Determining Normative Standards for Functional Independence Measure Transitions in Rehabilitation

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ABSTRACT. Long WB, Sacco WJ, Coombes SS, Copes WS, Bullock A, Melville JK. Determining normative standards for functional independence measure transitions in rehabilitation. Arch Phys Med Rehabil 1994;75: 144-8.

• We present a method for determination of normative standards for Functional Independence Measure (FIM) transitions in rehabilitation. Data from 230 consecutive brain-injured patients treated before 1991 were used to characterize transitions in patient FIM values between admission and discharge. The pre-1991 average and standard deviation FIM transitions, computed as a function of admission values, are used as standards ("norms") for comparing rehabilitation transitions among institutions or in one institution over time (say, yearly) and for identifying patients with striking transitions, believed worthy of audit. The evaluation method requires the computation of two statistics, z and W, which compare the actual transitions for patients of one time period (in this instance the 1991 patients) to the expected transitions as computed from the pre-1991 norms. The z and W values indicated that 1991 transitions were neither statistically nor clinically different from pre-1991 ones. Also introduced in the paper are the concepts of Mean Gain, Ideal Gain, and the ratio Mean Gain/Ideal Gain. Ideal Gain is the greatest possible "aggregated" transition score for a study patient set and the ratio Mean Gain/Ideal Gain may be interpreted as "the degree of ideal rehabilitation transitions achieved."

A major focus in trauma research is the development of reliable and valid outcome evaluations so that trauma services and systems can assess and improve care. Examples of such outcome evaluations are PARTITION[1] and TRISS.[2]

PARTITION was developed and has been used in Hawaii and Washington state to assess prehospital trauma care. PARTITION estimates the prehospital care contribution to a patient's "potential for survival" by separating its effects from those of hospital care. It is conceivable that superb prehospital care could be offset by poor hospital care, resulting in average or poor survival outcomes. Similarly, poor prehospital care could be overcome by superb hospital management, resulting in improved outcomes. Prehospital care personnel should not be penalized in examples of the first kind nor credited in examples of the second. PARTITION estimates the "gain" in a patient's survival potential from scene to emergency department admission, based on national norms. The PARTITION score is the total gain for 100 patients.

TRISS, a trauma severity score based on a patient's age, injuries, and vital signs at emergency department admission, permits clinicians to identify trauma patients with unexpected outcomes and to compare patient outcomes among institutions. TRISS was the basis for the American College of Surgeons-endorsed Major Trauma Outcome Study (MTOS).[3] MTOS began in 1982 to refine injury severity scoring methods, to establish national normative trauma outcomes, and to provide facilities with objective outcome evaluations. Through 1989, data on more than 170,0 injured patients treated at more than 175 hospitals were submitted to MTOS. Periodic confidential reports that compare institution outcomes to norm outcomes are sent to participating hospitals. The comparison method requires the computation of two statistics, z and W. In the MTOS application z compares the actual number of survivors in an institution (A) with the number expected (E), based on MTOS TRISS survival probability norms. z is defined as

$$z = (A - E)/S,$$

where E is the sum of the survival probabilities for all patients in the analysis, and S is a scale factor that accounts for statistical variation. If z exceeds 1.96 (is less than −1.96), there are statistically significantly more (fewer) survivors than expected from MTOS-TRISS norms.

W is computed only when z is statistically significant. W measures the clinical significance of statistically significant differences between the actual (A) and expected (E) number of survivors in a patient group. The ability to detect such differences, called statistical power, increases with sample size. Thus, for large samples, significant z values may indicate slight, but statistically significant, differences between A and E.[4] W is defined as

$$W = 100(A - E)/N,$$

where A and E are as defined for z, and N is number of patients analyzed. A positive (negative) W is the number of survivors more (less) than would be expected per 100 patients treated.

In this study we applied z and W statistics, based on the Functional Independence Measure (FIM), to evaluate

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Table 1: Extremes and Quartile Values for Age, ISS, RTS, and TRISS Survival Probability

	Age	ISS	RTS	P_s
Smallest	1	5	0.00	0.004
q .25	16	17	4.09	0.610
q .50	23	24	5.97	0.905
q .75	39	34	7.55	0.963
Largest	94	59	7.84	0.996

Abbreviations: ISS, Injury Severity Score; RTS, Revised Trauma Score; P_s, survival probability.

rehabilitation transitions of trauma patients. The application, illustrated for brain-injured patients, provides a way for a rehabilitation institution to identify patient transitions worthy of audit and to compare transitions with other institutions or internally, say from year to year.

METHODS

Retrospective data were from 230 consecutive brain-injured patients who received rehabilitation treatment at a rehabilitation center (in Portland, OR) and were discharged between March 21, 1988 and December 7, 1990; prospective data were from 79 consecutive brain-injured patients admitted to the center in 1991. Data include patient age, mechanism of injury, Injury Severity Score,[5] emergency department admission Revised Trauma Score,[6] length of stay, and admission and discharge FIM values.[7] FIM is the sum of 18 elements that reflect a patient's ability to perform activities of daily living. Each element takes values from 1 (total assistance required) to 7 (complete independence). Thus FIM takes values from 18 to 126. Retrospective and prospective data are used here to illustrate one application of the method, namely, to assess whether outcomes for a current year are different from those of previous years.

For the retrospective patient set changes in patient FIM values between admission and discharge were characterized by transition numbers (T_{ij}) and transition percentages (P_{ij}) based, arbitrarily in this model, on 12 equal nine-point FIM intervals. T_{ij} (P_{ij}) is the number (percent) of patients with an admission FIM value in interval i and a discharge FIM value in interval j. The FIM interval gain (from admission to discharge) is defined as j minus i. Average interval gains, denoted E_i, and corresponding standard deviations, denoted S_i, were computed for each FIM admission interval:

$$E_i = (1/T_i) \sum_j T_{ij}(j - i),$$

$$S_i^2 = [1/(T_i - 1)] \sum_j T_{ij}(j - i - E_i)^2$$

where T_i is the number of patients with admission FIM value in interval i.

Also computed were the Mean Gain (MG), Ideal Gain (IG), and the ratio MG/IG defined as follows:

$$MG = (1/T) \sum_i T_i E_i,$$

$$IG = (1/T) \sum_i T_i(12 - i),$$

where $T = \sum_i T_i$.

MG is the weighted sum of the average interval gains. IG, the maximum possible interval gain for the patient set, is a weighted mean of the maximum possible interval gains for patients. The ratio MG/IG can be interpreted as the "degree of ideal rehabilitation gains achieved." "Ideal gains" would be achieved if every patient were discharged from the rehabilitation facility with a FIM value of 126 (or, in our interval model, with a FIM value in interval 12). MG is analogous to the PARTITION score. We believe that IG and the ratio MG/IG are new concepts, with no historic precedents.

The norm we propose for rehabilitation outcome analysis is based on two statistics, z and W, defined by interval average gains and standard deviations. In this application z compares the actual gain (AG) in a sample of M patients (rehabilitation facility) to the expected gain EG as computed from a baseline (norm) population where,

$$z = (AG - EG)/S,$$

$$AG = \sum_i \sum_j m_{ij}(j - i),$$

$$EG = \sum_i (m_i e_i),$$

$$S = \sqrt{(\sum_i m_i S_i^2)}.$$

S is a scale factor that accounts for statistical variation, the m_{ij} are transition numbers for the sample patients, m_i is the number of sample patients with admission FIM value in interval i, and $m = \sum m_i$. The E' and S_i are those from baseline data. Absolute values of z greater than 1.96 indicate that differences between actual and expected gains are statistically significant ($p < 0.05$). Nonsignificant z values can result from small sample sizes for which z has limited statistical power or from outcomes that are indistinguishable from the norm.

Table 2: Extreme and Quartile Values for Length of Stay (days) for All Patients and by Admission FIM Interval

		FIM Interval											
	All	1	2	3	4	5	6	7	8	9	10	11	12
Smallest	3	8	14	9	7	10	6	4	5	4	3	5	6
q .25	12	25	23	22	27	17	13	11	11	7	7	5	6
q .50	23	43	30	46	35	29	20	19	16	15	9	7	6
q .75	37	73	63	63	39	46	29	29	23	18	16	12	6
Largest	137	137	96	103	59	76	60	73	42	42	27	15	6

Table 3: Average FIM Gain Per Week by FIM Admission Interval

Admission FIM	i Interval	Average Gain Per Week (points)
18-26	1	5.7
27-35	2	8.3
36-44	3	11.7
45-53	4	13.0
54-62	5	11.5
63-71	6	15.4
72-80	7	16.6
81-89	8	14.2
90-98	9	14.2
99-107	10	9.4
108-116	11	6.2
117-126	12	5.9

For large samples, statistically significant z values can result from small and clinically insignificant departures from norm expectations. Thus, rehabilitation facility performance cannot be inferred from the z value only. For institutions with significant z values, the statistic W measures the clinical or practical significance of differences between actual and expected gains.

$$W = (AG - EG)/m.$$

W is the average difference in actual gain and predicted gain over the patient set.

The z and W values were computed for the rehab center's 1991 patients using expected gains from the pre-1991 set to illustrate whether transitions for a given year are different from those of other (in this case, previous) years.

RESULTS

Table 1 shows the extremes and quartile values of ages, Injury Severity Scores (ISS), Revised Trauma Scores (RTS), and TRISS[3] survival probabilities for the pre-1991 patients. The median values are 23 years for age, 24 for ISS, 5.97 for RTS, and 0.91 for TRISS survival probability. The values reflect that the patients had moderately serious injuries but good likelihoods for survival at the time of emergency department admission. The predictions were borne out, of course, as all of these patients survived.

The extremes and quartile values for length of stay (days) are presented in table 2 for all patients and by FIM admission interval.

Table 3 shows the average FIM point gain per week by FIM admission interval. The smallest weekly gains are associated with the "low" FIM intervals (1, 2) and the "high" FIM intervals (10, 11, 12). The best weekly gains are associated with the middle intervals (intervals 4 to 9).

Table 4 shows the admission-to-discharge transition numbers (T_{ij}) and table 5 shows the percentages (P_{ij}) for the pre-1991 patients. As an example, for the 11 patients admitted with FIM values in the interval 99-107 (E_{10}), 2 (18.2%) were in the same interval at discharge (0 gain), 1 (9.1%) increased 1 interval, and 8 (72.7%) increased 2 intervals. The average interval gain of 1.55 is computed as follows:

$$E_{10} = (.182 \times 0) + (.091 \times 1) + (.727 \times 2) = 1.55.$$

The overall average admission and discharge FIM values are 67 and 103. Table 6 gives the average gains (E_i) and standard deviations (S_i) for each admission FIM interval. The average gains range from 0, for interval 117–126, to 6.37 for interval 36–44. The standard deviations vary from 0 to 4.04, decreasing almost monotonically from interval 18–26 to interval 117–126.

For the pre-1991 set the Mean Gain (MG), 4.03 intervals, is the weighted sum of the average interval gains, the weights being the ratios T_i/T. From table 6, we can compute:

$$MG = .0826(4.11) + .0609(5.14) + \cdots + .0347(1.55) + .0043(0) = 4.03.$$

The Ideal Gain (IG) for the pre-1991 set is 5.99 intervals, which is a weighted sum of the maximum possible gain for each interval, the weights being also the ratios, T_i/T. More explicitly,

$$IG = .0826(11) + .0609(10) + \cdots + .0347(1) + .0043(0) = 5.99.$$

Thus, the ratio MG/IG is 0.67 (4.03/5.99).

The z value for the prospective set (1991 patients) was 0.34 (and hence W is considered to be zero). Because these values are not statistically different from zero, we conclude, based on this model, that the prospective and retrospective patient set transitions were not significantly different.

Table 4: Admission to Discharge FIM Transition Numbers (T_{ij}) Traumatic Brain Dysfunction Impairments

Interval	No.	18-26	27-35	36-44	45-53	54-62	63-71	72-80	81-89	90-98	99-107	108-116	117-126
18-26	19	6	2		2	2			1	3		2	1
27-35	14		1	2	1		2	2		2	1	2	1
36-44	19			1	1		2			5		6	4
45-53	17							1	2	2	1	9	2
54-62	21						2	1	1	2	3	11	1
63-71	27								2	4	5	10	6
72-80	35									3	5	14	13
81-89	34									1	8	14	11
90-98	24											13	11
99-107	11										2	1	8
108-116	8											3	5
117-126	1												1
Total:	230												

Table 5: Admission-to-Discharge FIM Transition Percentages (P_{ij}) Traumatic Brain Dysfunction Impairments

Interval	No.	18-26	27-35	36-44	45-53	54-62	63-71	72-80	81-89	90-98	99-107	108-116	117-126
18-26	19	31.6	10.5		10.5	10.5			5.3	15.8		10.5	5.3
27-35	14		7.1	14.3	7.1		14.3	14.3		14.3	7.1	14.3	7.1
36-44	19			5.2	5.2		10.5			26.3		31.6	21.1
45-53	17							5.8	11.8	11.8	5.8	52.9	11.8
54-62	21						9.5	4.8	4.8	9.5	14.3	52.4	4.8
63-71	27								7.4	14.8	18.5	37.0	22.2
72-80	35									8.6	14.3	40.0	37.1
81-89	34									2.9	23.5	41.2	32.4
90-98	24											54.2	45.8
99-107	11										18.2	9.1	72.7
108-116	8											37.5	62.5
117-126	1												100.0
Total:	230												

DISCUSSION

The evaluation method mimics that used in the Major Trauma Outcome Study[3] to compare survival outcomes for patient groups. To our knowledge there are no such (z and W) published normative standards for rehabilitation FIM transitions. There are publications that give average FIM and FIM component transitions by impairment group.[8,9] But, it is obvious that the potential for FIM transitions depend on rehabilitation admission FIM values. As extreme examples, if all patients had FIM values of 126 at admission, the potential for "positive gains" is zero; and if all rehabilitation patients had FIM values of 18 at admission, the positive gain potential is substantial. Our method controls for admission FIM values.

Table 6 can serve as a preliminary norm for brain-injured patients from which a rehabilitation hospital can compare its FIM transitions to our rehab center using z and W. It can also be used as an audit filter to identify rehabilitation patients "worthy of review." A rehabilitation service could select patients, (perhaps, designated as unexpected outcomes) for audit whose Actual Gain differs by more than, say, one or 1.5 standard deviation(s) from the Expected Gain. The cases with gains below expectation could be reviewed for any system or clinical "shortcomings." The cases with gains above expectation could be reviewed for reasons for success. The reviews could influence protocols for future patient management.

Thus, the ability to access normative standards for FIM transitions has clinical significance for rehabilitation professionals. Such a system of objective analysis may assist the clinician in establishing a more reliable rehabilitation prognosis on a case-by-case basis. In addition, analysis of objective outcome data provides the rehabilitation unit with the ability to compare the outcomes of patient populations over time, using the figures as a bench mark of performance for their program. Also the methods offer the potential for discovering new prognostic factors through focused analysis of curious outcome data.

We illustrate the computation of z and W in table 7 for 25 hypothetical patients. Several patients (patients 11, 15, and 25 for example) have gains considerably larger than expected and contribute substantially to z despite the large

Table 6: FIM Interval Average Gains (E_i) and Standard Deviations (S_i)

Admission FIM Interval	i	E_i	S_i	T_i/T
18-26	1	4.11	4.04	19/230 (.0826)
27-35	2	5.14	3.30	14/230 (.0609)
36-44	3	6.37	2.75	19/230 (.0826)
45-53	4	6.24	1.48	17/230 (.0739)
54-62	5	4.90	1.76	21/230 (.0913)
63-71	6	4.51	1.22	27/230 (.117)
72-80	7	4.06	0.94	35/230 (.152)
81-89	8	3.03	0.83	34/230 (.148)
90-98	9	2.45	0.51	24/230 (.104)
99-107	10	1.55	0.82	11/230 (.0478)
108-116	11	0.63	0.52	8/230 (.0347)
117-126	12	0	0	1/230 (.0043)

Table 7: Illustrative Example for Computation of z and W, Based on 25 Hypothetical Patients

Patient	Admission Interval	Acutal Interval Gain, A_i	E_i	S_i	S_i^2
1	63-71	6	4.51	1.22	1.4884
2	36-44	6	6.37	2.75	7.5625
3	81-89	3	3.03	0.83	0.6889
4	90-98	3	2.45	0.51	0.2601
5	72-80	5	4.06	0.94	0.8836
6	36-44	6	6.37	2.75	7.5625
7	63-71	4	4.51	1.22	1.4884
8	27-35	1	5.14	3.30	10.8900
9	90-98	2	2.45	0.51	0.2601
10	81-89	3	3.03	0.83	0.6889
11	18-26	8	4.11	4.04	16.3216
12	90-98	3	2.45	0.51	0.2601
13	72-80	4	4.06	0.94	0.8836
14	72-80	3	4.06	0.94	0.8836
15	18-26	11	4.11	4.04	16.3216
16	63-71	5	4.51	1.22	1.4884
17	36-44	3	6.37	2.75	7.5625
18	81-89	3	3.03	0.83	0.6889
19	72-80	5	4.06	0.94	0.8836
20	72-80	5	4.06	0.94	0.8836
21	18-26	0	4.11	4.04	16.3216
22	36-44	9	6.37	2.75	7.5625
23	63-71	5	4.51	1.22	1.4884
24	90-98	2	2.45	0.51	0.2601
25	27-35	9	5.14	3.30	10.8900
		114	105.32		114.4735

$z = (114-105.32)/\sqrt{114.4735} = 0.81$. W was not calculated because z is not statistically significant.

associated standard deviations. In fact, z decreases to −0.71 if we do not include these three patients in the computation. To illustrate a computation that would result in statistically positive z and W values, we use the subset of patients for whom gains are greater than expected (that is, for whom $A_i > E_i$)—the 12 patients 1, 4, 5, 11, 12, 15, 16, 19, 20, 22, 23, 25. For this subset, z increases to a statistically significant value of 3.09, with a corresponding W value of 1.97 (nearly two intervals) above the "norm" per patient.

Also, a rehabilitation hospital could compute its MG/IG ratio to rate its care relative to ideal FIM improvement. We recognize that ideal care is undoubtedly unrealizable, but the MG/IG ratio offers a way to assess the state-of-the-art of rehabilitation management of brain-injured patients and to gauge progress. In the example given (table 7) the ratio is 105.32/162 = 0.65.

Some of the data from this study are curious. Sixty-nine (30%) of the patients had admission FIM values in the range 72-89 (table 4). The median admission FIM value is in the interval 63-71. The interval gains are strikingly variable for the admission interval 18-26, 27-35, and 36-44. For example the interval gains for the admission interval 18-26 range from 0 to 11, with 31.5% of the patients having a zero gain and 31.6% having a gain of at least eight. This suggests that the methodology be refined, as more data become available, perhaps by shrinking "admission intervals" to individual admission values, by accounting for injury severities, and by taking advantage of consensus outcomes of the ordinal scale "furor" as related to FIM.

Admission FIM Intervals

The use of FIM admission intervals in this paper was necessitated by the small sample size for the retrospective dataset. The choice of interval "width" was arbitrary, but influenced to some extent by the distribution of the admission FIM values. Obviously, the values of z and W are dependent on interval width. Use of intervals results in loss of transition information and is not desirable. For a large national database one could determine FIM admission-to-discharge transitions (and hence average and standard deviation transitions) for each FIM admission value.

Injury Severities

For a large database transition matrices could be determined as a function of patient injury severity as measured by TRISS, for example. One may conjecture that such a model would reduce transition variation and be a better assessment tool.

Ordinal Scale Issue

Recently, some critics of medical rehabilitation research[10-13] have claimed that studies, based on FIM, which is an ordinal scale, lead to "misinferences," and have proposed Rasch Model versions of FIM. They argue that Rasch analysis calibrates scale items according to difficulty, and the calibrations can be added to form meaningful interval level data for precise statistical analysis and better research conclusions. This technical issue has been discussed coherently in a series of "UDS Updates" published by the Uniform Data System Data Management Service, SUNY, buffalo, NY. The April 1993 UDS Update states "Rasch-converted FIM scores, called FIM measures, closely parallel raw FIM scores for the separate motor and cognitive scales, except at the endpoints of the scales. The work with the Rasch model has demonstrated that the FIM is a good scale that can be improved for research purposes by converting the raw scores to measures. In fact, it may be viewed as a testament to the collective work of clinicians and researchers across the country that the FIM performed so well under rigorous examination by the Rasch Model, and it is a major new step in medical rehabilitation to use the two measures of motor and cognitive to further the research process." On the other hand, the April 1993 UDS Update also states that "the ability of the raw FIM score to predict in a variety of circumstances has shown the scale to be valid for many aspects of medical rehabilitation" and references Heinemann[14] and Stineman (unpublished data) as examples. These comments suggest that the Raw FIM versus Rasch FIM issue has not achieved a clear consensus. In the interim we propose those who favor "Rasch-in-alizing" implement the method described in this paper with Rasch-converted FIM or FIM motor and cognition components.

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