Advanced Therapy in Traumatic Brain Injury Inpatient Rehabilitation: Effects on Outcomes During the First Year after Discharge

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Key words

Brain injuries, traumatic; Rehabilitation; Outcome assessment (health care); Physical therapy; Occupational therapy; Speech therapy; Recreation therapy; Propensity score

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Abstract

Objective: To use causal inference methods to determine if receipt of a greater proportion inpatient rehabilitation treatment focused on higher level functions, e.g. executive functions, ambulating over uneven surfaces (Advanced Therapy, AdvTx) results in better rehabilitation outcomes.

Design: A cohort study using propensity score methods applied to the TBI-Practice-Based Evidence (TBI-PBE) database, a database consisting of multi-site, prospective, longitudinal observational data.

Setting: Acute inpatient rehabilitation (IRF).

Participants: Patients enrolled in the TBI-PBE study (n=1843), aged 14 years or older, who sustained a severe, moderate, or complicated mild TBI, receiving their first IRF admission to one of 9 sites in the US, and consented to follow-up 3 and 9 months post discharge from inpatient rehabilitation.

Interventions: Not applicable.

Main Outcome Measures: Participation Assessment with Recombined Tools-Objective-17, FIM™ Motor and Cognitive scores, Satisfaction with Life Scale, and Patient Health Questionnaire-9.

Results: Controlling for measured potential confounders, increasing the percentage of AdvTx during inpatient TBI rehabilitation was found to be associated with better community participation, functional independence, life satisfaction, and decreased likelihood of depression during the year following discharge from inpatient rehabilitation. Participants who began rehabilitation with greater disability experienced larger gains on some outcomes than those who began rehabilitation with more intact abilities.

Conclusions: Increasing the proportion of treatment targeting higher level functions appears to have no detrimental and a small, beneficial effect on outcome. Caution should be exercised when inferring causality given that a large number of potential confounders could not be completely controlled with propensity score methods. Further, the extent to which unmeasured confounders influenced the findings is not known and could be of particular concern due to the potential for the patient's recovery trajectory to influence therapists' decisions to provide a greater amount AdvTx.

Abbreviations:

AdvTx	Advanced Therapy
ASD	Absolute standardized difference
CSI	Comprehensive Severity Index
FIM	Functional Independence Measure
HTE	Heterogeneity of treatment effect
IPW	Inverse probability weighting
OT	Occupational therapy
PART-O	Participation Assessment with Recombined Tools-Objective
PHQ-9	Patient Health Questionnaire-9
POC	Point of care
PSM	Propensity score methodology
PT	Physical therapy

RCT	Randomized controlled trial
SDC	Supplemental digital content
ST	Speech therapy
SWLS	Satisfaction with Life Scale
TBI	Traumatic brain injury
TBI-PBE	Traumatic brain injury Practice Based Evidence study
TR	Therapeutic recreation

Conventional rehabilitation theories are based on the assumption that a hierarchical sequence of recovery steps must be followed to restore normal function, and challenging patients too quickly or encouraging compensatory strategies too early is seen as a wasted effort, if not potentially counterproductive.[1-3] These "bottom-up" approaches, including neurodevelopmental treatment (e.g. the Bobath approach[1]) in motor rehabilitation and restorative techniques in cognitive rehabilitation[4] , assume underlying component skills or functions must first be restored before more complex functions can be addressed successfully. However, recent perspectives reflect an evolution of ideas that recognize the dynamic system's complexities and inter-relationships between functional abilities, neuroplasticity, and psychological factors, such as engagement and motivation. For instance, Winstein and Kay[5] posit that effective rehabilitation must engage and empower the individual, and to do so requires the active ingredients to be: 1) challenging; 2) progressively increasing in level of difficulty; and 3) intrinsically motivating and engaging. Likewise, recent recommendations in cognitive rehabilitation take a pragmatic perspective, introducing compensatory strategies earlier rather than later and thereby allowing the individual to engage in more advanced activities, even if some of the underlying functions have not been restored.[6]

These differing perspectives continue to co-exist in the literature.[7-10] Unfortunately, there is a dearth of empirical evidence to guide a clinician's decision-making as to when to provide challenging interventions, compensatory activities, and metacognitive strategies in TBI inpatient rehabilitation. The evidence that does exist is based on applications in alternative settings and with different levels of acuity. For example, a recent meta-analysis supported the initiation of intensive rehabilitation in the ICU to improve outcomes following severe traumatic brain injury (TBI).[8] However, the therapeutic activities studied targeted lower level functions, such as following commands and increasing awareness of the environment. At the other end of the continuum, compensatory and metacognitive strategies have been found effective for improving executive functioning, however most studies have been conducted in outpatient settings with patients many months post-injury.[7] The effect of introducing strategy training in the more acute stages of rehabilitation has received minimal investigation.

Recent findings from studies of stroke rehabilitation support the use of therapeutic interventions that target functions at a substantially higher level than the patient's current level of ability.[9] Practice-based evidence studies with patients who had a stroke have found that therapy that challenges patients with severe impairments, such as therapies targeting advanced gait (negotiating uneven surfaces), home management, and problem-solving, were associated with better outcomes than therapies targeting lower level functions such as bed mobility.[11,12] The authors of these studies conclude from these findings that a “leap-frog” approach that introduces challenge earlier rather than later is necessary for neuroplasticity and effective rehabilitation.

The TBI Practice-Based Evidence (PBE) study yielded findings similar to those found for the stroke population.[13-15] Differences in difficulty levels of therapy activities during inpatient rehabilitation added substantial variance to the prediction of TBI outcomes at rehabilitation discharge, with some of the most beneficial activities targeting relatively more advanced functions. Participants with the greatest cognitive impairments were among those who appeared to benefit most.

The purpose of the current study is to extend the previous studies by evaluating the effects of receiving a greater proportion of Advanced Therapy (AdvTx) using causal inference methods[16,17] and a multidisciplinary treatment classification system of AdvTx. The amount of AdvTx was determined by therapist discretion, environment, and other factors. For cognitive abilities, the targets of AdvTx were higher-level executive functions and the independent use of compensatory strategies with complex tasks. For physical abilities, the targets included capacity to manage unintended perturbation and skilled learning. The management of challenges within a changing environment, including distractions and physical barriers, were included in this definition. The functions targeted by rehabilitation fall along a continuum from more basic to the most advanced; for the purposes of this study we included functions and abilities at the extreme end of the continuum to ensure that the interventions are challenging for all patients, even those who presented with less severe disability at admission to rehabilitation.

The current study then evaluates the effects of the 'dose' of AdvTx relative to non-advanced. We hypothesized that when a greater proportion of therapists' time is spent providing AdvTx, patients achieve better outcomes. We also hypothesized that patients who presented to rehabilitation with the greatest amount of disability, and who were therefore most challenged by the AdvTx, would experience greater benefit from a higher proportion of AdvTx than those who presented with less severe disability.

METHODS

Participants. The Participant Flow Diagram for this cohort study can be found in supplemental digital content (SDC). A cohort of 1843 participants was drawn from the TBI-PBE Database (n=2120).[14] The criteria for inclusion in the current analysis were that the participant received their first course of rehabilitation for complicated mild, moderate, or severe TBI from one of 9 US sites during the recruitment and data collection period (2008-2011), consented to follow-up, received therapy after the initial assessment period (first 3 days of admission to rehabilitation) and was age 14 years or older. Institutional review board approval was obtained by the sites that participated in the original TBI-PBE study.

For the purposes of evaluating heterogeneity of treatment effects (HTE) the sample was divided into two subgroups. The Severe Group consisted of 820 patients who presented to rehabilitation requiring total or maximal assistance with all self-care needs (operationalized as FIM Motor < 28.75 and FIM Cognitive scores $\leq$ 15). The Less Severe Group consisted of the remainder of the sample (n=1023).

Data source for the intervention. As part of the original TBI-PBE study[14] , point of care (POC) forms and associated syllabi were developed by discipline-specific committees for occupational therapy, physical therapy, speech therapy, and therapeutic recreation (OT, PT, ST, TR). Therapists recorded the time spent in various treatment activities in each session on POC forms. Data collection quality was supported through a comprehensive quality assurance program.

As part of the current study, representatives from each discipline reviewed tables of treatment activities. Using the definition of AdvTx provided earlier, they identified those session components that met the definition. In a few instances, where the interpretation of the syllabus text was unclear, therapists outside of the research team were contacted to answer questions as to how they would classify the activity and/or intervention. See SDC for graphics illustrating the classification system.

The percentage of total therapy time spent in AdvTx was calculated, with the numerator equaling therapy minutes spent in AdvTx, and the denominator equaling all therapy minutes. The distribution of the proportion of time spent in AdvTx was slightly skewed, with a mean of 16.16% (SD=12.14) and median of 14.15%. The analysis compared outcomes of patients who received different proportions of time in AdvTx.

Outcomes. Data on outcomes were collected at discharge and at 3 and 9 months post-discharge. The primary outcome was community participation, as measured by the Participation Assessment with Recombined Tools-Objective (PART-O-17) at 9 months.[18,19] The PART-O-17 includes three subtests: Productivity, Being Out-and-About, and Social Relations. Test-retest reliability has been established[20] and studies of validity have focused on dimensionality and relationships with other measures and constructs.[21-24] In addition to a Total score that reflects the average of the 3 domain scores, an alternative method for calculating a unidimensional participation score has been developed based on Rasch analysis.[24] Since the two summary scores characterize the construct slightly differently, both the PART-O Rasch Total score and the original Total score were used in this study, along with the three domain scores.

Secondary outcomes included: functional independence as measured by the FIM™ Motor and Cognitive Rasch-converted scores[25-28] ; life satisfaction as measured by the Satisfaction with Life Scale (SWLS);[29] and depression as measured by the Patient Health Questionnaire-9 (PHQ-9). [30] All of these measures have established reliability and validity for use with persons with TBI. [18,21,23,24,31-36] The PHQ-9 was analyzed as a dichotomous variable: likely major depression vs. no major depression.[36] When the person with TBI was not able to complete the follow-up, the SWLS and PHQ-9 were not administered and the FIM and PART-O-17 were based on a proxy report.

Potential confounders. Since the purpose of the study was to examine the potential effectiveness of AdvTx, other potential predictors of these outcomes were considered confounders and controlled through propensity score methodology. Data on premorbid history, injury characteristics, and functioning at admission to rehabilitation were abstracted from rehabilitation medical records. Only variables that were unlikely to be influenced by treatment received in inpatient rehabilitation were considered as potential confounders, and therefore only those that were measured prior to treatment or at rehabilitation admission (first 3 days), were included in the propensity score model (admission assessments are conducted during the first 3 days of rehabilitation[15]). In addition to more traditional measures of severity, we used the *Comprehensive Severity Index* (CSI®)[11,37,38] Brain Injury and Non-Brain Injury scores to represent the complex interactions between physiological and psychological phenomena that contribute to disease.[14] We grouped sites by the typical length of their therapy sessions, with shorter session sites having a mean of .56 hours (SD .06) and longer session sites having a mean of .71 hours (SD .06).

Analysis. Data were analyzed using SAS v9.3[a] and STATA version 14.0[b]. Potential confounders were controlled using inverse probability weighting (IPW) based on a generalized propensity score. The proportion of AdvTx was allocated evenly across 10 quantiles or bins (5 bins were used when the sample was stratified due to smaller n). A cumulative logistic model was used to estimate the predicted probability of being in each quantile, and inverse probability weights constructed.[39] Multiple models were evaluated, including evaluation of interaction terms, until it was determined that the best possible balance was achieved. Participants with extreme weights (>10) or who were dropped from the generalized propensity score models were not included in subsequent analyses (n=17). The average absolute standardized difference (ASD) between all pairs of quantiles was calculated; if the ASD for a potential confounder exceeded .10 (a conservative threshold), the potential confounder was considered not to be sufficiently balanced by the weighting and considered for inclusion in the adjusted models used for the outcome analysis.[40,41] However, if the number of possible covariates threatened the stability of the model, covariates were also chosen based on a) content knowledge indicating which covariates were most influential and b) the distribution of the covariates (those that had sparse cells were not included). Since an ASD < .20 is often considered sufficient to indicate balance[42] , covariates with ASD ≥ .20 were of greatest concern.

The hypothesis that a higher proportion of AdvTx would be associated with better outcomes was evaluated through marginal regression models with robust sandwich error estimates. The first step included only AdvTx in the model; the next step added those confounders that did not meet the criterion for achieving sufficient balance through IPW. We assessed the impact of missing outcome data through the use of multiple imputations to simulate a complete sample, and then comparing results to those obtained with the sample for which the outcome data were complete. Multiple imputation models by chained equations (MICE), with predictive mean matching for continuous outcomes and K-nearest neighbors for categorical variables, included all outcomes, treatments and covariates explored between the treatment exposures and outcomes.

The extent that severity of initial disability modified the effect of AdvTx was tested with an interaction term (Severity*AdvTx). In addition, we evaluated whether results changed when the Severe and Not Severe subgroups were analyzed as separate strata.

Results

Table 1 lists key covariates describing the sample and the quantile distributions before and after weighting (a table with all 75 covariates appears in SDC). Prior to weighting, ASD ranged from .03-.79, with an average ASD of .17. After weighting, ASD ranged from .05 to .30, with an average ASD of .11; 40 covariates had an average ASD > .10. While there was a large number of covariates with ASD >.10, only 3 exceeded .20 (FIM Motor, FIM Cognitive, and days from injury to rehabilitation admission) and the maximum average ASD was still relatively low.

Prior to adjustment for the 40 unbalanced confounders, increasing the proportion of time in AdvTx was found to be associated with better community participation at both 3 and 9 months for the total scores (PART-O Total, PART-O Rasch Total) and most domain scores (PART-O Out-and-About at 9 months, Productivity, and Social Relations at 3 and 9 months). In addition, positive effects were observed for functional independence (FIM Cognitive and Motor) at discharge, 3 and 9 months ($p<.05$, see Table in SDC). Following adjustment for unbalanced covariates, the effects were somewhat attenuated, but more precise. As shown in Table 2, findings remained significant for the PART-O total scores, Productivity at 3 and 9 months, Out-and-About at 9 months, FIM Cognitive and Motor, and estimates became stronger for SWLS (9 months only) and PHQ-9 at 3 and 9 months (odds for depression decreased by 3% at each time point). No substantive differences in inference were noted following multiple imputation of outcomes.

HTE for initial level of disability. The interaction term for initial level of disability and proportion of AdvTx was used to assess HTE. Cumulative logistic regression models estimated the generalized propensity scores on the full cohort, with refinement to achieve balance by severity groups across 5 quantiles. Prior to IPW, the mean ASD for the Severe subgroup ranged from .04 to .57, averaging .18; after IPW, the ASD ranged from .03 to .36, averaging .14, with 55 covariates having ASD> .10 (11 covariates with ASD≥ .20). Prior to IPW, for the Less Severe subgroup ASD ranged from .03 to .63, averaging .17. After IPW, the ASD ranged from .06 to

.29, averaging .15 with 62 covariates > .10 (15 covariates with ASD $\geq$ .20). Since the combined number of covariates that did not meet the criterion of ASD <.10 was too large to include in the outcome analysis, the covariates were selected based on additional decision parameters (i.e. content knowledge, sparseness of cells).

Prior to adjustment for unbalanced covariates, the interaction term (Severity*AdvTx) was significant for FIM Cognitive and Motor scores, at all time points. No other outcomes showed significant interaction effects. After adjusting for unbalanced covariates, the effects were somewhat attenuated but remained significant for FIM Cognitive and Motor (Table 3). Those who presented with severe disability at admission appeared to experience more benefit from AdvTx on these two outcome variables, and no significant differences were observed on the other outcome variables.

We evaluated whether findings changed when the subgroups were analyzed separately. For the Severe group, prior to IPW the ASD ranged from .03 to .51, averaging .17. After IPW the ASD ranged from .05-.30, averaging .13 with 54 covariates with ASD $\geq$.10 (8 with ASD>.20). Prior to IPW, ASD for the Less Severe group ranged from .03 to .57, averaging .16. After IPW, it ranged from .03 to .20, averaging .10, with 29 covariates with ASD >. 10 (1 covariate with ASD $\geq$ .20). Using the models adjusted for unbalanced covariates (SDC Table), the Severe subgroup experienced greater benefits from greater proportion of AdvTx than the Less Severe subgroup on: FIM Cognitive and Motor (all time points), and PART-O Rasch Total, and Productivity at 3 months. These findings are generally consistent with those found using the interaction term.

Discussion

The current findings suggest therapeutic activities during acute inpatient TBI rehabilitation targeting the highest level functions in the physical and cognitive realms are associated with better community participation, functional independence, life satisfaction, and decreased likelihood of depression during the year following discharge from inpatient rehabilitation. Furthermore, participants who begin rehabilitation with greater disability experience larger gains on some outcomes than those who begin rehabilitation with more intact abilities.

The current findings are consistent with the previous TBI-PBE studies.[13 15 43] This consistency implies that the construct (AdvTx continuum) is relatively robust in the context of different operational definitions. The previous studies used a method for classifying treatment that differed from the current operational definition in three key ways: 1) previous studies defined 'advanced' activities relative to other activities within a discipline, rather than across disciplines; 2) to increase the likelihood that activities chosen as advanced were challenging for everyone, only the most challenging activities were designated as advanced in the current study; and 3) the current study used multiple sources of information from the POC forms (e.g. activities, interventions, targeted functions) while the previous studies only used information on activities.

Taken together, the findings support the notion that challenging patients to perform functions above their current level can spur recovery. As noted by Winstein and Kay[5] in their synthesis of the neuroplasticity and stroke rehabilitation literatures, cortical reorganization has been found to be dependent upon active problem-solving, challenges that are progressively more difficult, and engagement of the patient. While the current study design does not allow a direct assessment of the degree to which the activities were "progressively more difficult" for the individual patient, by definition AdvTx activities involved higher-level problem solving and the ability to adapt to a changing environment. In addition, patients were taught how to use compensatory strategies to perform more complex activities required for community integration, presumably facilitating patient engagement.

The observed effect sizes were relatively small, though meaningful. For example, using the PART-O Total Rasch-transformed score, increasing the proportion of AdvTx by 20% (e.g. 10% AdvTx to 30%) could increase the number of days out of the house in a week from 1-2 days to 5+ days at 9 months post-discharge. During an exercise to evaluate meaningful changes on the outcome measures, consumer stakeholders involved in the project indicated that even smaller changes (e.g. getting out of the house or socializing with friends one more time per week) were important. They noted that a small change in one area can prompt change in other, non-measured areas as well.

Winstein and Kay's[5] recommendation that therapy be "difficult, but not too difficult" should be kept in mind when applying the results of this study. The application of the findings to the practice of rehabilitation will need to take into account patients' level of functioning and factors that may impede their ability to participate in AdvTx, such as fatigue or pain. The potential risk for patients' safety will also need to be evaluated. Therapist and environmental factors may also influence the extent to which AdvTx can be consistently delivered across patients, given current demands on therapists to minimize preparation time and to see an increasing number of patients.

Limitations. Several limitations should be considered in interpreting and applying the study findings. This study may not represent all individuals receiving rehabilitation and only assesses the relationship of Advance Therapy during acute inpatient rehabilitation, not at later time points. We used multiple imputation to assess the impact of missing outcomes on the results; it is possible that the outcomes were not missing at random (as required for multiple imputation).

Other limitations apply to the use of causal inference methodology rather than an RCT to evaluate treatment effectiveness. Our confidence in the findings is dependent on the extent to which there is evidence to support assumptions. There may have been unmeasured confounders, including for example, unknown reasons for therapists choosing to use AdvTx. In particular, it is possible that patients who showed some initial benefit from AdvTx or who made unexpectedly fast progress were more likely to receive additional AdvTx. While the propensity score methodology controlled for confounders associated with the recovery trajectory, it is notable that the 3 variables that were least balanced by IPW are often strong predictors of rehabilitation outcomes (FIM Motor and Cognitive at admission and days from injury to rehabilitation). Our use of double-adjustment for unbalanced covariates should substantially reduce the influence of these unbalanced confounders.[41] However caution should be exercised in inferring causality. The analysis of heterogeneity of treatment effects requires particular caution in interpretation because the number of unbalanced confounders was substantial and it was not possible to include all in the outcome models.

While uncontrolled confounding may have inflated effect sizes, the method used for operationalizing AdvTx may have attenuated effect sizes. The categorization of a therapy segment as Advanced vs. non-Advanced was based on post-hoc sorting of POC entries, not on direct observation of the session. It is quite possible that the particular setting, instructions, feedback, and other ingredients selected by the therapist made a segment AdvTx, but was categorized as non-Advanced because we lacked some of these details on the POC forms. A prospective study with a carefully planned a priori categorization of treatment segments along the non-Advanced to Advanced dimension could result in increased effect sizes.

Conclusions

The findings suggest inpatient TBI rehabilitation patients, especially those presenting with the most severe level of disability, may benefit from tasks that target the highest level cognitive and physical functions. These findings are consistent with recent literature indicating that challenging patients in engaging tasks can lead to cortical reorganization and optimized outcomes.

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Suppliers

[a]SAS v9.3 38 (SAS Institute, Inc., Cary, NC)

[b]STATA version 14.0 39 (StataCorp, College Station, TX).

Figure 1, SDC, Participant Flow Diagram

Table 1. Selected confounding variables: minimum and maximum quantile values, average standardized differences between quantiles before and after inverse probability weighting.

	Prior IPW Minimum	Prior IPW Maximum	Prior IPW ASD	After IPW ASD
DEMOGRAPHICS				
Age at admission mean (SD)	36.6 (16.5)	50.98 (22.59)	**0.31**	**0.12**
Sex: Male	66.3%	78.8%	**0.11**	0.09
Race: White	72.1%	78.8%	0.05	0.10
Race: White Hispanic	3.8%	8.1%	0.07	**0.13**
Race: Black	13.0%	19.0%	0.04	**0.11**
Race: Asian, Other or Unknown	2.16	4.89%	0.05	0.06
Education: High School+	65.76%	65.76%	**0.11**	**0.15**
Payer: Private insurance, MCO, HMO	33.5%	56.3%	**0.19**	0.07
Payer: Medicare	6.6%	38.0%	**0.31**	0.10
Payer: Medicaid	12.0%	22.7%	**0.11**	0.10
Payer: Self, Other, None	10.6%	25.1%	**0.14**	**0.12**
PREMORBID CONDITIONS				
Preinjury Alcohol Misuse	23.5%	49.7%	**0.17**	0.08
Preinjury Other Drug Use	11.2%	31.2%	**0.18**	**0.11**
INJURY AND STATUS AT REHABILITATION ADMISSION				
Cause of Injury: Fall	22.3%	39.7%	**0.16**	0.08

Cause of Injury: Moving Vehicle Crash	50.8%	65.2%	**0.12**	0.06
Cause of Injury: Violence	3.9%	8.7%	0.08	**0.13**
Cause of Injury: Sports and other causes	2.7%	9.2%	0.09	**0.12**
Shorter session site	46.2%	87.4%	**0.38**	**0.17**
Time to Rehabilitation Admission mean days (SD)	16.04 (11.79)	56.25 (64.83)	**0.38**	**0.21**
FIM (Rasch) Motor-Admission mean (SD)	14.33 (15.95)	46.71 (9.62)	**0.79**	**0.30**
FIM (Rasch) Cognitive- Admission mean (SD)	21.98 (22.49)	46.99 (12.2)	**0.51**	**0.20**
Post-traumatic amnesia cleared prior to rehab	13.4%	60.7%	**0.38**	**0.18**
GCS: Intubated/Missing	36.6%	58.7%	**0.17**	0.09
GCS: Mild (13-15)	5.0%	20.8%	**0.13**	0.08
GCS: Moderate-Severe (3-12)	33.7%	45.4%	0.10	0.08

ASD: Average standardized difference; IPW: Inverse probability weighting; Bold indicates ASD > .10

Table 2. Adjusted* model for effect of Advanced Therapy, full cohort

Outcome	Time Point	N	Average Difference	Lower 95% CI	Upper 95% CI	p-value
PART-O Total Rasch	3-Month	1442	0.089	0.035	0.142	**0.001**
PART-O Total Rasch	9-Month	1383	0.130	0.069	0.191	**0.000**
PART-O Total	3-Month	1602	0.007	0.002	0.012	**0.005**
PART-O Total	9-Month	1519	0.009	0.005	0.013	**0.000**
PART-O Out-and-About	3-Month	1604	0.007	-0.001	0.014	0.072
PART-O Out-and-About	9-Month	1523	0.009	0.002	0.015	**0.007**
PART-O Productivity	3-Month	1609	0.009	0.004	0.013	**0.000**
PART-O Productivity	9-Month	1526	0.014	0.008	0.020	**0.000**
PART-O Social Relations	3-Month	1605	0.005	-0.001	0.011	0.073
PART-O Social Relations	9-Month	1520	0.003	-0.002	0.008	0.227
FIM Cognitive Rasch	Discharge	1826	0.153	0.064	0.242	**0.001**
FIM Cognitive Rasch	3-Month	1526	0.163	0.040	0.285	**0.010**
FIM Cognitive Rasch	9-Month	1428	0.256	0.148	0.364	**0.000**
FIM Motor Rasch	Discharge	1826	0.299	0.238	0.359	**0.000**
FIM Motor Rasch	3-Month	1512	0.313	0.209	0.416	**0.000**
FIM Motor Rasch	9-Month	1409	0.347	0.247	0.446	**0.000**
Satisfaction With Life	3-Month	1200	0.058	-0.021	0.137	0.148
Satisfaction With Life	9-Month	1218	0.074	0.001	0.148	**0.048**
PHQ-9 ^	3-Month	946	0.967	0.946	0.989	**0.003**
PHQ-9 ^	9-Month	1213	0.975	0.955	0.995	**0.016**

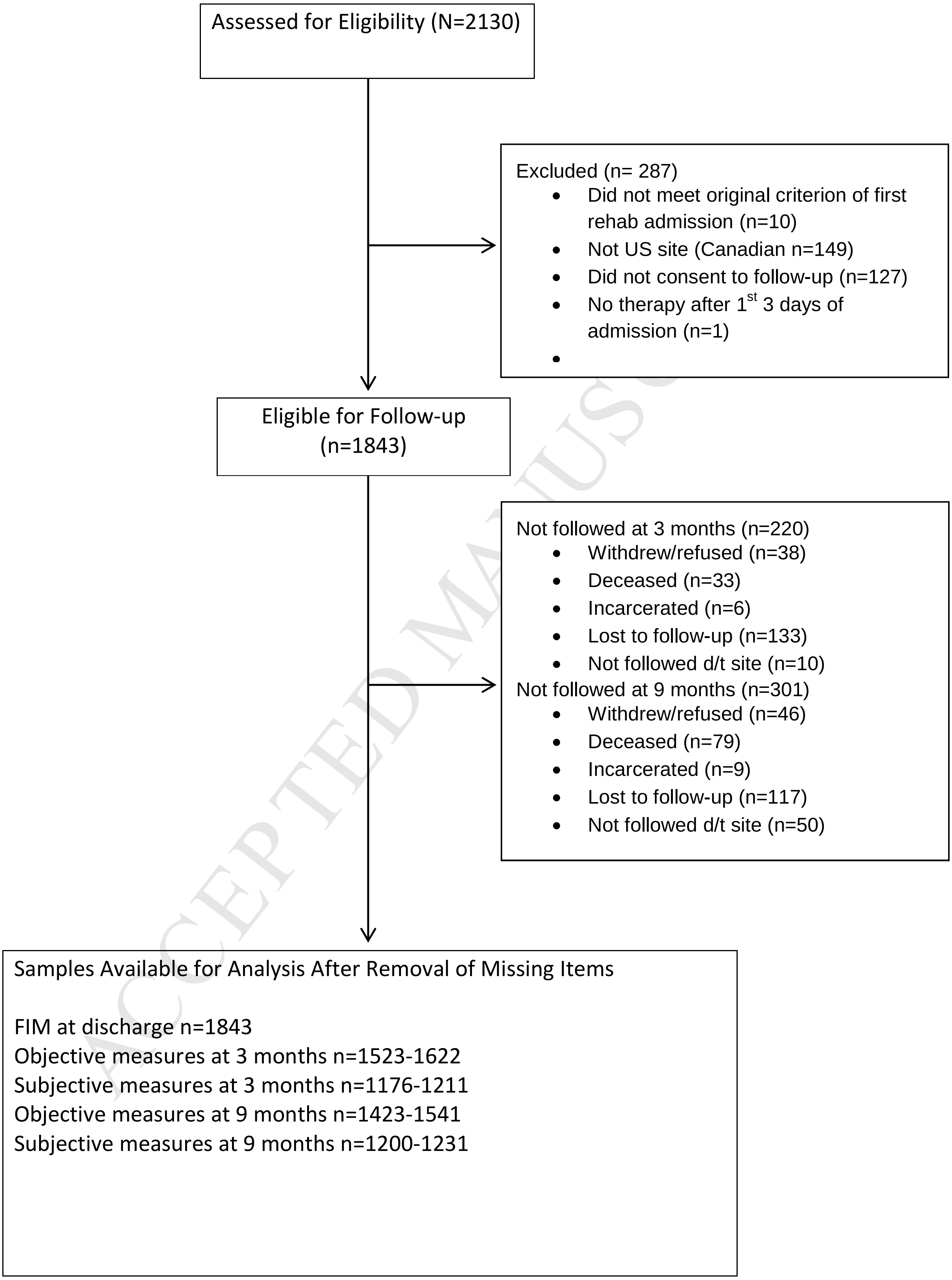
Bold indicates $p<.05$; SWLS= Satisfaction with Life Scale; PHQ-9=Patient Health Questionnaire-9. ^Odds ratio; the reference group is “not depressed”. *Adjusted for: age, race (white Hispanic, black), marital status (single, married) lived with (alone, significant other, family other than spouse, non-family member), retired, high school or greater education, pre-injury driver, payer private, managed care organization or health maintenance organization, previous brain injuries (none, one or two+), premorbid other drug use, premorbid impulse control problems, prior adult central nervous system disorder, premorbid pain problems, cause of injury (sports/other, violence) shorter session site, days injury to rehabilitation admission, FIM Motor, FIM Cognitive, CSI Brain Injury, CSI Non-Brain Injury, craniotomy, post-traumatic amnesia status at admission, open head injury with contusion/hemorrhage, facial fracture, skull fracture, weight-bearing precautions, moderate-severe aphasia, paralysis at admission.

Table 3. Adjusted* Model for Interaction of Initial Severity and Proportion of Advanced Therapy

			---------- Severe -------------			-------- Not Severe --------			Interaction p-value
Outcome	Time Point	N	Effect	Lower 95% CI	Upper 95% CI	Effect	Lower 95% CI	Upper 95% CI	
PART-O Total Rasch	3-Month	1442	0.130	0.028	0.231	0.082	0.020	0.145	0.42
PART-O Total Rasch	9-Month	1385	0.169	0.090	0.248	0.121	0.060	0.182	0.33
PART-O Total	3-Month	1602	0.006	-0.001	0.013	0.008	0.002	0.013	0.67
PART-O Total	9-Month	1521	0.010	0.003	0.017	0.009	0.004	0.013	0.76
PART-O Out-and-About	3-Month	1604	0.009	0.000	0.018	0.008	0.001	0.015	0.79
PART-O Out-and-About	9-Month	1525	0.010	0.001	0.019	0.009	0.002	0.015	0.83
PART-O Productivity	3-Month	1609	0.006	0.000	0.013	0.008	0.003	0.014	0.64
PART-O Productivity	9-Month	1528	0.017	0.007	0.027	0.011	0.005	0.018	0.29
PART-O Social	3-Month	1605	0.002	-0.008	0.013	0.007	0.000	0.014	0.46
PART-O Social	9-Month	1522	0.003	-0.008	0.014	0.006	-0.001	0.012	0.66
FIM Cognitive Rasch	Discharge	1827	0.483	0.390	0.576	0.012	-0.088	0.113	0.00
FIM Cognitive Rasch	3-Month	1526	0.414	0.229	0.600	0.050	-0.066	0.166	0.00
FIM Cognitive Rasch	9-Month	1430	0.400	0.179	0.620	0.055	-0.057	0.167	0.01
FIM Motor Rasch	Discharge	1827	0.580	0.477	0.683	0.235	0.176	0.295	0.00
FIM Motor Rasch	3-Month	1512	0.605	0.414	0.794	0.198	0.090	0.306	0.00
FIM Motor Rasch	9-Month	1411	0.532	0.337	0.726	0.249	0.143	0.355	0.01

SWLS	3-Month	1200	0.077	-0.029	0.182	0.116	0.028	0.203	0.55
SWLS	9-Month	1220	0.040	-0.074	0.155	0.082	0.009	0.155	0.54
PHQ-9^	3-Month	946	0.998	0.961	1.037	0.964	0.939	0.989	0.13
PHQ-9^	9-Month	1215	0.981	0.948	1.014	0.982	0.960	1.004	0.94

^Odds ratio, the reference group is "not depressed"; SWLS=Satisfaction with Life Scale; PHQ-9=Patient Health Questionnaire-9, *Adjustment covariates: days from injury to rehabilitation admission, FIM Cognitive, CSI Brain Injury, prior brain injury (none or 2+), payer (Medicaid, Medicare, private/MCO/HMO, or other/self/none), craniectomy, craniotomy, moderate-severe aphasia, post-traumatic amnesia at admission, shorter session site, weight-bearing precautions, race (white, black), prior adult central nervous system disorder, Glasgow Coma Scale 9-12; paralysis; injury cause (violence, sports/other), subdural hematoma, midline shift (none, 0 to 5 mm, not otherwise specified, unknown) premorbid driver, open head injury with contusion/hemorrhage, closed head injury with no contusion/hemorrhage, maximum pain score first 3 days, epidural hematoma, lived with non-family member, high school+ education; skull fracture, previous living situation, sex male, retired, intraventricular hemorrhage, premorbid learning disorder, premorbid difficulties with activities of daily living.


Assessed for Eligibility (N=2130)
Excluded (n= 287)
Did not meet original criterion of first rehab admission (n=10)
Not US site (Canadian n=149)
Did not consent to follow-up (n=127)
No therapy after 1st 3 days of admission (n=1)
Eligible for Follow-up (n=1843)
Not followed at 3 months (n=220)
Withdrew/refused (n=38)
Deceased (n=33)
Incarcerated (n=6)
Lost to follow-up (n=133)
Not followed d/t site (n=10)
Not followed at 9 months (n=301)
Withdrew/refused (n=46)
Deceased (n=79)
Incarcerated (n=9)
Lost to follow-up (n=117)
Not followed d/t site (n=50)
Samples Available for Analysis After Removal of Missing Items
FIM at discharge n=1843
Objective measures at 3 months n=1523-1622
Subjective measures at 3 months n=1176-1211
Objective measures at 9 months n=1423-1541
Subjective measures at 9 months n=1200-1231