Special issue article

Relationship of occupational therapy inpatient rehabilitation interventions and patient characteristics to outcomes following spinal cord injury: The SCIRehab Project

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Background/objective: Describe associations of occupational therapy (OT) interventions delivered during inpatient spinal cord injury (SCI) rehabilitation and patient characteristics with outcomes at the time of discharge and 1-year post-injury.

Methods: Occupational therapists at six inpatient rehabilitation centers documented detailed information about treatment provided. Least squares regression modeling was used to predict outcomes at discharge and 1-year injury anniversary for a 75% subset; models were validated with the remaining 25%. Functional outcomes for injury subgroups (motor complete low tetraplegia and motor complete paraplegia) also were examined.

Results: OT treatment variables explain a small amount of variation in Functional Independence Measure (FIM) outcomes for the full sample and significantly more in two functionally homogeneous subgroups. For patients with motor complete paraplegia, more time spent in clothing management and hygiene related to toileting was a strong predictor of higher scores on the lower body items of the self-care component of the discharge motor FIM. Among patients with motor complete low tetraplegia, higher scores for the FIM lower body self-care items were associated with more time spent on lower body dressing, manual wheelchair mobility training, and bathing training. Active patient participation during OT treatment sessions also was predictive of FIM and other outcomes.

Conclusion: OT treatments add to explained variance (in addition to patient characteristics) for multiple outcomes. The impact of OT treatment on functional outcomes is more evident when examining more homogeneous patient groupings and outcomes specific to the groupings.

Note: This is the third of nine articles in the SCIRehab series.

Key Words: Spinal cord injuries, Rehabilitation, Occupational therapy, Paraplegia, Tetraplegia, Participation, Quality of life, Functional outcomes, Activities of daily living, Practice-based evidence

Introduction

Impaired ability to perform self-care activities, such as eating, grooming, dressing, and toileting, is one of the immediate impacts an individual likely experiences following his/her spinal cord injury (SCI). These activities, also known as activities of daily living (ADL), are among the major areas that occupational therapy (OT) addresses during rehabilitation.

Methods of optimizing functional abilities after SCI vary with the level and completeness of injury, as well as medical complications resulting from the injury. People with higher levels of injury (e.g. cervical level (C) 4 and above) will have severe functional limitations

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due to the absence of upper-extremity (UE) control. People with C5 and C6 levels of injury will have some muscle and somatosensory function at the elbow (flexion) and wrist (extension), which may increase their ability to perform some ADL, such as upper body dressing, grooming, and self-feeding, as well as limited mobility skills. Injury at C7 affords a person elbow extension and increased independence with ADL and mobility. Individuals with injuries below C7 generally retain hand function, which aids in the performance of ADL, but continue to have deficits in trunk control and balance. Those with higher thoracic (T1–T6) injuries also have balance dysfunction that may affect their ability to perform certain ADL (such as lower body dressing, bowel, and bladder management) and transfers; those with injuries below T6 generally will be independent with both upper and lower body-related ADL. These functional expectations also vary depending on whether the injury is complete or incomplete.[1]

Occupational therapists (OTs) select interventions based on level of injury and functional expectations with the goal of optimizing functional independence. Interventions focusing on ADL are critical for individuals to live independently and to decrease the burden of care for others. For patients who have decreased functional use of their UE, more OT time may be devoted to addressing basic ADL; for patients with lower levels of injury (e.g. T1 and below) OT interventions generally focus on more advanced skills such as home management and toileting.[2]

Improvement in function and increased independence in ADL are not the only goals of OT; goals also include improving community integration, promoting fuller participation in society, and satisfaction with life. OT also attempts to improve health status by educating patients with SCI about their risk for potential medical complications and teaching the skills necessary to avoid secondary conditions such as pressure ulcers and shoulder joint deterioration. Therefore, there is a wide range of outcomes that OT could reasonably be expected to influence.

Patient factors and individual goals warrant consideration when examining associations of OT treatment with outcomes as they can influence the choice of OT intervention.[3] In two studies of patients with motor and sensory impairments due to stroke or SCI, investigators stressed the importance of considering multiple client (patient) factors during the OT treatment process.[4,5] They suggested that OT services, and the environment in which they are provided, may impact on outcomes in SCI rehabilitation.

Relating OT treatments to outcomes is further complicated by the difficulty of distinguishing between improvements in function resulting from OT interventions and improvements in function due to natural recovery of neurological function. Since the majority of people with SCI experience some degree of neurological recovery during the rehabilitation process, an examination of cases with minimal neurological recovery can better identify functional improvement due to rehabilitation interventions provided by OT and by physical therapy.[6]

The SCIRehab study provides the opportunity to examine the relationship between OT interventions and a broad range of outcomes across the full range of people with SCI, and then to focus the relationship between OT interventions and functional outcomes within specific subgroups of people with particular needs. The multi-center SCIRehab investigation classified treatments provided during rehabilitation so that data reflecting the routine practice of care could be used in analyses to examine the choices of intervention type and dosage for patients with specific types of injuries.[7,8] Clinicians from six sites worked together to develop a taxonomy for classifying and defining OT interventions typically delivered during inpatient rehabilitation.[9] Descriptive analysis of 600 patients enrolled during the first year demonstrated that the choice of therapeutic interventions varied with level and extent of injury. For example, OTs spent more time with patients at C5–C8 levels of injury than any other patient group.[10] Whether the specific choice of intervention leads to the highest functional outcomes after SCI when compared with others is not yet clear.

This article has two objectives. First, we examine associations of OT interventions and patient demographic and injury characteristics with outcomes at discharge from inpatient rehabilitation and at 1-year post-SCI for all patients enrolled in the SCIRehab study. Second, we examine the relationship between OT interventions and select functional outcomes within two homogeneous subgroups: motor complete low tetraplegia (C5–C8), and motor complete paraplegia (T1–T9).

Methods

The practice-based evidence research methodology[11,12] used in the SCIRehab study has been described previously and is summarized in the first article of this SCIRehab series.[7,8,13,14]

Study sample and facilities

Participants were patients with traumatic etiology of SCI who were 12 years of age or older, gave (or whose parent/guardian gave) informed consent, and were admitted for initial rehabilitation between the Fall of 2007 and December 31, 2009 to the SCI unit of one of six facilities (Craig Hospital, Englewood, Colorado; Shepherd Center, Atlanta, Georgia; Rehabilitation Institute of Chicago, Chicago, Illinois; Carolinas Rehabilitation, Charlotte, North Carolina; The Mount Sinai Medical Center, New York, New York; and MedStar National Rehabilitation Hospital, Washington, DC).

Patient data

Patient demographic and injury data were abstracted from a database designed specifically for the SCIRehab study or from the National Institute on Disability and Rehabilitation Research (NIDRR) SCI Model Systems' Form I, which contains information on injury through community discharge. The Functional Independence Measure (FIM®) served to describe a patient's functional independence in motor and cognitive tasks at admission;[15] and the International Standards of Neurological Classification of SCI (ISNCSCI) and its American Spinal Injury Association Impairment Scale (AIS)[16] were used to describe the neurological level and completeness of injury. Patients with AIS D were grouped together regardless of neurological level. Patients with AIS A, B, and C injuries were assigned to one of three groups: C1–C4, C5–C8, and paraplegia. The Comprehensive Severity Index (CSI®), which is a disease-specific measure to quantify the abnormality of the patient's diseases and disorders throughout the rehabilitation stay, provided a measure of medical severity.[17,18] Body mass index (BMI) was categorized as obese (BMI ≥30) or not. See Table 1 for all patient characteristics.

OT treatment data

OTs documented information about treatment provided during each OT session (date/time, number of minutes

Table 1 Patient and injury characteristics, overall and for two subgroups

	C5–8 AIS A, B* $n = 78$	T1–9 AIS A, B** $n = 158$	SCIRehab Study sample $n = 1032$
Age at injury, mean (SD)	31.7 (15.1)	31.5 (13.0)	37.7 (16.7)
Gender, % Male	81	79	81
Race/ethnicity (%)			
White	77	72	71
Black	17	22	22
Hispanic	1	3	3
Other	5	3	5
Primary language (%) English primary language	95	95	94
Payer (%)			
Medicare	4	3	7
Medicaid	20	24	18
Private insurance/pay	73	63	64
Worker's compensation	3	10	11
Marital status at injury (%) Married	23	32	38
Education (%)			
Less than high-school diploma	27	20	20
High-school diploma or GED	45	56	51
College	26	20	25
Other/unknown	3	4	4
Occupational status before injury (%)			
Working	63	73	66
Student	19	15	15
Retired	1	1	8
Other	17	11	11
Injury etiology (%)			
Vehicular	49	62	49
Violence	10	15	11
Sports	26	2	1%
Fall or falling object	15	18	25
Other	0	3	4
Injury work related? (%) No	97	87	86
Body mass index at admission (%) Less than 30	90	78	82
Admission motor FIM – Rasch transformed, mean (SD)	11.3 (9.5)	26.7 (5.4)	17.8 (12.6)
Admission cognitive FIM – Rasch transformed, mean (SD)	71.2 (15.4)	76.6 (16.0)	73.6 (18.1)
Comprehensive Severity Index, mean (SD)	40.6 (24.9)	35.5 (23.2)	40.0 (31.6)
Days from injury to rehabilitation, mean (SD)	34.7 (21.9)	30.9 (25.1)	31.0 (27.8)

*No change in neurological level or improvement to AIS C or D by discharge.
**No improvement to AIS C or D by discharge.

Table 2 OT treatment hours and other treatment variables, overall and for two subgroups

	C5–8 AIS A, B* *n* = 78	T1–9 AIS A, B** *n* = 158	SCIRehab Study sample *n* = 1032
Length of rehabilitation stay-days, mean (SD)	66.0 (42.5)	46.2 (23.5)	55.7 (36.6)
OT clinician experience, mean (SD)	6.3 (5.6)	4.7 (4.4)	4.9 (4.6)
Patient participation score – OT, mean (SD)	5.0 (0.6)	5.0 (0.7)	5.0 (0.6)
OT treatments – hours, mean (SD)			
Strengthening/endurance	16.0 (17.2)	9.9 (11.8)	12.0 (13.5)
Activities of daily living (total for 8 items below)	11.5 (8.4)	9.2 (5.4)	7.5 (6.4)
Bathing	0.9 (1.1)	1.7 (1.7)	1.0 (1.3)
Bladder management	1.1 (1.5)	0.7 (1.1)	0.06 (1.1)
Bowel management	0.9 (2.2)	0.7 (1.3)	0.4 (1.2)
Dressing – lower body	3.0 (3.6)	4.4 (2.8)	2.5 (0.8)
Dressing – upper body	1.3 (1.2)	0.8 (0.7)	0.8 (1.0)
Self-feeding	2.3 (4.1)	0.1 (0.3)	1.1 (2.2)
Grooming	1.9 (3.5)	0.3 (0.4)	0.8 (1.1)
Toileting – clothing management and hygiene	0.2 (0.4)	0.4 (0.7)	0.2 (0.5)
Range of motion/stretching	7.6 (9.7)	1.3 (2.5)	6.0 (9.6)
Education (not covered by other activities)	4.6 (5.1)	3.1 (2.6)	3.9 (4.8)
Therapeutic activities***	5.4 (5.1)	0.6 (1.8)	3.5 (6.0)
Interdisciplinary conferences (on patient's behalf)	2.9 (2.4)	2.2 (2.1)	2.5 (2.5)
Assessment	2.5 (2.0)	1.6 (1.5)	2.3 (1.9)
Equipment evaluation	1.9 (3.5)	0.6 (1.2)	1.9 (4.0)
Home management skills	2.4 (4.1)	2.0 (1.7)	1.9 (2.7)
Transfers	2.1 (2.1)	2.6 (1.9)	1.8 (1.9)
Modalities	1.8 (1.8)	0.2 (0.5)	1.6 (3.1)
Assistive technology	2.2 (3.7)	0.02 (0.1)	1.5 (3.4)
Balance	1.3 (1.9)	1.9 (2.7)	1.3 (2.0)
Wheelchair mobility – power	1.1 (1.6)	0.1 (0.5)	1.2 (2.9)
Communication	2.1 (2.8)	0.1 (0.4)	1.1 (2.0)
Bed mobility	1.1 (1.5)	1.2 (1.5)	0.7 (1.3)
Community reintegration outings	1.1 (1.8)	0.7 (1.5)	0.7 (1.6)
Skin management	0.6 (0.8)	1.2 (1.2)	0.7 (1.0)
Splint/cast fabrication	1.4 (1.9)	0.01 (0.1)	0.5 (1.2)
Wheelchair mobility – manual	0.5 (0.8)	0.09 (1.2)	0.5 (1.1)
Classes provided by OT	0.2 (0.5)	0.2 (0.5)	0.3 (0.8)
Airway/respiratory management	0.03 (0.1)	0.01 (0.1)	0.1 (0.3)

*No change in neurological level or improvement to AIS C or D by discharge.
**No improvement to AIS C or D by discharge.
***Therapeutic activities include fine motor activities, tenodesis training, manual therapy, vestibular training, edema management, breathing exercise, cognitive retraining, visual/perceptual training, desensitization, and don/doff adaptive equipment.

spent on 26 specified intervention activities, activity-specific details, and the level of patient participation) beyond what was available in traditional medical record documentation (Table 2). They entered these data into handheld personal digital assistants (PDAs) after each encounter with a patient.[9,10] The extent of each patient's participation during OT treatment sessions was quantified using the Pittsburgh Rehabilitation Participation Scale (PRPS), which defined a cluster of observable behaviors to serve as a surrogate for patient engagement.[19] PRPS scores from each OT session were averaged to calculate each patient's mean PRPS score over the entire stay.

Clinician experience

A clinician profile that included years of experience working in SCI rehabilitation was completed by each occupational therapist who provided treatment. Each hour of treatment was multiplied by the number of years of SCI rehabilitation experience of the occupational therapist providing treatment; then, the sum was divided by the total hours of treatment provided by all OTs to yield the average level of clinician experience for each patient.

Outcome data

The SCIRehab study utilized standardized outcome measures collected by the NIDRR SCI Model Systems that are obtained at the time of rehabilitation discharge and at 1-year post-injury, as described in the first article in this SCIRehab series.[14] Briefly, discharge location (home or elsewhere) and FIM scores are contained on Form I and follow-up status at the 1-year injury anniversary is included on Form II.[20] All FIM data (including the 11-item motor, 4-item cognitive scores, 6-item self-care component of the motor score, and the 3-item lower and upper body self-care items) were Rasch transformed to convert discrete, ordinal FIM scores into scores on a continuous interval scale.[21] Outcome measures derived primarily from the Form II (1-year post-injury) included the FIM motor score, four subscales (Physical Independence, Social Integration, Occupation, and Mobility) from the Craig Handicap Assessment and Reporting Technique (CHART),[22–24] the Diener Satisfaction With Life Scale (SWLS),[25] depressive symptoms as measured by the Patient Health Questionnaire – brief (9-question) version (PHQ-9),[26] place of residence, working or in-school status, presence of a pressure ulcer, and whether the patient was rehospitalized during the period from rehabilitation discharge to the anniversary interview.

Identification of patient subgroups

Sensory and strength improvement over the course of inpatient rehabilitation could be due to therapeutic intervention; they may also be due to naturally occurring neurological improvement.[27] To identify which OT interventions during rehabilitation contribute to desired outcomes, analyses were conducted for two subgroups of patients who had motor complete injuries at both rehabilitation admission and discharge.

The first subgroup included 199 patients with injuries at thoracic levels 1–9 (T1–9) that were motor complete (AIS A or B) at both admission and discharge. Forty-one patients with brachial plexus injuries and/or UE fractures were excluded to ensure all cases had intact UE function. Outcomes examined for the remaining 158 patients included the discharge motor FIM, the self-care component of the motor FIM, and the subset of lower body self-care items (lower body dressing, bathing, toileting).

The second subgroup included 78 patients with complete lower cervical spine injuries (C5–C8, AIS A or B) who neither changed neurological level (e.g. C5–C6) nor improved to AIS C or D by discharge. The discharge motor FIM, the upper body self-care (grooming, upper body dressing, self-feeding) item and the same lower body self-care items scored as with the T1–9 subgroup were examined.

Data analysis: regression modeling

Ordinary least squares stepwise regression modeling was used to predict outcomes at discharge and at 1-year post-injury. Multiple linear regression[28] was used for continuous outcomes and logistic regression for dichotomized ones.[29] Three blocks of independent variables were allowed in the following sequence to enter the regression models: (1) all patient demographic and injury characteristics described in Table 1; (2) treatment variables (Table 2) that included time spent in specific OT activities (unless fewer than 10 patients received the treatment, in which case the treatment variable was not considered), patient participation, clinician experience, and rehabilitation LOS; and (3) rehabilitation center. For multiple linear regressions, the adjusted R^2 reduces the unadjusted R^2 to take into account the number of predictors in the model. The adjusted R^2 value indicates the amount of variation explained in the outcome by the significant independent variables, and thus, the strength of the model. R^2 values range from 0.00 (no prediction) to 1.00 (perfect prediction); values that are closer to 1.00 indicate better models. For logistic regression, the Maximum Re-scaled R^2 (Max R^2) is reported as a measure of the strength of the model.[30] This value is scaled the same as the R^2 (0.00–1.00) and reflects the relative strength of the predictive logistic model. Discrimination was assessed by using the area under the receiver operator characteristic curve (*c* statistic) to evaluate how well the model distinguished patients who did not achieve an outcome from patients who did. Values of c that are closer to 1.00 indicate better discrimination.

In each regression model, adjusted R^2 (multiple linear regression) or the *c* statistic and the Max R^2 (logistic regression) are reported first for the prediction of the outcome with only the block 1 patient characteristics included as independent variables. Next, the same statistics are reported for the combination of treatment variables (block 2) and patient characteristics. Finally, to determine the added impact of rehabilitation center effects, dummy variables indicating the center where each patient was rehabilitated were added and the adjusted R^2 or *c* statistic/Max R^2 are reported. The change in the adjusted R^2 or *c* statistic/Max R^2 as the treatment variables and then the center variables are added indicates the additional explanation contributed by these components. For all outcome models, parameter estimates (for patient and treatment variables, but not center) are reported, indicating the direction and strength of the association between each independent variable and the outcome considered. In the multiple linear regression models, semi-partial Omega R^2s are reported, which indicate the proportion of the variance in the dependent variable that is associated uniquely with the predictor. In the logistic regressions, odds ratios (ORs) are reported to indicate the magnitude of the association of the predictor with the outcome. An OR of 2 indicates the outcome is twice as likely for each unit increase in the independent variable, and an OR of 0.5 indicates the outcome is half as likely with such a change. In all regression models, the *P* value associated with each significant predictor is also reported.

Results reported here are for a "primary analysis" subset (a randomly selected 75% of the 1376 patients in the sample); the regression models developed in this subgroup were tested using the validation subset, which contained the remaining 25% of patients. For multiple linear regression models, the relative shrinkage of the R^2 for the original model that included all patient and treatment variables as the independent variables was compared to the R^2 for the same outcome using the 25% sample and only the significant independent variables from the original model.[31] A relative shrinkage (difference in R^2) of <0.1 was considered to indicate a well-validated model. Validation was considered to be moderate when the relative shrinkage was between 0.1 and 0.2, and models were considered to be validated poorly if the relative shrinkage was >0.2. For dichotomous outcomes, the Hosmer Lemeshow (HL) goodness-of-fit test P value was calculated both for the original model and for its replication in the validation sample. Models validated well if the HL P value was >0.10 for both, which indicates no lack of fit in either model. Models were considered to validate moderately well if the HL P value was 0.05–0.10 for one or both models, indicating some lack of fit, and to validate poorly if the HL P value was <0.05 for one or both models (lack of fit in one or both of the models). Because of their small size, the C5–8 AB and T1–9 AB subsamples were not divided into development and validation subgroups.

Results

Patient characteristics

Patient demographic and injury characteristics are presented for the 1032 patients in the primary analysis subset as a whole and for each of the two subgroups separately in Table 1. The sample was 81% male; 71% white, and 22% black; 38% married; mostly not obese (82% had a BMI of <30), and 66% were employed at the time of injury. The average age was 38 years (SD 17). Vehicular crashes were the most common cause of injury (49%), followed by falls (25%), and sports and violence (11% each). The mean motor FIM raw score at admission was 23.5 (SD 11.3) and the cognitive score was 28.7 (SD 6.1). The Rasch-transformed motor FIM score at admission was 17.8 (SD 12.6) and the cognitive score was 73.6 (SD 18.1). A mean of 31 days (SD 28) had elapsed from the time of injury to the time of rehabilitation admission.

Treatment time

All 1032 patients received one or more OT treatment sessions during rehabilitation. SCIRehab OTs documented treatments provided during 56 477 OT sessions. The patients received a mean total of 53.8 hours (range, 2.0–246.5 hours, SD 36.7, median 42.1) of OT during their stay. Table 2 lists time spent in each OT activity for all patients and for patients in each of the two subgroups.

Associations of OT activities with key outcomes across all patients

Time spent in specific OT activities was associated with multiple outcomes at rehabilitation discharge and at the 1-year injury anniversary and added to the variance explained by patient demographic and injury characteristics.

Discharge FIM motor score

Patient characteristics predicted 65% ($R^2 = 0.65$) of the variation in discharge motor FIM Rasch-transformed score (Table 3). Patients with AIS A, B, or C injuries had lower motor FIM scores than patients with AIS D. Higher admission motor FIM also was a strong predictor of discharge motor FIM, as was having a work-related injury. Older age, higher medical severity (as measured by the CSI), longer time from injury to rehabilitation admission and being obese were associated with lower scores. The addition of OT treatment variables increased the R^2 to 0.74; greater patient participation in OT sessions and more time spent on OT activities of balance, bowel management, lower body dressing, and home management skills were associated with higher scores; more time in other areas, including transfer training, range of motion/stretching, self-feeding, upper body dressing, and classes led by OTs, etc. was associated with lower scores. Adding rehabilitation center to the model increased the R^2 slightly (to 0.76).

FIM motor score at anniversary

Patient characteristics, OT treatment variables, and rehabilitation center explained 58% of the variance in motor FIM 1 year after injury (Table 3). Injury group was the strongest predictor (patients with AIS D have higher scores) and higher admission motor FIM score also was predictive of a higher score. Older age, higher admission cognitive FIM scores, more medical severity during rehabilitation, longer time from injury to rehabilitation admission, and having Medicaid or workers compensation as payer were associated with lower scores. Greater patient participation during OT sessions and more OT time spent in strengthening and home management skills were associated with higher scores while more OT time spent working with patients on self-feeding, communication, bed mobility, and assistive

Table 3 Prediction of motor FIM* at discharge and 1-year post-injury

Outcome	Discharge motor FIM*			1-year motor FIM*		
Observations used		1031			859	
Step 1: Pt. characteristics: adj. R^2		0.65			0.51	
Step 2: Pt. characteristics + treatments: adj. R^2		0.74			0.56	
Step 3: Pt. characteristics + treatments + center identity: adj. R^2		0.76			0.58	
Independent variables**	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2
Neurological group	–	<0.001	0.046	–	<0.001	0.072
C1–4 ABC	−10.649	<0.001	–	−24.601	<0.001	–
C5–8 ABC	−9.749	<0.001	–	−20.188	<0.001	–
Para ABC	−4.247	<0.001	–	−16.866	<0.001	–
All Ds (reference)	0.000	–	–	0.000	–	–
Admission FIM motor*	0.339	<0.001	0.039	0.476	<0.001	0.022
Admission FIM cognitive*				−0.081	0.014	0.003
Comprehensive Severity Index	−0.047	<0.001	0.006	−0.108	<0.001	0.012
Days from trauma to rehabilitation admission	−0.041	<0.001	0.007	−0.097	<0.001	0.011
Age at injury	−0.050	0.001	0.003	−0.182	<0.001	0.010
Injury is work related	2.275	0.013	0.001			
BMI ≥30	−2.087	<0.001	0.004			
Primary payer	–	0.039	0.001	–	0.008	0.005
Medicare	−1.481	0.098	–	−1.903	0.448	–
Medicaid	−1.016	0.060	–	−3.816	0.008	–
Worker's compensation	−1.866	0.072	–	−4.541	0.011	–
Private insurance/pay (reference)	0.000	–	–	0.000	–	–
Rehabilitation length of stay	0.092	<0.001	0.013			
Patient participation score – OT	1.736	<0.001	0.006	3.650	<0.001	0.007
OT hours of specific treatments						
Airway/respiratory management	−1.814	0.005	0.002			
Assessment	0.407	0.004	0.002	1.543	<0.001	0.010
Assistive technology	−0.454	<0.001	0.007	−0.439	0.030	0.002
Balance	0.321	0.007	0.002			
Bed mobility				−0.929	0.038	0.002
Bowel management	0.398	0.033	0.001			
Classes	−0.951	<0.001	0.003			
Communication				−2.046	<0.001	0.013
Dressing – lower body	0.299	0.003	0.002			
Dressing – upper body	−0.566	0.025	0.001			
Education (not covered by other activities)	−0.211	0.001	0.002			
Self-feeding	−0.255	0.017	0.001	−0.869	0.001	0.005
Home management skills	0.277	0.004	0.002	0.916	0.001	0.006
Range of motion/stretching	−0.211	<0.001	0.009			
Strengthening/endurance				0.173	<0.001	0.007
Transfers	−0.484	<0.001	0.004			

*Motor and cognitive FIM were Rasch transformed.
**All patient and treatment variables listed in Tables 1 and 2 were allowed to enter the models. Only statistically significant predictors are reported here; a missing variable name means that the variable did not predict any of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.

technology was associated with lower scores. Adding rehabilitation center to the model increased the R^2 by 0.02 (to 0.58).

Discharge location

Most patients (89%) were discharged to home (Table 4). Predictors of discharge to home (c statistic for patient and treatment variables = 0.81, Max $R^2 = 0.26$) included: higher admission motor FIM, being married, more time spent in OT bathing training and education sessions. Older age, race of black or Hispanic, more medical severity (CSI), and more time spent learning to self-feed were associated with discharge to a location other than home. Adding rehabilitation center to the model increased the c statistic to 0.84 and the Max R^2 to 0.31.

Residential location at 1-year injury anniversary

The only patient variable that was significant in predicting whether the patient resides at home at the anniversary is having English as the primary language (c statistic is only 0.55). The c statistic increases to 0.75 (Max $R^2 =$ 0.15) with the addition of OT treatment variables; more time spent in clothing management and hygiene as

Table 4 Prediction of discharge location, place of residence at 1-year anniversary, and working or being in school at 1-year anniversary

Outcome	Discharged to home			Reside at home at 1-year anniversary			Work/school at 1-year anniversary		
Observations used	1031: Yes = 917, No = 114			878: Yes = 828, No = 50			856: Yes = 236, No = 620		
Step 1: Pt. characteristics: c/Max R^2	0.79/0.21			0.55/0.02			0.81/0.33		
Step 2: Pt. characteristics + treatments: c/Max R^2	0.81/0.26			0.75/0.15			0.82/0.35		
Step 3: Pt. characteristics + treatments + center identity: c/Max R^2	0.84/0.31			0.77/0.17			0.83/0.36		
Independent variables*	Parameter estimate	Odds ratio	*P* value	Parameter estimate	Odds ratio	*P* value	Parameter estimate	Odds ratio	*P* value
Neurological group							–	–	<0.001
C1–4 ABC							−1.589	0.204	<0.001
C5–8 ABC							−0.928	0.395	0.004
Para ABC							−0.304	0.738	0.267
All Ds (reference)							0.000	–	–
Admission FIM motor-Rasch transformed	0.036	1.037	<0.001						
Comprehensive Severity Index	−0.010	0.990	0.007						
Traumatic etiology							–	–	0.018
Medical/surgical/other							−0.345	0.708	0.510
Violence							0.288	1.333	0.429
Sports							0.979	2.663	0.001
Fall							−0.003	0.997	0.992
Vehicular (reference)							0.000	–	–
Age at injury	−0.043	0.958	<0.001				−0.021	0.979	0.017
Marital status is married	0.716	2.045	0.005						
Race	–		<0.001				–	–	0.047
Black	−0.875	0.417	<0.001				−0.580	0.560	0.034
Hispanic	−1.492	0.225	0.002				**	**	**
All other minorities	−0.707	0.493	0.112				−0.607	0.545	0.129
White (reference)	0.000	–	–				0.000	–	–
Occupational status at injury							–	–	<0.001
Unemployed/other							−0.782	0.458	0.040
Student							1.644	5.175	<0.001
Retired							−0.758	0.469	0.182
Working (reference)							0.000	–	–
Highest education achieved							–	–	<0.001
High school							0.242	1.274	0.390
College							0.977	2.656	0.002
< 12 Years/other/unknown (reference)							0.000	–	–
Primary language is English				1.221	3.392	0.008			
Primary payer							–	–	0.005
Medicare							−0.808	0.446	0.197
Medicaid							−0.747	0.474	0.007
Worker's compensation							−0.849	0.428	0.018
Private insurance/pay (reference)							0.000	–	–
OT clinician experience				−0.061	0.941	0.019			
Patient participation score – OT							0.364	1.438	0.026
OT hours of specific treatments									
Bathing	0.230	1.258	0.046						
Classes provided by OT							−0.450	0.638	0.020
Education (not covered by other activities)	0.132	1.141	<0.001						
Self-feeding	−0.111	0.895	0.005				−0.126	0.882	0.044
Range of motion/stretching				−0.037	0.964	0.001			
Therapeutic activities***				−0.049	0.952	0.010			
Toileting, clothing management, and hygiene				1.895	6.655	0.020			

*All patient and treatment variables listed in Tables 1 and 2 were allowed to enter the models. Only statistically significant predictors are reported here; a missing variable name means that the variable did not predict any of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.
**Hispanic was combined with "all other minorities".
***Therapeutic activities include fine motor activities, tenodesis training, manual therapy, vestibular training, edema management, breathing exercise, cognitive retraining, visual/perceptual training, desensitization, and don/doff adaptive equipment.

related to toileting was associated with greater likelihood of residing at home while more time spent in range of motion and "therapeutic" activities was associated with a smaller chance. The *c* statistic increased to 0.77 with the addition of rehabilitation center. See Table 4.

Work/school

Patients who were college educated or were injured in sports-related accidents were over 2.5 times more likely (OR = 2.6 for each; reference group <12 years education/other and vehicular accident, respectively) and patients who participated actively in OT sessions were about 1.5 times more likely to be working or in school at the time of the injury anniversary (Table 4). Patients with high tetraplegia were less likely than were patients with AIS D to be working or in school. Patient variables explained most of the variation (*c* statistic = 0.81); it increased to 0.82 with the addition of treatments and to 0.83 with the addition of rehabilitation center.

Societal participation

Table 5 contains regression models that use patient characteristics and OT treatments as the independent variables to predict the four dimensions of the CHART: Physical Independence ($R^2 = 0.47$), Social Integration ($R^2 = 0.15$), Occupation ($R^2 = 0.27$), and Mobility ($R^2 = 0.33$). Patients with AIS D injuries achieve higher Physical Independence and Mobility scores than do patients with AIS A, B, or C injuries, regardless of motor level. Higher admission motor FIM was a significant predictor for all dimensions except for Social Integration. Persons who were married at the time of injury had higher Social Integration, Occupation, and Mobility scores. Being black (rather than white) was associated with lower Mobility scores. Level of education achieved prior to injury was significant in each model: having a college education was associated with higher scores (<12 years combined with other was the reference group). Payer also was significant: having Medicaid was associated with lower Social Integration and Mobility scores while having workers compensation was associated with lower Physical Independence scores (private insurance was the reference group). Several OT treatment activities were significant predictors. Higher patient participation score in OT treatment sessions was associated with better outcomes in three dimensions. More time in lower body dressing, home management skill training, and strengthening was associated with higher Physical Independence scores while more time in upper body dressing, range of motion/stretching, communication, and classes led by OT was associated with lower scores. For Mobility, more time spent in home management skill training and modalities was associated with higher scores and more time in airway/respiratory management and self-feeding was associated with lower scores. More time in airway/respiratory management was associated with lower Social Integration scores, while more time working on bed mobility was associated with higher scores. For the CHART Occupation dimension, more time spent in home management skills and skin management training was a significant positive predictor while more time in communication training was negative. The addition of center added 0.01 to the adjusted R^2 for each model.

Mood state and life satisfaction

Patient variables, OT treatments, and rehabilitation center were not strong predictors of depressive symptomatology, as measured by the PHQ-9, after injury (adjusted R^2 of 0.09); the only significant treatment variables were more time in bathing (with lower PHQ-9) and airway/respiratory management (with higher PHQ-9). Patient and treatment variables predicted 9% of the variation in the Satisfaction with Life (SWLS) scores. More time spent in ROM/stretching and strengthening exercises with OT was associated with lower scores (less satisfaction). The addition of rehabilitation center to the models increased the R^2 to only 0.11 (data not shown).

Rehospitalization

Higher medical severity during rehabilitation, longer time from injury to rehabilitation admission, and older age were associated with rehospitalization, along with more OT time spent in bathing and ROM/stretching. Higher admission motor FIM, longer rehabilitation LOS, and greater patient participation in OT activities were associated with a smaller likelihood of rehospitalization (*c* statistic = 0.69, Max $R^2 = 0.14$). The addition of rehabilitation center as a predictor did not improve the *c* statistic (data not shown).

Pressure sore(s) at the 1-year injury anniversary

Persons with paraplegia were five times more likely to report a pressure sore at the time of the 1-year interview than were persons with AIS D injuries. Other positive predictors included higher medical severity during rehabilitation, longer duration from injury to rehabilitation admission, and having Medicare as one's payer. Predictors of less reporting of pressure sores included: higher admission motor FIM scores, being retired at the time of injury, and more time spent during OT sessions on lower body dressing and home management skills (data not shown).

Table 5 Prediction of social participation

Outcome	CHART: Physical Independence			CHART: Social Integration			CHART: Occupation			CHART: Mobility		
Observations used		856			830			845			843	
Step 1: Pt. characteristics: adj. R^2		0.41			0.11			0.24			0.27	
Step 2: Pt. characteristics + treatments: adj. R^2		0.47			0.15			0.27			0.33	
Step 3: Pt. characteristics + treatments + center identity: adj. R^2		0.47			0.16			0.28			0.34	
Independent variables*	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2
Neurological group	–	<0.001	0.018							–	0.008	0.007
C1–4 ABC	−22.170	<0.001	–							−9.771	0.001	–
C5–8 ABC	−10.991	0.005	–							−6.260	0.023	–
Para ABC	−5.701	0.081	–							−5.353	0.018	–
All Ds (reference)	0.000	–	–							0.000	–	–
Admission FIM motor score-Rasch transformed	0.699	<0.001	0.017				0.846	<0.001	0.051	0.258	0.004	0.006
Comprehensive Severity Index	−0.130	0.001	0.006									
Days from trauma to rehabilitation admission	−0.214	<0.001	0.022				−0.094	0.026	0.004	−0.086	0.001	0.008
Traumatic etiology	–	0.004	0.007				–	0.041	0.005			
Medical/surgical/other	−11.699	0.027	–				−10.887	0.079	–			
Violence	−5.677	0.101	–				−8.381	0.038	–			
Sports	−9.659	0.004	–				3.201	0.416	–			
Fall	0.481	0.854	–				−5.095	0.088	–			
Vehicular (reference)	0.000	–	–				0.000	–	–			
Age at injury	−0.256	0.001	0.006	−0.332	<0.001	0.029	−0.348	0.001	0.009	−0.479	<0.001	0.040
Gender is male							−8.978	0.003	0.007			
Marital status is married				8.443	<0.001	0.027	6.876	0.011	0.005	4.984	0.004	0.006
Race										–	0.019	0.006
All other minorities										−4.135	0.226	–
Black										−5.464	0.003	–
Hispanic										−2.987	0.528	–
White (reference)										0.000	–	–
Occupational status at injury				–	<0.001	0.023	–	0.013	0.007	–	0.008	0.007
Unemployed/other				−6.977	0.003	–	0.372	0.924	–	−3.672	0.132	–
Student				2.252	0.335	–	11.591	0.003	–	6.316	0.011	–
Retired				10.308	0.001	–	−8.660	0.091	–	1.708	0.617	–
Working (reference)				0.000	–	–	0.000	–	–	0.000	–	–
Highest education achieved	–	<0.001	0.009	–	0.013	0.007	–	<0.001	0.016	–	<0.001	0.017
High school	8.549	0.001	–	1.768	0.348	–	4.612	0.153	–	3.598	0.071	–
College	12.630	<0.001	–	5.850	0.008	–	15.231	<0.001	–	10.464	<0.001	–
<12 Years/other/unknown (reference)	0.000	–	–	0.000	–	–	0.000	–	–	0.000	–	–
Primary language is English							14.384	0.005	0.006	12.888	<0.001	0.010
Primary payer	–	0.003	0.007	–	0.013	0.008				–	0.006	0.008
Medicare	−5.446	0.226	–	−5.327	0.107	–				2.022	0.568	–
Medicaid	−0.598	0.823	–	−5.684	0.003	–				−6.709	0.001	–
Worker's compensation	−12.228	<0.001	–	−1.064	0.640	.				0.722	0.768	–
Private insurance/pay (reference)	0.000	–	–	0.000	–	–				0.000	–	–
OT clinician experience				−0.303	0.037	0.003						
Patient participation score – OT				4.862	<0.001	0.018	8.608	<0.001	0.016	5.187	<0.001	0.013

OT hours of specific treatments:												
Airway/respiratory management				−5.353	0.006	0.007				−13.364	<0.001	0.031
Assessment	3.018	<0.001	0.015									
Bed mobility				1.235	0.019	0.005						
Classes	−3.089	0.019	0.003									
Communication	−2.084	0.004	0.005				−1.646	0.036	0.003			
Dressing – lower body	1.433	0.001	0.006									
Dressing – upper body	−4.483	<0.001	0.008									
Self-feeding										−1.017	0.003	0.006
Home management skills	1.377	0.005	0.004				1.526	0.003	0.007	0.692	0.010	0.004
Modalities										0.643	0.013	0.004
ROM/stretching	−0.400	0.003	0.005									
Skin management							2.172	0.049	0.003			
Strengthening/endurance	0.185	0.023	0.003									

*All patient and treatment variables listed in Tables 1 and 2 were allowed to enter the models. Only statistically significant predictors are reported here; a missing variable name means that variable did not predict any of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.

Model validation

Linear regression models for motor FIM at discharge and CHART Physical Independence at 1-year anniversary validated well (relative shrinkage <0.1). Models for motor FIM at the anniversary and CHART Social Integration and Occupation validated moderately well (relative shrinkage 0.1–0.2). Three models validated poorly (relative shrinkage >0.2): CHART Mobility, PHQ-9, and life satisfaction. For dichotomous outcomes, all but one of the models validated well (HL *P* value >0.1 for both): the only exception was residential location at discharge, which validated moderately well.

Functional outcomes for patients with thoracic complete injuries

The 158 patients with T1–T9 AIS A or B injuries who did not transition to AIS C or D during rehabilitation were similar in age to the patients with low tetraplegia and tended to be younger than the full study group. They also were less likely to have been married and working prior to injury, and more likely to have been injured in a vehicular accident (Table 1). These patients spent most of their time with OT working on strengthening/endurance (mean 10 hours, SD 12), and ADL activities, most of which was dedicated to lower body dressing (mean 4 hours, SD 3) and bathing (mean of 2 hours, SD 2) (see Table 2).

Discharge and anniversary motor FIM

Some of the variation (R^2 of 0.28) in the discharge motor FIM scores was explained by patient characteristics alone; the addition of OT treatment variables almost doubled the R^2 to 0.58 (Table 6). More time spent in clothing management and hygiene work related to toileting, and longer rehabilitation LOS were associated with higher scores. More OT time spent on grooming, strengthening/endurance exercises, and general education, along with more time that OTs spend in interdisciplinary conferencing on a patient's behalf and longer duration of lower body dressing training (greater percent of the stay), were associated with lower scores. The addition of rehabilitation center increased the explanatory power to 65%. A less strong model is seen for the anniversary motor FIM (23% for patient variables, 41% for patient plus treatment variables, and 44% with the addition of center variables (Table 7). Significant positive treatment variables included more time spent in ROM/stretching exercises and higher patient participation scores during OT sessions; more time in grooming activities, equipment

Table 6 Prediction of FIM* at discharge (motor, self-care items, and lower body components) for patients with motor complete low paraplegia (T1–9)

Discharge FIM	Motor (11 items)*			Self-care (6 items)*			Lower body self-care components* (3 items)		
Observations used		158			158			158	
Step 1: Pt. characteristics:adj. R^2		0.28			0.20			0.26	
Step 2: Pt. characteristics + treatments: adj. R^2		0.58			0.51			0.54	
Step 3: Pt. characteristics + treatments + center identity: adj.		0.65			0.58			0.58	
Independent variables:**	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2
Admission FIM motor*	0.317	<0.001	0.055	0.514	<0.001	0.059	0.864	<0.001	0.076
Comprehensive Severity Index	−0.050	0.010	0.016	−0.101	0.002	0.029	−0.099	0.034	0.010
Days from trauma to rehabilitation	−0.040	0.002	0.023	−0.059	0.009	0.019	−0.103	0.001	0.028
Gender is male	4.581	<0.001	0.081	4.602	0.001	0.033	9.049	<0.001	0.058
BMI ≥30	−2.258	0.007	0.017	−2.865	0.040	0.010	−4.556	0.024	0.012
Rehabilitation LOS	0.206	<0.001	0.186	0.329	<0.001	0.194	0.468	<0.001	0.178
OT hours of specific treatments									
Education (not covered by other activities)	−0.579	<0.001	0.038	−0.515	0.040	0.010	−1.220	0.001	0.031
Grooming	−2.937	0.001	0.030	−5.153	<0.001	0.041	−9.033	<0.001	0.059
Interdisciplinary conference on patient's behalf	−0.648	0.003	0.021	−0.887	0.015	0.016	−1.371	0.010	0.017
Strengthening/endurance	−0.207	<0.001	0.088	−0.336	<0.001	0.114	−0.464	<0.001	0.082
Toileting – clothing management and hygiene	1.153	0.027	0.011				2.518	0.040	0.010
Percent of rehabilitation stay between first and last lower body dressing session	−0.052	0.003	0.021						

*Motor FIM and its component subscores were Rasch transformed.
**All patient and treatment variables listed in Tables 1 and 2 were allowed to enter the models. Only statistically significant predictors are reported here; a missing variable name means that the variable did not predict any of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.

evaluation, and in interdisciplinary conferencing (by therapists) were negative.

Self-care component of the motor FIM at discharge and anniversary

OT treatments also contributed to highly predictive models for the six self-care items of the discharge motor FIM: R^2 increased from 0.20 for patient variables alone to 0.51 for patient and OT treatment variables (Table 6). Higher admission motor FIM score and being male were associated with higher scores. Higher medical severity, longer time from trauma to rehabilitation admission, and being obese were associated with lower scores.

Significant OT treatments in the model had negative associations

More time spent in grooming, strengthening/endurance exercises, general education, interdisciplinary conferencing on the patient's behalf was associated with lower FIM self-care scores. The addition of rehabilitation center increased the R^2 to 0.58. For the anniversary motor FIM (self-care component) the R^2 increased from 0.11 for patient variables only, to 0.31 with the addition of OT treatments; higher patient participation score in OT sessions was the most predictive variable (positive) and more time spent in equipment evaluation/provision and grooming was associated with lower scores. The addition of rehabilitation center increased the predictive power by 10%.

Lower body self-care items of the motor FIM

Similar patient characteristics (higher admission FIM scores and being male) were predictive ($R^2 = 0.26$) of higher value on a FIM subscore for the three lower body self-care items at the time of rehabilitation discharge. Longer time from trauma to rehabilitation admission, higher medical severity during rehabilitation, and being obese were negative predictors (Table 6). The R^2 showed more than a two-fold increase (to 0.54) with the addition of OT treatment variables. More time spent in clothing management and hygiene related to toileting was a positive predictor, while more time spent in grooming, strengthening/endurance exercises, general education, and interdisciplinary

Table 7 Prediction of FIM* at 1-year post-injury (motor, self-care items, and lower body components) for patients with motor complete low paraplegia (T1–9)

One-year post-injury FIM	Motor (11 items)*			Self-care (6 items)*			Lower body self-care components* (3 items)		
Observations used	132			131			131		
Step 1: Pt. characteristics: adj. R^2	0.23			0.11			0.12		
Step 2: Pt. characteristics + treatments: adj. R^2	0.41			0.31			0.33		
Step 3: Pt. characteristics + treatments + center identity: adj.	0.44			0.41			0.39		
Independent variables:**	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2
Traumatic etiology	–	0.007	0.037						
Other	−1.973	0.252	–						
Fall or hit by falling object	4.963	0.007	–						
Vehicular (reference)	0.000	–	–						
Age at injury	−0.213	<0.001	0.066	−0.289	0.013	0.029	−0.475	0.002	0.046
Primary language is English	6.459	0.018	0.021	12.187	0.038	0.018			
Patient participation score – OT	2.783	0.005	0.033	8.518	<0.001	0.083	10.971	<0.001	0.078
OT hours of specific treatments									
Equipment evaluation and provision	−1.285	0.013	0.024	−3.194	0.005	0.037	−4.443	0.003	0.041
Grooming	−5.990	0.001	0.046	−12.189	0.002	0.050	−12.738	0.014	0.027
Interdisciplinary conference on patient's behalf	−0.859	0.007	0.029						
Range of motion/stretching	0.682	0.015	0.023						
Therapeutic activities***							−2.591	0.026	0.021

*Motor FIM and its component subscores were Rasch transformed.
**All patient and treatment variables listed in Tables 1 and 2 were allowed to enter the models. Only statistically significant predictors are reported here; a missing variable name means that the variable did not predict any of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.
***Therapeutic activities include fine motor activities, tenodesis training, manual therapy, vestibular training, edema management, breathing exercise, cognitive retraining, visual/perceptual training, desensitization, and don/doff adaptive equipment.

conferencing on the patient's behalf were negative predictors. The addition of rehabilitation center variables added another 0.04 to the strength of the model.

The explained variation in the lower body self-care scores at the time of the anniversary also more than doubled with the addition of treatment variables to patient predictors (0.12–0.33); greater participation in OT treatments during rehabilitation was the most predictive positive factor (Table 7). More time spent in equipment evaluation, grooming, and therapeutic activities (fine motor activities, tenodesis training, manual therapy, vestibular training, edema management, breathing exercise, cognitive retraining, visual/perceptual training, desensitization, and don/doff adaptive equipment) was associated with lower score. The addition of rehabilitation center increased the R^2 to 0.39.

Functional outcomes for patients with motor complete low tetraplegia

In addition to the motor FIM, the subscores for self-care items were analyzed for 78 patients with C5–C8 AIS A or B who did not have a transition to an AIS C or D or change in neurological level of injury during rehabilitation. Compared to the full SCIRehab sample, these patients were younger, less likely to have been married, more often injured in a sports-related accident, and had longer lengths of stay in the rehabilitation center. They also had lower admission motor FIM scores (Table 1).

The OT activities that consumed the most time for these patients (Table 2) included therapeutic strengthening/endurance (mean 16 hours (SD 17), ROM/stretching (mean 7.6 hours, SD 9.7), therapeutic activities (mean 5.4 hours, SD 5.0), general education (mean 4.6 hours, SD 5.1), and training in lower body dressing (mean 3.0 hours, SD 3.6).

Discharge and anniversary motor FIM

Patient variables explained 39% of the variation in the discharge motor FIM score; the addition of OT treatment variables improved the prediction to 61% (Table 8). Older patients and those with C5 or C6 injuries (compared to C7–8) had lower scores; patients who were married had higher scores. Higher levels of

Table 8 Prediction of FIM* at discharge (motor, self-care items, lower body components, and upper body components) for patients with motor complete low tetraplegia (C5–8)

Discharge FIM	Motor (11 items)*			Self-care (6 items)*			Lower body self-care components (3 items)*			Upper body self-care components (3 items)*		
Observations used		78			78			78			78	
Step 1: Pt. characteristics: adj. R^2		0.39			0.44			0.37			0.45	
Step 2: Pt. characteristics + treatments: adj. R^2		0.61			0.69			0.65			0.64	
Step 3: Pt. characteristics + treatments + center identity: adj.		0.62			0.66			0.67			0.63	
Independent variables:**	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2
Neurological group	–	<0.001	0.173	–	<0.001	0.103	–	<0.001	0.149	–	<0.001	0.119
C5	−8.911	<0.001	–	−12.659	<0.001	–	−14.433	<0.001	–	−19.279	<0.001	–
C6	−5.341	0.006	–	−10.337	0.000	–	−21.618	<0.001	–	−11.310	0.007	–
C7–8 (reference)	0.000	–	–	0.000	–	–	0.000	–	–	0.000	–	–
Admission FIM self-care*				0.196	0.013	0.023						
Admission FIM self-care upper body*										0.344	<0.001	0.067
Age at injury	−0.226	<0.001	0.127	−0.277	<0.001	0.073	−0.190	0.022	0.020	−0.479	<0.001	0.109
Marital status is married	4.558	0.006	0.037									
Patient participation score – OT	3.403	0.004	0.042	4.920	0.006	0.029						
Clinician experience, years – OT										−0.622	0.020	0.021
OT hours of specific treatments												
Airway/respiratory management				24.369	0.009	0.025						
Assistive technology							−0.811	0.018	0.022			
Bathing				3.152	0.002	0.040	3.386	0.010	0.027			
Classes provided by OT	−3.884	0.001	0.053	−5.832	0.002	0.040	−6.271	0.007	0.030	−9.910	<0.001	0.060
Dressing – lower body							1.289	0.004	0.036			
Home management skills				0.679	0.009	0.025				1.181	0.002	0.043
Interdisciplinary conference on patient's behalf				1.023	0.013	0.023						
Skin management	2.138	0.004	0.041				5.440	0.001	0.052			
Therapeutic activities***										0.614	0.040	0.016
Toileting – clothing management and hygiene	3.749	0.009	0.031	6.811	0.002	0.038				9.314	0.004	0.036
Wheelchair mobility – manual							4.489	0.003	0.038			

*Motor FIM and its component subscores were Rasch transformed.
**All patient and treatment variables listed in Tables 1 and 2 were allowed to enter the models. Only statistically significant predictors are reported here; a missing variable name means that the variable did not predict any of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.
***Therapeutic activities include fine motor activities, tenodesis training, manual therapy, vestibular training, edema management, breathing exercise, cognitive retraining, visual/perceptual training, desensitization, and don/doff adaptive equipment.

Table 9 Prediction of FIM* at 1-year post-injury (motor, self-care items, lower body components, and upper body components) for patients with motor complete low tetraplegia (C5–8)

One-year FIM	Motor (11 items)*			Self-care (6 items)*			Lower body self-care components (3 items)*			Upper body self-care components (3 items)*		
Observations used	67			67			67			67		
Step 1: Pt. characteristics: adj. R^2	0.27			0.33			0.26			0.31		
Step 2: Pt. characteristics + treatments: adj. R^2	0.39			0.40			0.54			0.42		
Step 3: Pt characteristics + treatments + center identity: adj.	0.39			0.37			0.52			0.41		
Independent variables:**	Parameter estimate	*P* value	Semi-partial Omega^2	Parameter estimate	*P* value	Semi-Partial Omega^2	Parameter estimate	*P* value	Semi-Partial Omega^2	Parameter estimate	*P* value	Semi-partial Omega^2
Neurological group	–	0.020	0.058				–	0.010	0.055			
C5	−7.516	0.007	–				−18.574	0.003	–			
C6	−2.961	0.337	–				−14.523	0.053	–			
C7–8 (reference)	0.000	–	–				0.000	–	–			
Admission FIM motor*	0.284	0.024	0.040									
Admission FIM self-care*				0.670	<0.001	0.228						
Admission FIM self-care upper body*										0.877	<0.001	0.325
Days from trauma to rehabilitation admission										−0.224	0.043	0.029
Rehabilitation LOS										0.273	<0.001	0.114
OT hours of specific treatments												
Bathing							7.327	0.004	0.054			
Education							−1.574	0.003	0.057			
Skin management	4.367	0.001	0.112	6.604	0.005	0.068	12.307	<0.001	0.107			
Wheelchair mobility – manual							6.727	0.015	0.036	−4.471	0.032	0.033

*Motor FIM and its component subscores were Rasch transformed.

**All patient and treatment variables listed in Tables 1 and 2 were allowed to enter the models. Only statistically significant predictors are reported here; a missing variable name means that the variable did not predict any of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.

patient participation in OT sessions and more time spent in OT activities of skin management and clothing management/hygiene related to toileting were associated with higher scores; more time in classes provided by OTs was associated with lower scores. The addition of center identity increased the explanatory power only slightly (to 62%). The explained variance for the anniversary motor FIM was 27% for patient variables and 39% for patient plus treatment and center variables (Table 9).

Discharge and anniversary self-care

Patient variables explained 44% of the variation in the self-care component of the motor FIM at discharge (Table 8) and 33% at the 1-year injury anniversary (Table 9). When OT treatment variables were added to the models, the R^2 increased to 69 and 40%, respectively. The admission FIM self-care score and greater patient participation in OT sessions, along with more time that OTs provide training for bathing, clothing management, and hygiene related to toileting, home management skills, and airway/respiratory management, were associated with higher discharge scores. Older patients and those with C5 or C6 injuries (as compared to C7–C8) and more time spent in classes provided by OTs had lower scores. For the anniversary self-care score, higher admission self-care scores, and more time in skin management training were associated with higher scores.

Lower body self-care components of the motor FIM

Table 8 shows the R^2 increased from 0.39 for patient characteristics alone to 0.65 with the addition of OT treatment variables in the model predicting the lower body self-care score at discharge. More time spent on skin management, lower body dressing, bathing, and manual wheelchair mobility training was associated with higher scores; more time in classes was associated with lower scores. An increase in the R^2 was also seen for the 1-year anniversary score (Table 9) – R^2 increased from 0.26 for patient characteristics alone to 0.54 with the addition of OT treatment variables. Again, more time in OT activities of bathing, skin management, and manual wheelchair mobility training was associated with a higher score. Adding rehabilitation center to the models did not increase the R^2.

Upper body self-care components of the Motor FIM

Large increases (from 45 to 64%) also were noted in the predictive power for the upper body self-care items on discharge when OT treatment variables were added to patient variables (Table 8). More time spent on home management skill training, clothing management, and hygiene as related to toileting, and therapeutic activities were associated with higher scores.

For the anniversary score, the R^2 increased from 0.31 for patient characteristics alone to 0.42 with the addition of OT treatments (Table 9). Admission of upper body self-care score and longer rehabilitation LOS were positive predictors; longer time from trauma to rehabilitation admission and more time spent in power wheelchair mobility training were negative.

Discussion

Knowing the level and completeness of injury helps rehabilitation clinicians, including OTs, tailor treatment plans, and guide activity selection according to patient need and predict the amount of function patients will likely achieve after rehabilitation. Patients with motor complete higher levels of injury may need more treatment activities that focus on basic care needs such as self-feeding or grooming and OTs strive to maximize the level of independence for skills that require use of the head and neck only or involve minimal arm movement. Patients with less severe injuries will be able to participate in activities involving higher-level functioning and greater complexity.

Analysis of all outcomes across the full sample

We began our analyses of a range of outcomes using the full analytic subsample of 1032 patients, which includes patients of all injury levels, some with complete and some with incomplete injuries. It is not surprising that patient variables, which includes the injury group to which the patient was classified (C1–C4, AIS A, B, C; C5–C8 AIS A, B, C, Para AIS A, B, C, and AIS D regardless of neurological level) are most predictive of outcomes and especially functional outcomes (motor FIM). In fact, most of the time, injury group is the strongest predictor as indicated by the lowest P value and highest omega. The large amount of variation (65%) for the motor FIM score at discharge and at the anniversary explained by injury group, along with other patient variables (age, admission FIM scores, BMI, payer) leaves little room for treatment variables to add to the explanation. Our results showed that OT treatment variables increased the explanatory power by only 9 and 1%, respectively. Some OT activities (equipment evaluation, ROM, and physical agent modalities such as electrical stimulation, hot or cold packs, etc.) were typically associated with lower scores. However, these treatments may provide small functional advances, whether achieved through repeated practice, use of adaptive equipment, or most likely both, that may not be captured within the measurement constraints of the motor

FIM score – that is, the FIM may be insensitive to the small improvements in function that these treatments may achieve. ADL training consumes much of OT treatment time,[10] however, once patients achieve the desired independence levels or when patients are making progress toward established goals, OT interventions will likely focus on more advanced training such as balance and home management skills, which we see associated with higher discharge motor FIM scores. Thus, negative associations should not be interpreted as "bad" but rather may be an indicator of patient need and that the outcome (FIM) may not be sensitive enough to quantify small levels of progress.

The amount of patient participation (engagement) in OT sessions was a consistent predictor of better outcomes (motor FIM, rehospitalization, CHART dimensions, and working or attending school at 1 year, etc.), which reinforces earlier work by Lenze *et al.*[19] who reported that high levels of patient participation or motivation is a determinant of successful rehabilitation outcomes.

The determinant of living in a home environment may be maximizing ADL performance. If patients are able to perform or at least participate in more complex ADL such as bathing, which requires coordination and demand that is more physical, the burden of the caregiver is lessened. Indeed, we see that more time spent on bathing correlated positively with returning home at discharge. Additionally, increased hours spent on toileting and clothing management (another complex ADL) were associated with a higher likelihood of residing at home at the 1-year anniversary, whereas spending more time on self-feeding, a more basic ADL, and an indication of greater care-giver burden, was associated with lesser likelihood of discharge to home.

Pressure ulcers are one of the most common complications after SCI.[32,33] The model predicting the presence of a pressure ulcer at the time of the 1-year anniversary did not show strong predictive power, but it is noteworthy that more time spent in lower body dressing and home management skill training during OT sessions was associated with less reporting of pressure sores. Lower body dressing practice often requires a patient to work on rolling, various sitting positions, increased flexibility, and management of lower extremities. This work may provide pressure relief and promote proper skin management to prevent and/or heal pressure ulcers.

Various OT treatments are predictive of a variety of outcomes when examined for the full sample of 1032 patients together, however, the added explanatory power (above that explained by patient characteristics alone) is small. Because functional need helps determine interventions provided, we hypothesized that OT treatments may be more influential when examining functional outcomes for functionally homogeneous groups of patients.

ADL-related outcomes for patient subgroups

We created two motor complete injury subgroups that could be considered more homogeneous than the overall sample. The goal in creating these subgroups (one for low tetraplegia C5–C8 and one for thoracic injuries T1–T9) was to increase one's confidence that differences in outcomes could be attributed mostly to treatment, rather than natural recovery. Table 10 summarizes the increases in predictive power explained by OT treatments as patient groupings become more homogeneous and the outcomes become more relevant to the subgroup.

Cervical level 5–8

Foy, *et al.*[10] found OTs spend significantly more time working with patients who have C5–8 spinal injuries than patients with other injury levels. These patients typically lack full UE utilization that limits ADL/IADL (instrumental ADL) independence or functional mobility and benefit from interventions focused on UE functional training. For this homogeneous group of patients with motor complete low tetraplegia, we saw a greater effect of OT treatments than we did for the full sample when examining discharge motor FIM scores (R^2 increased 0.22 with the addition of treatment variables, compared to an increase of 0.09 for the full sample). A similar pattern was seen for the anniversary motor FIM: R^2 increased 0.12 with the addition of treatment variables for the group of motor complete low tetraplegia compared to 0.05 for the full sample.

After examining the discharge motor FIM score, we attempted to make the outcome more relevant to the subgroup by examining only the self-care components. When we did this, an even stronger influence of OT treatments was found (the R^2 increased from 0.44 for patient characteristics alone to 0.69 with the addition of OT treatments). Moreover, we separated the self-care items into the upper body and lower body self-care domains to help further examine the impact of specific OT treatments on the upper and lower body self-care outcomes, respectively. The strength of the model predicting the discharge and the anniversary lower body self-care FIM approximately doubled when OT treatment variables were added to patient characteristics. Most of the variation explained by

Table 10 Comparison of R^2 for motor FIM, self-care component, upper-body items, and lower body items* at discharge and 1-year post-injury for all patients and for patients with motor complete low tetraplegia and paraplegia

FIM	Motor (11 items)* Adjusted R^2		Self-care (6 items)* Adjusted R^2		Lower body self-care components (3 items)* Adjusted R^2		Upper body self-care components (3 items)* Adjusted R^2	
	Patient characteristics only	Patient and treatment characteristics	Patient characteristics only	Patient and treatment characteristics	Patient characteristics only	Patient and treatment characteristics	Patient characteristics only	Patient and treatment characteristics
Rehabilitation discharge								
Full sample (1032)	0.65	0.74	–	–	–	–	–	–
C5–8 AB (78)	0.39	0.61	0.44	0.69	0.37	0.65	0.45	0.64
T1–9 AB (158)	0.28	0.58	0.20	0.51	0.26	0.54	–	–
One-year post-injury								
Full sample (1032)	0.51	0.56	–	–	–	–	–	–
C5–8 AB (78)	0.27	0.39	0.33	0.40	0.26	0.54	0.31	0.42
T1–9 AB (158)	0.23	0.41	0.11	0.31	0.12	0.39	–	–

*Motor FIM, self-care component, upper body and lower body items were Rasch transformed.

patient characteristics was attributable to the injury level, which confirmed the need to include the level of tetraplegia in the models. The large increase in explanatory power due to OT treatments was due primarily to the influence of lower body dressing training.

An increase in the R^2 from 0.45 (patient characteristics alone) to 0.64 (with addition of OT treatments) for the model predicting the upper body component scores speaks to the importance of OT training in achieving maximal independence. More time dedicated to practicing "higher level" activities (home management skills and clothing management/hygiene for toileting) were strong positive predictors. Also a positive predictor was the category of "therapeutic activities", which involves OT activities such as tenodesis and fine motor training, etc. that assist with increasing the function and performance of the hand.[9]

Thoracic level 1–9

The amount of variance in the discharge and anniversary motor FIM explained by OT treatments in addition to patient characteristics was considerably larger, (increase of 0.30) when examining the homogeneous subgroup of patients with thoracic injuries (T1–T9 AIS A or B) as compared with the full group (increase of 0.09). Clothing management and hygiene as related to toileting was the only positive predictor. Toileting independence is a prime goal of OT treatment and an area to which significant efforts are devoted. Other significant treatment variables (grooming, strengthening/endurance exercises, and general education), however, had negative associations. Patients who would be working on these activities may have had complicating factors that limited their ability to work on more functionally oriented activities and the patient variables may not have been sensitive enough to capture this need for basic type of activities. It may also indicate that OT time could be better spent working on more functional tasks (e.g. clothing management/hygiene and other ADL) rather than in general education sessions or strengthening/endurance exercises.

Persons with paraplegia typically have full UE innervation and function and the potential to be independent with or without use of a device for most ADL. When we increased the specificity of the outcome to include only the lower body items of the self-care FIM, we again saw clothing management and hygiene as related to toileting as the lone positive predictor. We hypothesize that positive associations with training in lower body dressing or bathing were not seen because once mastery of these tasks is accomplished, OTs therapists typically introduce more challenging skills, such as toileting or IADL skills not measured in the FIM, rather than repeated training in skills already attained.

Limitations

The FIM is used widely in rehabilitation units in the United States, includes a certification process for clinicians who use the measure, and allows the ability to compare scores on specific tasks on admission and discharge. However, despite these advantages, the FIM also has been criticized for its lack of specificity for SCI,[34,35] significant ceiling and floor effects,[36] susceptibility to bias,[37] and limitations in measuring change.[38–40] However, the FIM is the only measure that was used consistently in the participating rehabilitation centers. Therefore, caution must be used when interpreting FIM scores.

Knowledge about key functional differences between categories of injury was the basis for assigning patients into neurological injury subgroups. Patients with low tetraplegia (C5–8) typically have functional use of their UEs; however; there are large variations in functional abilities, just by virtue of the level of injury. While the specific level of injury was treated as a predictor variable in the C5–8 subgroup analysis, this may not have been fully adequate to control for patient variation in muscle innervation.

OTs developed the OT taxonomy approximately 1 year prior to the start of data collection during which time each facility continued routine operations that may have resulted in practice change that could not be captured in study documentation. Clinicians documented therapy activities on a PDA, which was a new documentation process and required additional time spent by clinicians in addition to time spent on traditional documentation. It is possible that not all treatment sessions delivered are represented in the dataset and that there was some variability in the way clinicians documented a given treatment activity.

Rehabilitation is an interdisciplinary process in which responsibilities are shared among disciplines. OTs often share treatment responsibilities with physical and speech therapy, as well as nursing. The taxonomies utilized to capture data were developed so that shared activities were described similarly; however, each discipline documented only their work.

SCIRehab centers serve patients with diverse clinical and demographical characteristics and provide varied care delivery patterns. The centers include some of the largest SCI rehabilitation centers in the United States. They are not a probability sample, therefore, not representative of the rehabilitation centers that provide care for patients with SCI in the United States.

Conclusion

Rehabilitation is not a typical one-size-fits-all practice, but rather a dynamic patient-centered approach. Patient characteristics, treatments provided (in this case, OT), and patient participation are important issues that can affect patient outcomes. In this study, patient participation during OT treatment sessions was found to be significantly predictive of most of the functional outcomes and of some domains of social participation. One important implication is that OTs should collaborate with their patients to create an environment that facilitates patients' full engagement with therapy. Overall, time spent in specific OT activities contributes to variation explained in a variety of functional and social participation outcomes upon rehabilitation discharge and at the 1-year injury anniversary. However, the influence of OT treatments on functional outcomes (motor FIM and its components) became much stronger when examined in homogeneous subgroups of patients with complete injury. Our findings provide associations of specific types of OT treatments with a variety of outcomes, which may have implications for treatment planning. These findings may also serve to guide future clinical trials to show the causation between select OT treatments and outcomes.

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