracy 0.755
Tokunaga et al. [5]	Stroke	1,884	mFIM gain 17	Quantitative data	Predictive accuracy 0.779
Mizrahi et al. [7]	Hip fracture	759	mFIM gain 21	Quantitative data	
Hershkovitz et al. [8]	Hip fracture	605	mFIM MRFS0.3		
Tang et al. [9]	Merastatic spinal cord compression	63	FIM gain13	Quantitative data	
Gotou et al. [10]	Disuse syndrome	102	mFIM gain 13	Quantitative data	
Naruishi et al. [11]	Elderly inpatients	1,079	FIM gain10		
This study	Stroke	2,542	mFIM gain 18	Quantitative data Categorized into four groups Two stratified formulae	Predictive accuracy 0.684Predictive accuracy 0.760Predictive accuracy 0.763

Table 4: Reports which used binary logistic regression analysis to predict FIM gain (Abbreviations: FIM, Functional Independence Measure; mFIM, Motor FIM; MRFS, Montebello Rehabilitation Factor Score. Motor FIM was not used as an independent valiable in two reports [8-11].

The following considerations may be raised as limitations of the present study. First, the results of categorization and stratification will differ according to the number of divisions made and at which scores. Second, while predictive accuracy is listed in three reports [4-6], the fact that the subject populations differ means that comparison of predictive accuracy between these reports is not possible.

Which factors other than mFIMa are effective to categorize and to what extent the predictive accuracy of mFIM gain can be improved by combining the categorization of various factors are challenges for future study.

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