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ORIGINAL RESEARCH

Cognitive and Motor Recovery and Predictors of Long-Term Outcome in Patients With Traumatic Brain Injury

Check for updates

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Abstract

Objectives: To explore the patterns of cognitive and motor recovery at 4 time points from admission to 9 months after discharge from inpatient rehabilitation (IR) and to investigate the association of therapeutic factors and conditions before and after discharge with long-term outcomes.

Design: Secondary analysis of traumatic brain injury (TBI) and practice-based evidence dataset.

Setting: IR in Ontario, Canada.

Participants: Patients with TBI consecutively admitted for IR between 2008 and 2011 who had data available from admission to 9 months after discharge (N=85).

Interventions: Not applicable.

Main Outcome Measure: FIM-Rasch cognitive and motor scores at admission, discharge, 3 months after discharge, and 9 months after discharge.

Results: Cognitive and motor recovery showed similar patterns of improvement with recovery up to 3 months but no significant change from 3 to 9 months. Having fewer postdischarge health conditions was associated with better long-term cognitive scores (95% confidence interval, -13.06 to -1.2) and added 9.9% to the explanatory power of the model. More therapy time in complex occupational therapy activities (95% confidence interval, .02 to .09) and fewer postdischarge health conditions (95% confidence interval, -19.5 to -3.8) were significant predictors of better long-term motor function and added 14.3% and 7.2% to the explanatory power of the model, respectively.

Conclusion: Results of this study inform health care providers about the influence of the timing of IR on cognitive and motor recovery. In addition, it underlines the importance of making patients and families aware of residual health conditions following discharge from IR.

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Traumatic brain injury (TBI) is a critical public health problem globally and is projected to remain the major cause of disability from neurologic disease until 2031.[1] Long-lasting disability following TBI continues to be challenging for patients, families, and clinicians[2,3] and imposes significant financial burden on health care systems.[4,5] Thus, improving cognitive and motor recovery following inpatient rehabilitation (IR) and maintaining the long-term effect of IR are important to patients, families, and the care team.

The course of functional recovery has been studied widely in patients with moderate to severe TBI. While few studies have focused on early recovery,[6-15] others have investigated a change in function over a longer period after TBI.[14,16-26] Studies that focused on the first year postinjury have shown that most cognitive and motor recovery is reached within 5 to 6 months postinjury, while patients do not show significant functional improvement

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over the latter part of the first year.[6,9,13,14,27-29] Some studies have noted that cognitive function reached a plateau after 1-year postinjury.[20,24,30,31] The majority of patients were assessed at 2 time points within the first year postinjury.[6-8] This has made it difficult to compare changes in function between various time points over longer periods.[9,32] Moreover, these studies did not include patients' data from IR admission to follow-up, which may introduce selection or attrition bias.[33] Thus, knowledge of the timing of functional recovery at 4 time points from admission to 1 year after IR injury will be particularly useful for practitioners to provide appropriate treatments at the right time.

It is also important to consider factors that may influence cognitive and motor function after rehabilitation discharge. Most studies have investigated predictors of longer-term follow-up from 2 to 30 years postinjury.[14,15,18] However, Till[30] and Ruff[34] and colleagues pointed out the importance of examining predictors of function in patients who are in the chronic stages of TBI earlier than 1 year postinjury to identify risks of functional decline after rehabilitation in this population. Literature indicates that studies of predictors of long-term outcomes following TBI fall broadly in 2 major categories: (1) preinjury and demographic characteristics and (2) clinical features. Their findings showed that younger age,[10,11] higher education,[11] white race,[12] shorter posttraumatic amnesia,[12,35] having insurance coverage,[12,30] fewer number of comorbidities,[11,12] and fewer days from injury to IR admission[11,12] were associated with better cognitive function. With respect to better motor function, these determinants included younger age,[10,12] sex (male),[11,23] white race,[12] having insurance coverage,[11,12] fewer comorbidities,[11,23] lack of open head injury,[12] shorter time from injury to IR admission,[11,12,23] and accessing home support services or home modification.[23] Few studies examined the association of time spent in activities by level of complexity with long-term outcomes.[11] Information on complexity of activities could assist clinicians in goal setting and understanding the therapeutic value of activities. Patients' participation in therapy session also was found to be another important factor in the process of rehabilitation. However, few studies have explored the association of these factors with long-term outcomes[11,36-38] and none of them have focused on a Canadian environment. Results of a study on patients from the United States found that adding time spent on activities and level of effort (LOE) to baseline factors resulted in 29% and 8% additional explanatory power in the variation of cognitive and motor scores, respectively.[11] Existing data has shown that health care delivery models are varied between Canada, the United States, and other developed countries (eg, Medicare 3-hour rule in the United States for IR).[32,39-41] The Canadian health care system operates within a national legislative framework through the Canada Health Act. In Canada, responsibilities for the health care system are shared between federal, provincial, and territorial governments.[42] The primary health care system is a tax-based public insurance that covers all medically necessary hospital services, diagnostics, and physician services free of charge for eligible Canadians (eg, IR). Also, outpatient rehabilitation, for example, physical therapy (PT) and occupational therapy (OT), is largely financed through supplemental private health insurance such as workers' compensation and auto insurance.[42] Health care in the United States is multilayered and includes both public and private insurance, which is not structured based on a single nationwide health care system approach. Thus, only patients with appropriate insurance coverage may have benefits to cover postacute care in the United States.[39] Moreover, differences in the practice framework of rehabilitation disciplines (eg, OT) between Canada and the United States, underlines the importance of further exploration of the contribution of therapeutic factors and patient engagement to explain functional outcome variation in a Canadian population with TBI.[43,44] Evidence has shown that the prevalence of long-term mental and physical deficits is very high following TBI and these factors may contribute to difficulties in community reintegration and lower quality of life in this population.[45,46]

Our hypotheses for this study were that (1) IR gains are maintained from discharge to 3 months after IR discharge for both cognitive and motor scores which may not continue from 3 to 9 months after IR discharge and (2) more complex activities and fewer postdischarge comorbid conditions are associated with better cognitive and motor scores at 9 months after IR discharge.

List of abbreviations:

ANOVA	**analysis of variance**
CSI	**comprehensive severity index**
ED	**emergency department**
IR	**inpatient rehabilitation**
LOE	**level of effort**
LOS	**length of stay**
OT	**occupational therapy**
PBE	**practice-based evidence**
PT	**physical therapy**
TBI	**traumatic brain injury**

Methods

Data source and population

This study is a secondary analysis of the TBI practice-based evidence (PBE) multicenter dataset[47] with a total sample of 2120 patients with a primary diagnosis of TBI who were consecutively admitted to 10 IR facilities; 1 in Canada (n=149) and 9 in the United States (n=1971) between 2008 and 2011. Follow-up data were gathered through telephone interviews from patients or their caregivers at 3 and 9 months after discharge by trained researchers and practitioners. Evidence of valid use of the postdischarge instrument via telephone interview has been reported for patients with neurologic disorders in IR.[48] The complete explanation of the study methodology and validity and reliability of collected data is published elsewhere.[47] For this study, patients who were treated at Toronto Rehabilitation Institute and had data available at all 4 time points of admission, discharge, and 3 and 9 months after discharge were included in the analyses (N=85). This largest rehabilitation facility in Canada was employed, one that offers IR programs for patients with different diagnoses such as brain and spinal cord injuries, and musculoskeletal disabilities. This study was approved by the research ethics board of Toronto Rehabilitation Institute.

A total of 149 Canadian patients were enrolled in this study with 65.8% (n=98) and 63.8% (n=95) participating in a follow-up interview at 3 and 9 months after discharge, respectively. Comparing baseline characteristics between participating patients and patients who were lost to follow-up at 2 time points showed that participating patients were significantly more likely to be younger and had higher admission and discharge cognitive scores and more discharge motor scores than patients who were lost to follow-up (supplemental table S1, available online only at http://www.archives-pmr.org/). It should be noted that the *t* test or Mann-Whitney *U* test was used for comparing baseline variables considering the distribution of data.

Variables

Demographic characteristics included age, sex, educational, and employment status. Clinical features included mechanism of injury, days from injury to rehabilitation admission, and rehabilitation length of stay (LOS). Injury severity at the time of injury was measured by the Glasgow Coma Score. Comorbidities and severity of illness at IR admission were measured by the comprehensive severity index (CSI),[a] which defines severity as both physiological and psychological complexity. CSI has been validated in various IR and long-term care studies and was used previously in studies on populations with TBI.[10,49] Additionally, the availability of insurance through a secondary payer system was reported as a proxy of accessibility to outpatient rehabilitation based on the type of insurance coverage (eg, private, work-related compensation). Postdischarge clinical features included a list of 22 health issues for both physical and mental health conditions in which patients received medical attention postdischarge, number of referrals to emergency department (ED), and patient living situation after IR discharge (appendix 1).

Therapeutic factors in IR included time spent in therapeutic activities and average of LOE during OT and PT sessions. In addition to total therapy time spent in OT and PT, activities in each discipline were stratified into basic and advanced groups based on the functional abilities (appendix 2). To calculate time spent in activities in each discipline per week, the total minutes of therapy activities were divided by rehabilitation LOS/7days. No distinction was made between services provided on weekends and weekdays. Due to a significant amount of missing data in speech language pathology and psychology activities, data from these 2 disciplines were not included in the analysis. The LOE was measured using the Rehabilitation Intensity of Therapy Scale, which includes 60 goal-directed activities scored weekly with a single-item, 7-point scale.[50] Effort is defined as the physical and mental energy of patients within the therapy context including initiating activity, incorporating therapist feedback, and persevering when therapies become challenging.[50,51]

Outcome measures

The main outcome measures were Rasch-adjusted cognitive and motor components of the FIM at admission, discharge, and 3 and 9 months after discharge from the IR facility.[52] The FIM-Rasch ranged from 0 to 100 points to provide an interval level metric for both cognitive and motor scores and to address measurement error associated with summing of ordinal-level scores.[53]

Statistical analysis

All analyses were performed using SAS 9.4.[b] Descriptive results were reported using mean and SD or median and interquartile range for continuous variables and frequency of categorical variables. To investigate the functional score changes over time, multiple comparisons were performed between 4 time points using repeated measures analysis of variance (ANOVA). In the case of significant ANOVA results, a Bonferroni adjustment was used for pairwise multiple comparisons of means to determine significant differences of FIM-Rasch scores between each pair of time points.

For the second hypothesis, univariate linear regression was conducted to identify factors that had a significant association with outcome measures at 9 months after discharge. Multivariable linear regression was used to examine the independent association of therapeutic and postdischarge factors with long-term functional outcomes. Demographic and clinical factors were entered first as the known confounding variables to the model and therapeutic factors and postdischarge variables were entered in the last step regardless of their significance value, as target variables. Confounding factors (demographic and clinical features) were chosen based on potential clinical relevance, availability of variables in the dataset, results of univariate regression, and results of previous studies.[10,54,55]

Multicollinearity was examined using the variance inflation factor >10. In the case of multicollinearity, one of a pair of variables was removed from the regression (eg, admission or discharge cognitive and motor FIM-Rasch scores) or if possible, 2 variables were combined (ie, time spent in activities and rehabilitation LOS combined as minutes per rehabilitation LOS/7 days). Where possible, missing data were reported as a separate category for categorical variables and the final sample size was reported for each model. Values of R^2 and adjusted R^2 were used to capture variation in outcome measures that were accounted for by the predictors in a linear regression. Also, R^2 change and F-change were calculated to differentiate the contribution of adding demographic, clinical, therapeutic, and postdischarge variables to the model. A P value of $<.05$ with 95% confidence interval was considered statistically significant.

Results

Functional recovery

The descriptive analysis results on all variables are reported in table 1. Results of repeated measures ANOVA and Bonferroni test revealed that most of the improvement on cognitive and motor scores occurred from IR admission to discharge with some additional gains on cognitive scores from discharge to 3 months. However, no significant changes were observed after IR discharge for motor scores and 3 months after discharge for cognitive scores (table 2). Also, exploratory analysis of the ceiling effects in FIM-Rasch cognitive and motor scores of 100 revealed that patients did not show a ceiling effect in admission cognitive and motor scores. However, the percentages of patients with a ceiling of 100 in cognitive scores from discharge to 9 months after discharge were between 1.1 and 9.4 and in motor scores were between 5.5 and 14.1 for the same period (supplemental table S2, available online only at http://www.archives-pmr.org/).

Predictors of cognitive and motor function at 9 months after discharge

Demographic and clinical characteristics together explained 16.5% and 23.5% of the variation in cognitive and motor scores at 9 months after discharge, respectively (table 3). Adding LOE did

Table 1 Demographic and clinical characteristics of those patients who had data available on FIM at 4 periods of time from admission to 9 months after discharge

N=85	Mean ± SD, Median (IQR), n (%)
Age at admission, mean ± SD (y)	44.2±18.3
Sex (male), n (%)	62 (72.9)
Education, n (%)	
Bachelor and higher degree	20 (23.5)
Associate and lower degree	64 (75.3)
Unknown	1 (1.2)
Employment status, n (%)	
Employed	51 (60.0)
Not employed/retired	28 (32.9)
Student	6 (7.1)
Clinical features	
Cause of injury, n (%)	
MVCs	45 (52.9)
Fall	31 (36.5)
Other	9 (10.6)
GCS category, n (%)	
Intubated/severe	47 (55.3)
Moderate	17 (20.0)
Mild	15 (17.6)
Unknown	6 (7.1)
Days from injury to admission to IR, median (IQR)	48 (54)
Rehabilitation LOS, mean ± SD (d)	43.6±19.9
Admission Comprehensive Severity Index, mean ± SD	22.9 (13.6)
Secondary insurance payer, n (%)	
Private, work compensate or no-fault auto	23 (27.1)
None	11 (12.9)
Unknown	51 (60.0)
Therapeutic variables	
OT PT LOE, mean ± SD	4.6±1.1
OT and PT total min/wk, median (IQR)	489.4 (299.8)
OT basic activity total min/wk, median (IQR)	12.82 (28.6)
OT advanced activity total min/wk, median (IQR)	164.2 (123.3)
PT basic activity total min/wk, median (IQR)	5.9 (18.9)
PT advanced activity total min/wk, median (IQR)	162.4 (104.6)
Postdischarge conditions, n (%)	
Number of health issues postdischarge (≥1 issue)	41 (48.2)
Living situation postdischarge (not alone)	40 (47.5)
Number of referral to ED (≥2 times)	14 (16.5)
Outcomes, mean ± SD	
Admission FIM cognitive score	23.1±5.0
Discharge FIM cognitive score	28.4±4.5
Admission FIM motor score	70.8±18.1
Discharge FIM motor score	84.3±10.8
Admission total score	93.9±20.8
Discharge total score	112.8±13.5
Admission FIM-Rasch cognitive score	56.2±9.6
Discharge FIM-Rasch cognitive score	68.7±11.7
FIM-Rasch cognitive score 3 months after discharge	75.6±15.4
FIM-Rasch cognitive score 9 months after discharge	73.4±14.5
Admission FIM-Rasch motor score	63.3±15.4
Discharge FIM-Rasch motor score	81.5±16.3
FIM-Rasch motor score 3 months after discharge	83.7±16.0
FIM-Rasch motor score 9 months after discharge	83.1±16.0

(*continued on next column*)

Abbreviations: GCS, Glasgow Coma Scale; IQR, interquartile range; MVC, motor vehicle collision.

not make a significant contribution to the amount of variation in cognitive and motor scores. The therapy time spent in basic and complex activities explained 14.3% additional variation in motor scores but did not make a significant difference in cognitive scores (2.7%). Adding postdischarge conditions to the model explained a significant variation in cognitive (9.9%) and motor (7.2%) scores.

Multivariate regression results showed that none of the therapeutic factors were significantly associated with cognitive function at 9 months after discharge when controlling for confounding factors. Among the postdischarge factors, fewer health conditions were significantly associated with better cognitive function (table 4).

More time spent in complex OT activities (eg, cognitive tasks, instrumental activities of daily living, community reintegration, and prevocational activities) and fewer postdischarge health issues were significantly associated with better long-term motor function after controlling for the remaining factors. Fewer days from injury to IR admission was significantly associated with better motor function at follow-up (table 5).

Discussion

To the best of our knowledge, this is the first study in Canadian patients with TBI to provide estimates of cognitive and motor function at 4 time points from IR admission to 9 months after discharge and to investigate the association of therapeutic factors and postdischarge conditions with long-term functional outcomes.

The results of this study are consistent with previous studies in that patients with moderate to severe TBI experienced more cognitive recovery from IR admission to discharge compared to postdischarge.[9,10,14,27] The lack of significant cognitive improvement from 3 to 9 months of follow-up may be attributed to the high number of postdischarge comorbidities that can impact on cognitive function at follow-up as demonstrated in our analysis. Another study of patients with TBI showed that patients

Table 2 Pairwise comparison of the mean differences of FIM-Rasch cognitive and motor scores between 4 time intervals using repeated measure ANOVA

(N=85)	Mean Differences	Bonferroni Follow-up Test (95% CI)
Cognitive score		
Admission to discharge	12.4	8.5-16.4*
Discharge to 3 months after discharge	6.9	2.9-10.8*
Three to 9 months after discharge	-2.2	-6.2 to 1.6
Motor score		
Admission to discharge	18.1	13.3-23.0*
Discharge to 3 months after discharge	2.2	-2.6 to 7.0
Three to 9 months after discharge	-0.5	-5.4 to 4.2

Abbreviation: CI, confidence interval.
* Significant <.0001.

who experienced a higher level of anxiety at 5 and 12 months after injury had more hippocampal atrophy in the long term, suggesting a possible explanation for the lack of cognitive improvement.[56] Furthermore, earlier studies have concluded that patients who had less access to insurance funding after IR, are at higher risk of psychosocial problems and less cognitive improvement.[3,30]

This study revealed that patients showed most motor recovery from admission to discharge which they were able to maintain to 3 and 9 months after discharge. This result is consistent with prior studies that have focused on patterns of motor recovery from IR admission to up to 1 year after discharge.[6,29] A previous study on motor recovery following TBI indicated that motor improvement could be retained for a longer period when compared with cognitive recovery.[28] The lack of significant improvement in cognitive and motor scores at 3 months after discharge may be due to the natural course of recovery.

The lack of association of therapy time and patient LOE with cognitive function at 9 months after discharge was not consistent with prior studies. Total therapy hours per week in the first 5 months postinjury were significantly correlated with better cognitive scores at 1 to 3 years after injury in a prior study with a small sample size (N=33).[30] However, this study did not identify the type of therapy by setting or program. Additionally, they did not control for the contribution of premorbid and postdischarge health issues. Furthermore, differences in time to follow-up may explain this inconsistency (9 months vs 1-3y after discharge). Results of this study were not consistent with a study on patients from the United States using the same PBE methodology with respect to the contribution of the LOE and therapy time in cognitive scores.[11] This may reflect differences in rehabilitation LOS and time spent in therapy between the 2 health care systems or the small sample size of this analysis. For example, patients from the United States in the TBI-PBE study received more therapy time, were admitted to IR earlier, and experienced a shorter rehabilitation LOS.[11]

A positive association of therapy time in complex OT activities during IR with better long-term motor scores might be due to a greater functional improvement or a higher tolerance of therapy in patients who participated in the follow-up study. Some of these complex activities include cognitive tasks (eg, executive function, problem solving and time management), instrumental activities of daily living (eg, home management and money management), community reintegration (eg, shopping, banking, and using community resources), and prevocational (eg, prepare patients to perform either paid or volunteer work) activities. This result is also consistent with prior TBI-PBE studies on the United States population[11] and with a study on patients with a history of stroke who were treated in a Canadian facility.[57] However, the clinical reasoning for selecting more complex vs basic activities warrants more attention in future studies.

The association of a greater number of postdischarge health issues with lower motor scores at 9 months after discharge suggests the need to provide postdischarge services for patients and caregivers to raise awareness of these health issues and to help with managing these conditions. This result is consistent with a recent study that showed that late functional changes are mainly associated with postdischarge depression and anxiety in this population.[58]

The lack of association between patient LOE with motor scores is consistent with a prior study on the United States population in the TBI-PBE project,[11] where LOE was not associated with postdischarge motor function in patients who were admitted to IR with relatively high admission cognitive scores (≥21) and it added little to the explanatory power of the model.[11] Also, missing data on patients with lower cognitive scores in the follow-up study and including patients with higher cognitive scores may explain the lack of association of LOE with motor scores at 9 months after

Table 3 Contribution of blocks of variables to the model at 9 months after discharge

Blocks of Variables	Cognitive Outcome R^2	Cognitive Outcome R^2 Change	Cognitive Outcome F-Change *P* Value	Motor Outcome R^2	Motor Outcome R^2 Change	Motor Outcome F-Change *P* Value
Demographics + clinical	.165	.165	.01	.235	.235	<.0001
Demographics + clinical +LOE	.176	.011	ns	.261	.026	ns
Demographics + clinical+ LOE+ time in therapy	.203	.027	ns	.404	.143	.004
Demographics + clinical+ LOE+ time in therapy+ postdischarge conditions	.302	.099	.01	.476	.072	.03

NOTE. Time in therapy indicated time in therapy for basic and advanced activities in OT and PT.
Abbreviation: ns, not significant.

Table 4 Predictors of FIM-Rasch cognitive score at 9 months after discharge

	Unadjusted	Adjusted
n=80, R^2=.284, Adjusted R^2=.157, P<.0001	Parameter Estimate (β) 95% CI	Parameter Estimate (β) 95% CI
Education (bachelor and above) vs others	8.6 (1.4-15.9)	ns
Admission CSI score	-.4 (-.6 to -.2)	ns
Average OT and PT level of effort over stay	2.2 (-.4 to 4.9)	ns
OT basic activities min/wk	-.1 (-.2 to .01)	ns
OT complex activities min/wk	-.007 (-.03 to .02)	ns
PT basic activities min/wk	-.06 (-.1 to .04)	ns
PT complex activities min/wk	.01 (-.02 to .04)	ns
Health issue postdischarge (≥1 issues vs none)	-7.5 (-13.6 to -1.3)	-7.4 (-13.06 to -1.2)
Referral to ED postdischarge (≥2 times vs 1 time)	-5.2 (-12.6 to 2.08)	ns
Living situation postdischarge (not alone vs alone)	-1.7 (-10.8 to 7.3)	ns

NOTE. Only significant confounders and target variables were used in the final adjusted model. These variables were not entered into final model because of lack of significant association with outcome in unadjusted model or multicollinearity with other variables: age, sex, employment status, cause of injury, days from injury to rehabilitation, rehab length of stay, Glasgow Coma Score, admission and discharge motor and cognitive FIM scores, and OT and PT total min/wk. R^2 and adjusted R^2 were reported for the final adjusted model.
Abbreviations: CI, confidence interval; ns, not significant.

discharge. Another explanation could be the strong association of clinical factors, postdischarge health conditions after discharge, and time spent in activities with follow-up motor scores (as shown in table 5) that potentially minimizes the longer-lasting effect of LOE. Additionally, a prior study on the TBI-PBE data in the United States revealed that a higher LOE is associated with a younger age, lower levels of agitated behavior, lower severity scores, and fewer numbers of comorbidities.[50] Further studies are needed to investigate the mediating effect of these factors on the LOE and time spent in therapeutic activities.

In this study, age was not a significant predictor of cognitive and motor scores, contrary to previous studies.[10,11] This may be explained by less variation of age in this population due to the limited participation of older adults in follow-up interviews. The number of ED admissions after discharge and living situation did not significantly explain the variation of long-term cognitive and motor scores. Rather, it may reflect the small percentage of patients who were admitted to ED or living alone after discharge in this dataset.

Results of this study provide novel information for clinicians and patients in IR settings in Ontario. The primary comparison of the baseline factors and functional scores between results of the current study and data of the National Rehabilitation Reporting System in IR facilities in Ontario for patients with TBI (N=1730) during the same time period shows relatively similar profiles for patients, suggesting that the population is generalizable to other IR facilities in Ontario (National Rehabilitation System Ontario data: age (20-64y) 53.9%, men 70.1%, admission FIM cognitive score of 23.5±7.5, and admission FIM motor score of 58.9±22.2).[59] These data are also comparable to National Rehabilitation System reports on IR facilities in Canada (N=4503).[60] It should be noted that although health care

Table 5 Predictors of FIM-Rasch motor score at 9 months after discharge

	Unadjusted	Adjusted
n=80, R^2=.481, Adjusted R^2=.388, P<.0001	Parameter Estimate (β), 95% CI	Parameter Estimate (β), 95% CI
Age at admission (y)	-.3 (-.4 to -.1)	ns
Days from injury to IR admission	-.1 (-.1 to -.04)	-.081 (-.14 to -.01)
Admission CSI score	-.4 (-.6 to -.1)	ns
Average OT and PT level of effort over stay	.1 (-2.7 to 3.1)	ns
OT basic activities min/wk	-.2 (-.3 to -.09)	-.22 (-.34 to -.09)
OT complex activities min/wk	.02 (-.01 to .05)	.05 (.02 to .09)
PT basic activities min/wk	-.1 (-.2 to .01)	ns
PT complex activities min/wk	.01 (-.01 to .04)	ns
Health issue postdischarge (≥ 1 issue vs none)	-6.7 (-13.5 to .07)	-7.85 (-19.5 to -3.8)
Referral to ED postdischarge (≥2 times vs 1 time)	-3.7 (-11.9 to 4.4)	ns
Living situation at 9 months after discharge (not alone vs alone)	-8.6 (-18.5 to 1.1)	ns

NOTE. Only significant confounders and target variables were used in the final adjusted model. These variables were not entered into final model because of lack of significant association with outcome in unadjusted model or multicollinearity with other variables: sex, education status, employment status, cause of injury, rehabilitation LOS, Glasgow Coma Score, admission and discharge motor and cognitive FIM scores, and OT and PT total min/wk. R^2 and adjusted R^2 were reported for the final adjusted model.
Abbreviations: CI, confidence interval; ns, not significant.

systems in Canada operate within a national legislative framework, given the differences in tax revenue and regional variability in availability of rehabilitation services, generalizing the results of this study to some provinces and territories across Canada should be applied cautiously. For instance, while Newfoundland, Labrador, and Yukon have little or no brain injury rehabilitation services, other regions such as Ontario, Quebec, and British Colombia have relatively more.[61,62]

Study limitations

Missing data on secondary insurance payers and therapeutic factors from speech language pathology and psychology treatments prevented us from exploring the influence of these factors on postdischarge functional recovery. The majority of nonparticipants in the follow-up study were older adults with lower admission and discharge cognitive scores and lower discharge motor scores, which may limit the variability of samples. Due to 5.8% to 14.1% and 1.1% to 9.4% ceiling effects in the FIM-Rasch motor and cognitive scores, respectively from discharge to 9 months after discharge, this study suggests that an alternate instrument with a scale range needs to be considered to measure higher levels of cognitive and motor function in future studies. The small sample size of Canadian patients limited our ability to include more covariates in the model that were measured in the PBE study in the United States. As stated above, results of this study may be generalizable to Ontario and other provinces in Canada with similar provincial health care delivery. However, generalizing the results of this study to provinces with different tax revenue, with limited access to IR, and other countries without universal health care should be applied cautiously.

Conclusion

This study informs clinicians about functional change over time for patients with TBI in Ontario, Canada. The association between postdischarge health issues with long-term cognitive and motor scores suggests the need to ensure that patients and families are aware of residual mental and physical health conditions in discharge planning from IR and introduce community and outpatient resources to help with managing these issues. Additionally, these findings reveal the association of more complex OT activities with maintaining motor gains after discharge in patients with better function that may help clinicians in the process of clinical reasoning and selecting appropriate activities. Results of this study present valuable information for care teams in IR facilities in Ontario and other provinces with similar provincial health care system. It also provides a foundation for future multicenter research on the content and components of IR in the Canadian population and other nations that have similar health care systems, baseline factors, and IR availability (eg, Australia).[63] Further studies are needed to shed light on the clinical reasoning for selecting therapeutic activities and the association between environmental factors, continuous rehabilitation after IR, and the presence of postdischarge health conditions with long-term outcomes.

Suppliers

a. CSI software; International Severity Information Systems, Inc.
b. SAS 9.4; SAS Institute.

Keywords

Brain injuries; Outcome assessment; Rehabilitation

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Appendix 1 List of Health Issues at Time of Follow-up That Patients Received Medical Attention For

Seizures
Headaches
Other pain
Fatigue
Confusion or not thinking clearly
Memory, concentration, or other thinking skills
Medications
Not sleeping/sleeping too much
Swallowing problems
Sexual function
Fertility
Spasticity
Vision problems
Hearing problems
Depression
Anxiety
Anger
Apathy
Level of physical function
Maintaining or developing social relationships
Dizziness
Other

Appendix 2 Category of Activities Based on Their Level of Complexity in Occupational and Physical Therapy Sessions

Occupational Therapy	Physical Therapy
Basic Activities	Basic Activities
Bed, chair, wheelchair transfer	Preparation time
Bed mobility	Resting
Serial casting	Sitting
Splinting	Standing
Environmental adaption	Basic transfers
Feeding	Casting/splintering
Grooming	Developmental sequencing
Lower body dress	Bed mobility
Upper body dress	Wheelchair mobility
Education	Equipment management
Sexuality	
Visual activities	
Perceptual activities	
Wheelchair management	
Advanced Activities	Advanced Activities
Bathing	Therapeutic exercise
Toileting	Pregait
Car transfer	Gait
Toilet transfer	Stairs
Tub-shower transfer	Community mobility
Upper extract activity	Advanced gait
Prefunctional activity	Prefunctional activity
Community mobility	
Community transportation	
Community reintegration	
Functional mobility	
Home management	
Leisure performance	
Meal management	
Money management	
Predriving activity	
Prevocational activity	
Cognitive activity	

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