Special issue article

Relationship of speech-language pathology inpatient rehabilitation interventions and patient characteristics to outcomes following spinal cord injury: The SCIR rehab Project

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Background/objective: Describe associations of patient characteristics and speech-language pathology (SLP) interventions provided during inpatient rehabilitation for spinal cord injury (SCI) to outcomes at discharge and 1-year post-injury.

Methods: Speech-language pathologists at six inpatient rehabilitation centers documented details of treatment provided. Least squares regression modeling was used to predict outcomes at discharge and 1-year injury anniversary. Cognitive, participation, and mood outcomes for a subsample of patients with traumatic brain injury (TBI) and cognitive-communication limitations (CCLs) were examined.

Results: SLP treatment factors explain a small amount of variation in cognitive Functional Independence Measure (FIM), participation, and mood. Variation explained by treatment factors for cognitive outcomes at the time of discharge increased when the patient group was more homogeneous (patients with TBI and CCLs). More time in SLP cognitive-communication interventions had a negative relationship, while longer length of stay was positive. The added explanatory power was not seen for similar outcomes at 1-year post-injury.

Conclusion: Patients with SCI who have the greatest need for interventions to address cognitive limitations due to TBI receive the most SLP cognitive-communication treatment and show the greatest amount of improvement during rehabilitation. Their cognitive functioning remained impaired at discharge; this likely accounts for the consistent finding that more hours of SLP cognitive-communication treatment is associated with lower cognitive FIM scores at discharge. Future research on individuals with dual SCI and TBI should include more comprehensive assessment of individual differences in cognitive performance in order to better examine the complex relationships between SLP treatments and outcomes.

Note: This is the fifth of nine articles in this SCIR rehab series.

Keywords: Spinal cord injuries, Rehabilitation, Traumatic brain injury, Dual diagnosis, Practice-based evidence, Speech-language pathology, Participation, Cognitive outcomes

Introduction

Individuals with spinal cord injury (SCI) often present to inpatient rehabilitation with cognitive-communication limitations (CCLs) that may be the result of multiple causes, including general trauma, medications, pain, newly acquired traumatic brain injury (TBI), hypoxic injury secondary to respiratory compromise at

the time of the accident, sleep disturbance, emotional distress, and/or longstanding problems such as developmental attention deficit hyperactivity disorder, language and learning disability, and/or prior TBI or other pre-existing disease. It is important to diagnose the underlying cause of any CCL accurately because different etiologies respond to different treatments, e.g. CCLs arising from medication side effects require a different treatment approach than those arising from TBI. Diagnosing CCLs in patients with acute SCI is a

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difficult process because, while the mechanism of injury raises the likelihood of a TBI component, TBI signs and symptoms may be obscured by the acute medical complexity of the injury, e.g. associated trauma, medication sedation effects, inability of the patient to verbally communicate, etc.

Published incidence rates of dual-SCI/TBI range from 24 to 74%, depending on the definition of TBI used and the method for determining the diagnosis.¹⁻⁹ Studies of rehabilitation outcomes comparing individuals with dual SCI/TBI to those with SCI only have reported that individuals with dual SCI/TBI have decreased motor and cognitive Functional Independence Measures (FIMs[®]) gains during acute rehabilitation,⁶ decreased social and occupational participation as measured by Craig Handicap Assessment and Reporting Technique (CHART) at 1-year post-injury¹⁰ and decreased emotional adjustment at 2-year post-injury.¹¹ However, virtually no research has focused on the impact of interventions provided by speech-language pathologists on outcomes after dual SCI/TBI.

The SCIREhab project, a multi-center investigation based in the USA^{12,13} included, as a first stage, the development of treatment taxonomies for each rehabilitation discipline, including speech-language pathology (SLP). The SLP taxonomy is comprised of eight activities delivered during individual or group sessions.¹⁴ In the second stage of SCIREhab, analyses were conducted to better understand the type and amount of interventions that are provided in inpatient rehabilitation. Brougham *et al.*¹⁵ reported a significant difference in time spent in each SLP activity among different neurological groups. There is, however, a paucity of evidence regarding what specific SLP interventions are most important to patients with cognitive-communication needs in order to achieve the best outcomes. The large sample size in the SCIREhab study and the use of a defined taxonomy of SLP interventions provide a unique opportunity to examine CCLs and relationships of SLP interventions to outcomes at rehabilitation discharge and 1-year post-injury for people with dual SCI/TBI.

This paper describes a group of patients admitted to the SCI units at six rehabilitation centers, the frequency of co-occurring TBI and CCLs, and the types and amount of treatment provided by the speech-language pathologist. In addition, it examines associations of SLP services, as well as patient characteristics (demographic and injury-related) with outcomes at discharge from inpatient rehabilitation and at 1-year post-injury for the SCIREhab primary sample and for a subsample of patients with co-occurring TBI and CCLs.

Methods

The practice-based evidence research methodology¹⁶⁻¹⁸ used in the SCIREhab study has been described previously and is summarized in the first article of this series.^{12,13,19,20}

Study sample and facilities

The SCIREhab project enrolled 1376 patients who were 12 years of age or older, and gave (or whose parent/guardian gave) informed consent. Patients were admitted to the SCI unit at one of six facilities (Craig Hospital, Englewood, CO; Shepherd Center, Atlanta, GA; Rehabilitation Institute of Chicago, Chicago, IL; Carolinas Rehabilitation, Charlotte, NC; The Mount Sinai Medical Center, New York, NY; and MedStar National Rehabilitation Hospital, Washington, DC) for initial rehabilitation following traumatic SCI, between the fall of 2007 and December 31, 2009.

Subsample analysis

A subsample of patients with acute SCI who were diagnosed with a TBI and who were rated as having CCLs on their admission FIM, was identified for subsample analysis and hereafter referred to as SCI/TBI + CCL. Patients were considered to have a TBI if, in their medical chart there was: (1) an ICD-9 code of 800-801.99, 803-804.99, 850-854.19, 873.0-873.1, 873.8-873.9, 905.0, 907.0, 959.01 or (2) notation of any reported loss of consciousness at time of or after the accident/injury or any reported brain injury complication, e.g. subarachnoid hemorrhage, cerebral contusion, concussion, that occurred prior to rehabilitation admission. Patients were considered to have a CCL, if their admission cognitive FIM score was <30, indicating that on at least one FIM cognitive subscale (comprehension, expression, social interaction, problem solving, or memory), the patient was rated as requiring at least coaching or cuing assistance.

Patient data

Patient demographic and injury data were abstracted from the patient medical record, either as part of the National Institute on Disability and Rehabilitation Research (NIDRR) SCI Model Systems Form I, which contains information on injury through community discharge, or in a database designed specifically for the SCIREhab study. The International Standards of Neurological classification of SCI (ISNCSCI) and its American Spinal Injury Association Impairment Scale (AIS)²¹ were used to describe the neurological level and completeness of injury; the FIM served to describe a patient's functional independence in motor and cognitive tasks at admission;²² and the

Comprehensive Severity Index (CSI®), which is a disease-specific measure to quantify the medical severity of the patient throughout the rehabilitation stay, provided a measure of illness severity.^{23,24} Body mass index (BMI) was categorized as obese (BMI ≥ 30) and not obese (BMI < 30).

SLP services

Speech-language pathologists documented detailed information about treatment provided during each SLP session (date/time, number of minutes spent on each intervention activity, and activity-specific details). Clinicians were trained in the use of the documentation system and entered data into handheld personal digital assistants after each encounter with a patient. The SLP treatment taxonomy has been described previously¹⁴ and includes activities commonly employed in an SCI rehabilitation setting: initial assessment, cognitive-communication treatment and the deficit addressed (orientation, attention, memory, organization/sequencing, processing speed, problem solving, pragmatics, safety/insight, and executive functioning), swallowing exercises (e.g. pharyngeal strengthening exercises, use of neuromuscular electrical stimulation), swallowing evaluations for oral-intake recommendations, communication treatment, motor speech and/or voice therapy (for patients with or without a tracheostomy and/or ventilator), and patient-family education.

Outcome data

Outcome measures were obtained at the time of rehabilitation discharge and at 1-year post-injury and are described in full in the first article in this SCIREhab series.¹⁹ Five outcomes thought to be relevant to patients with SCI/TBI or to SLP treatment goals were selected: two measures of cognitive status – cognitive FIM score at discharge and at 1-year post-injury; two measures of societal participation – CHART^{10,25,26} Social Integration and Occupation; and one measure of mood state as measured by the Patient Health Questionnaire – brief 9 question version (PHQ-9).²⁷ Cognitive FIM items include comprehension, expression, social interaction, problem solving, and memory. These were assessed by FIM-certified rehabilitation clinicians (nurses, occupational therapists, physical therapists, and speech language pathologists) based on their observations at the time of rehabilitation discharge and taken from medical record documentation. These FIM raters may or may not have been the primary care provider. The 1-year cognitive FIM was derived from respondent answers to survey questions about the same cognitive FIM items asked by

project-trained research interviewers. This information was used to supplement NIDRR SCI Model Systems data (cognitive FIM is not included on Form I for discharge or Form II for 1-year post-injury). All FIM data were Rasch transformed to convert discrete, ordinal FIM scores into scores on a continuous interval scale; this process is described in the Whiteneck article in this series.¹⁹ A Rasch-transformed cognitive FIM score ≤ 70 , equating to a raw cognitive FIM score of < 30 , was used to define CCL.

Data analysis: regression modeling

Linear regression modeling was used to predict outcomes at discharge and 1-year post-injury.²⁸ Three groups of independent variables were allowed to enter the stepwise regressions: (1) all patient demographic and injury characteristics described in Table 1, (2) treatment variables that included time spent in SLP activities and rehabilitation length of stay (LOS) (Table 2), and (3) rehabilitation center. The adjusted R^2 reduces the unadjusted R^2 to take into account the number of predictors in the model and 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 (no prediction) to 1 (perfect prediction); values that are closer to 1 indicate stronger models.

In each regression, the adjusted R^2 is reported first for the prediction of the outcome with only patient characteristics included as independent variables (step 1). Next, the same statistic is reported for the combination of treatment variables and patient characteristics (step 2). Finally, to determine the added impact of rehabilitation center effects, in step 3 dummy variables indicating the center where each patient was rehabilitated were added to the model (in addition to the treatment and patient variables) and the adjusted R^2 is reported. The change in the adjusted R^2 as the treatment variables and then the center variables are added indicates the strength of additional explanation contributed by these components. The P value associated with each significant predictor also is reported. Parameter estimates (based on the regressions including patient/injury and treatment variables, but not center) indicate the direction and strength of the association between each independent variable and the outcome. The semi-partial Omega R^2 indicates the proportion of the variance in the dependent variable that is associated uniquely with the predictor variable.

Results reported here are for 1032 patients in the primary analysis sample (75% of the full SCIREhab dataset of 1376 patients). The regression models were then tested using the validation subset, which contained

Table 1 Patient demographic and injury characteristics for SCIRehab primary sample and two subgroups

	SCI/TBI + CCL subgroup <i>n</i> = 248	All others <i>n</i> = 784	SCIRehab primary sample <i>n</i> = 1032
Neurological group (%)*			
C1–4, AIS A, B, C	37	26	29
C5–8, AIS A, B, C	19	20	20
Para, AIS A, B, C	32	37	36
AIS D	12	17	16
Age at injury-years, mean (SD)	38.0 (15.5)	37.5 (17.1)	37.7 (16.7)
Gender, % Male	81	81	81
Race* (%)			
White	73	70	71
Black	15	24	22
Hispanic	3	3	3
Other	9	4	5
Primary language, % English primary language	92	95	94
Primary payer* (%)			
Medicare	6	8	7
Medicaid	13	20	18
Private insurance/pay	66	63	64
Worker's compensation	16	9	11
Marital status at injury*, % married	44	36	38
Education level prior to injury (%)			
Less than high-school diploma	20	20	20
High-school diploma or GED	55	50	51
More than high-school diploma	24	25	25
Other/unknown	2	5	4
Occupation status at injury (%)			
Working	71	65	66
Student	14	15	15
Retired	5	8	8
Unemployed/other	10	12	11
Traumatic etiology (%)*			
Vehicular	65	44	49
Violence	2	14	11
Sports	6	12	11
Fall or falling object	27	25	25
Medical/surgical or other	0	5	4
Injury work related?* % no	82	87	86
Body mass index at admission, % <30	84	81	82
Admission motor FIM-Rasch transformed, mean (SD)*	15.2 (12.2)	18.6 (12.7)	17.8 (12.6)
Admission cognitive FIM – Rasch transformed, mean (SD)*	56.3 (9.8)	79.2 (16.6)	73.6 (18.1)
Comprehensive Severity Index (CSI), mean (SD)*	50.4 (36.0)	36.7 (29.4)	40.0 (31.6)
Days from injury to rehabilitation, mean (SD)*	34.9 (29.1)	29.8 (27.3)	31.0 (27.8)

*Indicates statistically significant differences between SCI/TBI + CCL and 'all other' subgroups at $P < 0.05$.

Table 2 Hours of SLP activities received, for SCIRehab primary sample and two subgroups

	SCI/TBI + CCL subgroup <i>n</i> = 248	All others <i>n</i> = 784	SCIRehab primary sample <i>n</i> = 1032
SLP activities	mean hours (SD)		
Assessment/evaluation***	1.0 (2.0)	0.4 (1.0)	0.5 (1.3)
Cognitive-communication interventions***	3.9 (7.4)	0.7 (3.1)	1.5 (4.7)
Communication interventions**	0.5 (3.0)	0.1 (1.7)	0.2 (2.1)
Education – patient and/or family***	0.4 (0.8)	0.1 (0.5)	0.2 (0.6)
Motor speech or voice disorder interventions	0.4 (1.7)	0.2 (2.4)	0.3 (2.3)
Tracheostomy-ventilator support interventions*	0.4 (1.6)	0.2 (1.1)	0.2 (1.3)
Swallowing – exercises	0.7 (3.1)	0.4 (3.6)	0.5 (3.5)
Swallowing – feeding trials	0.6 (2.0)	0.4 (1.9)	0.4 (2.0)
Interdisciplinary conferencing***	1.2 (1.7)	0.5 (1.6)	0.7 (1.7)

Difference between SCI/TBI + CCL and 'all other' subsamples statistically significant at: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

the remaining 25% of patients. The relative shrinkage of the R^2 for the original linear 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.²⁹ 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 . The SCI/TBI + CCL subsample analyses were not validated due to small sample sizes.

Results

Patients were assigned to one of four neurological injury groups (high cervical (1–4) AIS A, B, C; low cervical (C5–8) A, B, C; paraplegia (T1 and distal) A, B, C; and AIS D regardless of injury level). Forty-two percent ($n = 430$) were identified as having a co-occurring TBI (Fig. 1). The distribution of TBI was not significantly different between the neurological injury groups (Chi-square $P = 0.83$); C1–4 = 43%, C5–8 = 43%, paraplegia = 42%, and AIS D = 39%.

There were 473 patients identified as having a CCL (admission Rasch-transformed cognitive FIM score of ≤ 70 , which is the equivalent of a raw FIM score of <30). The subsample of 248 patients with both a TBI

and a CCL (SCI/TBI + CCL) was used for subsample analyses (Fig. 1). Excluded from the SCI/TBI + CCL subsample were 182 patients with SCI who were diagnosed with a TBI, but were not considered to have a cognitive limitation at the time of rehabilitation admission. Additionally, 225 individuals who were rated as having CCLs but without a diagnosed TBI (Fig. 1) were excluded because the etiology of the cognitive FIM limitation was unclear; it could have been due to chronic cognitive issues, medication effects, extent of physical disability, psychological disturbance, etc. In such cases, SLP would not typically be consulted.

Table 1 lists patient demographic and injury characteristics for the SCIREhab primary sample of 1032 (additional details are provided in the first article in this series¹⁹) and for two subsamples (with and without TBI + CCL). The SCI/TBI + CCL subsample has significantly more patients who are married but there are no significant differences by age, gender, primary language, educational level, or occupation status at the time of injury. Significant differences also are seen in etiology of injury (more injuries due to vehicular crashes and fewer due to violence, sports, or other causes), neurological grouping (more high tetraplegia, less paraplegia, and AIS D), race (fewer Black), and payer (more workers compensation and less Medicaid). Patients in this group also had a longer duration from injury to rehabilitation admission, higher

Figure 1 Venn diagram of patient subsamples.

Comprehensive Severity Index (CSI) (overall medical severity), and lower cognitive and motor FIM.

SLP services

Fig. 1 shows that 514 patients (50% of the SCIREhab primary sample) and 74% of the SCI/TBI + CCL subgroup received SLP services during inpatient rehabilitation. Table 2 displays the mean amount of time spent in each SLP activity for the SCIREhab primary sample and the subsamples with and without SCI/TBI + CCL. The most SLP time was spent on cognitive-communication intervention; significantly more time was spent with patients in the SCI/TBI + CCL subgroup than with patients without TBI + CCL. Significantly, more time also was spent on other SLP activities for this subgroup (assessment/evaluation, communication interventions, patient/family education, tracheostomy-ventilator support, and time spent by speech-language pathologists in interdisciplinary conferences planning for patient care).

Predicting cognitive FIM at discharge and 1-year post-injury

SCIREhab primary sample

Six patient characteristics explained 41% of the variance ($R^2 = 0.41$) in the discharge cognitive FIM (Table 3). Higher admission cognitive FIM, being married, and ventilator use at admission were associated with higher discharge cognitive FIM. More days from injury to rehabilitation admission, older age, and Black race (White is the reference group) were associated with lower scores. The R^2 increased to 0.45 with the addition of treatments. Longer LOS was associated with higher discharge cognitive FIM scores and more hours of SLP cognitive-communication intervention, education, and tracheostomy tube/ventilator support were associated with lower scores. Adding center variables increased the explained variance by 2% (to 47%). This regression model validated well (relative shrinkage <0.1).

At 1-year post-injury, four of the six significant patient predictors of cognitive FIM at discharge remained significant (higher admission cognitive FIM remained positive, while more days from injury to rehabilitation admission, older age, and being Black remained negative); in addition, being insured by Medicaid compared to private insurance was an additional significant negative predictor (Table 3). The amount of variance explained by these patient characteristics was only 16% and the addition of treatment variables increased the variance explained to only 17%. Longer rehabilitation LOS was positively

associated and amount of SLP education hours was negatively associated with 1-year cognitive FIM score; more time in motor speech and/or voice disorder interventions was an additional negative predictor. Adding center variables increased the variance explained to 18%. This regression model validated poorly (relative shrinkage >0.2).

SCI/TBI + CCL subsample

Patient characteristics accounted for 22% of the variance in the discharge cognitive FIM (Table 4). Higher admission motor and cognitive FIM were associated with higher discharge cognitive FIM; older age and longer duration from injury to rehabilitation admission were negatively correlated. Adding treatment variables to patient characteristics increased the explained variance by 16% (R^2 increased from 0.22 to 0.38). Rehabilitation length of stay provided the strongest unique contribution to the model; longer stays were associated with higher discharge cognitive FIM. More time spent in SLP cognitive-communication intervention was associated with lower scores. Adding rehabilitation center to the model improved the explained variance by another 3% (to 41%).

Patient and treatment variables were less predictive of cognitive FIM at 1-year post-injury than they were for cognitive FIM at rehabilitation discharge, explaining only 12% of the variance (Table 4). Higher admission cognitive FIM was associated with a higher score, while longer duration from injury to rehabilitation admission, and payers of Medicare, Medicaid, and worker's compensation (private insurance was reference group) had negative associations. There were no significant SLP treatment variables and center variables increased the explained variance by only 2%.

Predicting societal participation at 1-year post-injury

SCIREhab primary sample

Regression models were conducted for two measures of societal participation at 1-year post-injury; the CHART Social Integration and Occupation subscales (Table 5). For CHART Social Integration, patient characteristics explained only 12% of the variance, and only one SLP treatment (cognitive-communication intervention) was significant (negatively related), which only increased the variance explained to 13%. The addition of center variables increased the variance explained to 14%. This regression model validated well (relative shrinkage <0.1).

For the CHART Occupation subscale, patient characteristics explained 24% of the variance. Injury group

Table 3 Prediction of cognitive FIM* at discharge and 1-year post-injury for SCIR rehab primary sample ($n = 1032$)

Cognitive FIM* at discharge				Cognitive FIM* at 1 year		
	Parameter estimate	P value	Semi-partial Omega ²	Parameter estimate	P value	Semi- partial Omega ²
Observations used	1031			927		
Step 1: Pt characteristics: adj. R^2	0.41			0.16		
Step 2: Pt characteristics + treatments: adj. R^2	0.45			0.17		
Step 3: Pt characteristics + treatments + center identity: adj. R^2	0.47			0.18		
Independent variables**						
Ventilator use at rehabilitation admission (no is reference)	3.308	0.026	0.002			
Admission FIM cognitive*	0.456	<0.001	0.232	0.165	<0.001	0.076
Days from trauma to rehabilitation admission	-0.086	<0.001	0.023	-0.031	0.008	0.006
Age at injury	-0.139	<0.001	0.017	-0.081	<0.001	0.012
Marital status is married	1.943	0.019	0.002			
Race	-	0.037	0.003	-	0.022	0.006
Black	-2.215	0.011	-	-1.727	0.021	-
Hispanic	-3.500	0.093	-	1.035	0.587	-
All other minorities	-0.587	0.726	-	2.396	0.095	-
White (reference)	0.000	-	-	0.000	-	-
Primary payer				-	0.011	0.007
Medicare				-1.063	0.448	-
Medicaid				-2.428	0.003	-
Worker's compensation				-1.925	0.054	-
Private insurance/pay (reference)				0.000	-	-
Rehabilitation length of stay	0.072	<0.001	0.022	0.019	0.042	0.003
SLP hours of specific treatments:						
Cognitive-communication intervention	-0.401	<0.001	0.013			
Education	-2.290	0.002	0.005	-1.968	0.001	0.009
Motor speech and/or voice disorder intervention				-0.393	0.002	0.008
Tracheostomy tube and/or ventilator support intervention	-0.950	0.002	0.004			

*Cognitive FIM was 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 either of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.

Table 4 Prediction of cognitive FIM* at discharge and 1-year post-injury for SCI/TBI + CCL subgroup (n = 248)

Outcome	Cognitive FIM* at discharge			Cognitive FIM* at 1 year		
Observations used	248			215		
Step 1: Pt characteristics: adj. R^2	0.22			0.12		
Step 2: Pt characteristics + treatments: adj. R^2	0.38			0.12		
Step 3: Pt characteristics + treatments + center identity: adj. R^2	0.41			0.14		
Independent variables**	Parameter estimate	P value	Semi-partial Omega ²	Parameter estimate	P value	Semi-partial Omega ²
Admission FIM motor*	0.204	0.013	0.013			
Admission FIM cognitive*	0.596	<0.001	0.097	0.226	0.003	0.032
Days from trauma to rehabilitation admission	-0.167	<0.001	0.081	-0.092	0.001	0.046
Age at injury	-0.117	0.037	0.009			
Primary payer						
Medicare				-9.472	0.009	-
Medicaid				-5.418	0.017	-
Worker's compensation				-4.799	0.024	-
Private insurance/pay (reference)				0.000	-	-
Rehabilitation length of stay	0.197	<0.001	0.136			
SLP cognitive-communication intervention hours	-0.492	<0.001	0.039			

*Cognitive and motor 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 either of the outcomes in this table; a blank cell means that the variable was not a significant predictor for the outcome examined.

C1-4 ABC (AIS D was the reference), longer time from trauma to rehabilitation admission, traumatic etiologies of violence or falls (vehicular was the reference), older age, and male gender were associated with a lower score; being married, higher admission motor FIM, student status prior to injury, college education, and English as the primary language were associated with a higher score. More time spent in cognitive-communication intervention hours was associated positively and increased the variance explained to 25%. Adding center variables increased the explained variance to 27%. This regression model validated moderately well (relative shrinkage 0.1-0.2).

SCI/TBI + CCL subsample

Patient characteristics and treatments explained relatively little variance (9%) for the CHART dimension of Social Integration (Table 6). Younger age and being married were associated with higher Social Integration scores. Patient characteristics were somewhat stronger predictors for Occupation (20%); a C 1-4 AIS ABC injury was associated with a lower score compared to patients with AIS D (reference group); student status prior to injury (working is reference) and higher admission motor FIM were associated with higher scores. No SLP treatment variables were significant in either model. There was no increase in predictive power by adding center variables and in fact, when additional variables were added, the adjusted R^2 decreased in both models.

Predicting Mood at 1-year post-injury

SCIRehab primary sample

Weak relationships were found with mood state as measured by the PHQ-9 (Table 5). Patient characteristics explained only 7% of the variance and treatment variables only increased the explained variance to 8%. Only one treatment variable was significant – more SLP time providing tracheostomy tube/ventilator support interventions was associated with higher scores (more depressive symptoms). The addition of center variables did not add to the variance explained. The model for PHQ-9 validated poorly (relative shrinkage >0.2).

SCI/TBI + CCL subsample

Patient and treatment variables were not strong predictors of mood state at 1-year post-injury, explaining only 11% of the variance (Table 6). Being unemployed at time of injury (working is reference), and the injury being work related were associated with a higher PHQ-9, indicating more depressive symptoms, while being obese was associated with a lower score (less depressive symptoms). More time spent in SLP communication intervention also was associated with a higher score.

Cognitive FIM ratings for patients with SCI/TBI + CCL who received SLP interventions

Of the 248 patients in the SCI/TBI + CCL subsample, 124 (50%) received SLP interventions. Regression model associations for this subset of 124 patients (data

Table 5 Prediction of CHART Social Integration and Occupation and Mood State (PHQ-9) for SCIR rehab primary sample (n = 1032)

Outcome:	CHART: Social Integration			CHART: Occupation			PHQ-9		
Observations used		830			845			809	
Step 1: Pt characteristics: adj. R^2		0.12			0.24			0.07	
Step 2: Pt characteristics + treatments: adj. R^2		0.13			0.25			0.08	
Step 3: Pt characteristics + treatments + center identity: adj. R^2		0.14			0.27			0.08	
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
Neurological group				–	0.017	0.007			
C1–4 ABC				–13.443	0.005	–			
C5–8 ABC				–4.734	0.285	–			
Para ABC				–5.901	0.108	–			
All Ds (Reference)				0.000	–	–			
Admission FIM motor – Rasch transformed	0.178	0.001	0.010	0.880	<0.001	0.033			
Days from trauma to rehabilitation admission				–0.115	0.007	0.006	0.022	<0.001	0.015
Traumatic etiology				–	0.019	0.007			
Medical/surgical/other				–9.970	0.112				
Violence				–9.893	0.015				
Sports				2.960	0.464				
Fall				–6.118	0.043				
Vehicular (Reference)				0.000	–				
Age at injury	–0.306	<0.001	0.025	–0.435	<0.001	0.014	0.034	0.016	0.006
Gender is male				–9.104	0.002	0.007	–1.020	0.022	0.005
Marital status is married	8.101	<0.001	0.025	8.142	0.003	0.007			
Race	–	0.023	0.007						
All other minorities	0.161	0.959	–						
Black	–4.640	0.007	–						
Hispanic	–7.488	0.088	–						
White (Reference)	0.000	–	–						
Occupational status at injury	–	<0.001	0.023	–	0.020	0.006	–	0.001	0.017
Unemployed/other	–6.646	0.005	–	–2.046	0.603	–	1.810	0.003	–
Student	1.793	0.447	–	10.577	0.008	–	–0.874	0.136	–
Retired	10.752	0.001	–	–8.568	0.097	–	–1.037	0.183	–
Working (Reference)	0.000	–	–	0.000	–	–	0.000	–	–
Highest education achieved	–	0.005	0.009	–	0.000	0.020	–	0.033	0.006
High school	1.486	0.438	–	4.825	0.140	–	–0.964	0.045	–
College	6.292	0.005	–	16.624	<0.001	–	–1.443	0.009	–
<12 years/other/unknown (Reference)	0.000	–	–	0.000	–	–	0.000	–	–
Injury is work related			–			–	1.211	0.017	–
BMI ≥ 30							–1.719	<0.001	0.015
Primary language is English				13.461	0.010	0.005			
Primary payer	–	0.019	0.007						
Medicare	–5.453	0.102							
Medicaid	–5.477	0.005							
Worker's compensation	–0.870	0.707							
Private insurance/pay (Reference)	0.000	–	–						
SLP cognitive-communication intervention hours	–0.367	0.011	0.006	0.548	0.026	0.004			
SLP tracheostomy tube and/or ventilator support intervention hours							0.322	0.022	0.005

*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.

Table 6 Prediction of CHART social integration and occupation and mood state (PHQ-9) for SCI/TBI + CCL subgroup (n = 248)

Outcome:	CHART: Social Integration			CHART: Occupation			PHQ-9		
Observations used	199			204			195		
Step 1: Pt characteristics: adj. R^2	0.09			0.20			0.09		
Step 2: Pt characteristics + treatments: adj. R^2	0.09			0.20			0.11		
Step 3: Pt characteristics + treatments + center identity: adj. R^2	0.08			0.18			0.10		
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
Neurological group				–	0.020	0.028			
C1–4 ABC				–29.336	0.003	–			
C5–8 ABC				–11.828	0.208	–			
Para ABC				–12.625	0.126	–			
All Ds (reference)				0.000	–	–			
Admission FIM motor – Rasch transformed				0.693	0.026	0.016			
Age at injury	–0.459	<0.001	0.067						
Marital status is married	14.804	<0.001	0.076						
Occupational status at injury				–	0.018	0.029	–	0.002	0.055
Unemployed/other				–10.230	0.221	–	4.22	<0.001	–
Student				20.772	0.007	–	–0.216	0.838	–
Retired				–5.647	0.644	–	–0.172	0.914	–
Working (reference)				0.000	–	–	0.000	–	–
Injury is work related							2.026	0.023	0.020
BMI ≥ 30							–2.514	0.006	0.031
SLP communication intervention hours							0.314	0.018	0.022

*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.

not reported in tables) were similar to those for the SCI/TBI + CCL (248 patients). Patient characteristics accounted for 25% of the variance in the discharge cognitive FIM. Higher admission cognitive FIM was associated with higher discharge cognitive FIM, while older age and longer duration from injury to rehabilitation admission were negatively correlated. Adding treatment variables to patient characteristics increased the explained variance by 14% (R^2 increased from 0.25 to 0.39). Rehabilitation length of stay provided the strongest unique contribution to the model; longer stays were associated with higher discharge cognitive FIM. More time spent in SLP cognitive-communication intervention and in SLP tracheostomy tube and/or ventilator support intervention was associated with lower scores. Adding rehabilitation center to the model improved the explained variance by another 2% (to 37%). At 1-year post-injury, patient characteristics explained 13% of the variance of cognitive FIM. Higher admission cognitive FIM was associated with a higher score, while longer duration from injury to rehabilitation admission had a negative association. The addition of treatment variables increased explained variance by another 8% (to 21%). SLP tracheostomy tube and/or ventilator support intervention was again negatively associated with 1-year cognitive FIM. Patient characteristics

explained 11% of CHART Social Integration and PHQ-9, and 15% of the variance in CHART Occupation scores. Adding treatment factors increased explained variance of CHART Social Integration and Occupation by 4%, and did not contribute any additional explained variance to PHQ-9.

Cognitive FIM change for patients with SCI/TBI + CCL who received SLP cognitive-communication intervention

When stratified by discreet admission cognitive FIM categories based on Rasch-transformed scores (Table 7), patients with minimal CCLs (cognitive FIM 60–70) received 3.7 hours of cognitive-communication intervention and had a positive FIM change of 17 points from rehabilitation admission to discharge. Those in the cognitive FIM 50–59 group received two and a half times the number of SLP cognitive-communication intervention hours (9.4 hours) as the minimal limitation group and also improved 17 points. Those with most severe admission CCLs (cognitive FIM ≤49) received almost three times the cognitive-communication intervention hours (10.8 hours) as the FIM 60–70 group and a little more than the FIM 50–59 group. This group exhibited the largest cognitive FIM improvement from admission to discharge (24.1

Table 7 SCI/TBI + CCL subsample who received SLP cognitive-communication interventions stratified by admission cognitive FIM score* (mean (SD)), N = 124

Admission cognitive FIM* Group	N	Admit cognitive FIM*	Cognitive intervention hours (SD)	DC cognitive FIM*	1-year cognitive FIM*
60–70	42	65.0 (3.2)	3.7 (4.4)	82.0 (12.7)	94.7 (8.8)
50–59	49	54.0 (2.4)	9.4 (7.5)	70.5 (10.0)	93.2 (11.0)
≤49	33	41.4 (5.4)	10.8 (12.0)	65.5 (16.0)	86.1 (12.7)

*All FIM data were Rasch transformed.

points), but continued to exhibit CCLs at discharge (cognitive FIM of 65.5). The SLP cognitive-communication interventions that the patients with FIM scores ≤ 70 received were diverse and overlapping: 44% of patients participated in sessions focused on memory, 33% on problem-solving/reasoning, 27% on attention, 23% on executive functioning, 22% on processing speed, 21% on organization/sequencing, 15% on safety/insight, 13% on orientation, and 5% on pragmatics interventions.

At 1-year post-injury, all cognitive FIM groups exhibited improvements in cognitive FIM and had a score > 70 (as derived from participant interview) compared to the cognitive FIM score at rehabilitation discharge.

Discussion

Not all patients with SCI need or receive SLP services during inpatient rehabilitation. Speech-language pathologists often are consulted to evaluate and treat swallowing, motor speech-voicing, and cognitive-communication functions.^{14,15} It can be particularly challenging to differentiate the type and severity of CCLs and to identify and adapt appropriate cognitive-communication interventions for individuals with SCI. Fig. 1 highlights the difficulty with diagnosing cognitive impairment and delivering appropriate SLP treatment in acute SCI; three seemingly related subgroups of CCL, TBI, and SLP intervention have only an 18% overlap. While 42% of the SCIREhab primary sample was identified as having a TBI, only 58% of this group was rated as having CCLs at admission. It is possible that many of the co-occurring TBIs were of mild severity and had resolved by the time of rehabilitation admission, which is consistent with another study reporting that the majority of co-occurring TBI in acute SCI are in the mild range of severity.⁷

Conversely, while 46% of the SCIREhab primary sample was rated as having CCLs on FIM at admission to rehabilitation, only 52% was also identified as having a co-occurring TBI. TBI may have been under diagnosed; however, it is also possible that factors other than TBI affected cognitive functioning such as general trauma, medications, pain, hypoxia, sleep

disturbance, emotional distress, and/or pre-existing cognitive dysfunction. Physical disability may also affect admission cognitive FIM ratings by preventing the individual from being able to demonstrate or verbalize his/her full cognitive capacity. For example, patients who were on mechanical ventilation and who were unable to vocalize may have had lower cognitive FIM ratings due to the patient's inability to communicate effectively. In such cases, significant improvements would likely occur when the patient was again able to communicate, even though cognitive functioning may not have changed. Indeed, regression modeling found mechanical ventilation at the time of rehabilitation admission to be positively associated with higher cognitive FIM at discharge for the SCIREhab primary sample, but not for patients in the SCI/TBI + CCL subsample. Thus, patients without brain injuries and cognitive communication limitations who are on mechanical ventilation are likely to be scored higher on cognitive FIM once the patient is able to vocalize or ventilation is no longer needed.

Fig. 1 also shows that only 70% of patients with CCLs and only 58% of patients with TBI received SLP services during inpatient rehabilitation. It is understandable that a patient with SCI and co-occurring TBI who experienced rapid recovery from the TBI would not need or be referred for SLP services. The reasons that patients with observed CCLs at rehabilitation admission were not referred for SLP services are not clear, especially for the 45% of patients who also had a TBI.

In regression models for the SCIREhab primary sample there were several weak negative and positive associations of SLP interventions with the outcome measures, but treatment contributed little explanatory power beyond that provided by patient characteristics: 1–4% for discharge cognitive FIM, and 1% for social participation and mood state at 1-year post-injury. The influence of SLP treatments increased when the sample of patients became more homogeneous in the SCI/TBI + CCL subsample. The explained variance for discharge cognitive FIM increased by 16% when SLP services were added to patient characteristics, but the only significant treatment predictor was a negative

relationship with SLP cognitive-communication intervention. It may be that patients with more severe initial CCLs have greater need for intervention and, thus, receive more treatment. Indeed, patients with TBI and the lowest admission cognitive FIM ratings (most severe group with FIM ≤ 49) received the most SLP services for cognition intervention and showed the greatest gain in FIM score from admission to discharge. However, despite the greatest gain in cognitive FIM from admission to discharge, this group's discharge and 1-year post-injury cognitive FIM scores were lower than the for patients with higher admission cognitive scores.

In an era with shortened lengths of stay for inpatient rehabilitation post-SCI³⁰ our results show that length of stay is significantly and positively associated with discharge cognitive FIM, and that it is the strongest predictor of discharge cognitive FIM for the SCI/TBI + CCL subsample. This is an important consideration for acute SCI rehabilitation programming. Patients need to learn essential rehabilitation skills to prepare them to function effectively beyond the hospital setting. For such patients, CCLs may interfere with efficient acquisition of skills required for maximal independence (e.g. transfers, managing curbs, etc.) and/or for self-directing care; consequently, longer lengths of stay may be required for information to be acquired, practiced, and mastered. SLP interventions may help to develop compensatory strategies that are needed to acquire new information, thereby augmenting the acquisition of essential rehabilitation skills taught in nursing care, and physical and occupational therapies.

Limitations

The participating rehabilitation centers are not a probability sample of the rehabilitation facilities that provide care for patients with SCI in the United States and may not generalize to all rehabilitation centers. They include some of the largest SCI rehabilitation programs in the USA and serve patients with diverse clinical and demographic characteristics. Some SCIREhab centers have dedicated dual-SCI/TBI programs, some admit patients with dual-SCI/TBI to TBI programs (may depend on the severity of the TBI), and others admit them to SCI programs. The analysis provided in this study focused only on those patients with SCI/TBI who were treated in SCI rehabilitation programs, and thus, excluded those who were treated on TBI services.

Use of the cognitive FIM to identify CCLs associated with TBI may not have been adequately sensitive to identify all cognitive impairment associated with TBI

secondary to ceiling effects,³¹ thereby underestimating the extent of cognitive impairment. It is important to note that objective testing of language and cognitive abilities typically is included in an SLP assessment of patients with SCI/TBI, but the assessments were not standardized across centers. Thus, while the cognitive FIM may be a less sensitive measure of cognitive status,^{32,33} it was used as a standard at the six SCIREhab centers.

Physician referral patterns for SLP services vary within and across centers, influencing the receipt of SLP services for study patients. The taxonomy and data collection system used to document SLP interventions was developed for this study. While it is comprehensive, it has not been used or validated in other studies. While the service data captures time spent in various SLP activities/interventions, it lacks sufficient specificity to differentiate time spent on specific cognitive-communication interventions such as attention, memory, problem solving, etc.

Conclusions

Patients with SCI who also have TBI and thus, the greatest need for interventions to address CCLs, appear to receive more cognitive-communication SLP treatment and show the greatest amount of improvement from admission to discharge in cognitive FIM, but CCLs are not fully resolved by discharge. This phenomenon likely accounts for the consistent finding that more hours of SLP cognitive-communication treatment is associated with lower cognitive FIM scores at discharge. Future research on individuals with the dual diagnosis of SCI and TBI should include more comprehensive assessment of individual differences in cognitive-communication performance in order to better examine the complex relationships between SLP treatments and outcomes.

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