NeuroRehabilitation 36 (2015) 243–251
DOI:10.3233/NRE-151213
IOS Press

Neurologic continuum of care: Evidence-based model of a post-hospital system of care

Frank D. Lewis[a,*] and Gordon J. Horn[b]
[a]*NeuroRestorative National Clinical Outcomes, Medical College of Georgia at Georgia Regents University, Augusta, GA, USA*
[b]*NeuroRestorative National Clinical Outcomes, Florida State University, College of Medicine, Tallahassee, FL, USA*

Abstract.
BACKGROUND: There is increasing need for a well-organized continuum of post-hospital rehabilitative care to reduce long term disability resulting from acquired brain injury.
OBJECTIVE: This study examined the effectiveness of four levels of post-hospital care (active neurorehabilitation, neurobehavioral intensive, day treatment, and supported living) and the functional variables most important to their success.
METHODS: Participants were 1276 adults with acquired brain injury who were being treated in one of the four program levels. A Repeated Measures MANOVA was used to evaluate change from admission to discharge on the Mayo Portland Adaptability Inventory–4 T-scores. Regression analyses were used to identify predictors of outcome.
RESULTS: Statistical improvement on the MPAI-4 was observed at each program level. Self-care and Initiation were the strongest predictors of outcome.
CONCLUSION: The results support the effectiveness of a continuum of care for acquired brain injury individuals beyond hospitalization and acute in-hospital rehabilitation. It is particularly noteworthy that reduction in disability was achieved for all levels of programming even with participants whose onset to admission exceeded 7 years post-injury.

Keywords: Brain injury, continuum of care, neurologic outcomes, predictors, post-hospital rehabilitation

1. Introduction

According to the Center for Disease Control health statistics (2013) the cost and burden of healthcare in the United States has risen steadily since 2000 reaching $2.3 trillion dollars by 2011. Those individuals younger than age 44, had lower overall healthcare costs, whereas those >44 years of age accounted for 2/3 of hospitalization cost. The Brain Trauma Foundation, The American Association of Neurological Surgeons, Congress of Neurological Surgeons, and the AAN/CNS Joint Section on Neurotrauma and Critical Care (2007) provided guidelines for the acute care of adults with severe brain injury. Their conclusion was that widespread adoption of these guidelines could lead to a 50% reduction in deaths, and savings of $288 million in medical and rehabilitation costs.

The Center for Disease Control reports there were approximately 2.5 million acquired brain injuries sustained in 2013. According to the current findings, approximately 20% of acquired brain injuries fall in the moderate to severe category and require support following hospital discharge. This group accounts for

*Address for correspondence: Frank D. Lewis, National Director of Clinical Outcome Services, NeuroRestorative and Adjunct Assistant Professor, Georgia Regents University, 1227 Augusta West Parkway, Augusta, GA 30909, USA. Tel.: +1 706 496 1975; E-mail: Frank.Lewis@neurorestorative.com.

Table 1
Total sample demographic characteristics

Diagnostic group	Sample size	Percent of total	Average age	Gender Male/Female	Average LOS (days)
Traumatic Brain Injury	902	69%	38.9	80% / 20%	187
Cerebrovascular accident	77	6%	42.9	69% / 31%	155
Anoxia	155	12%	53.6	64% / 36%	102
Tumor	21	2%	46.2	62% / 38%	124
Medical/disease	121	9%	39.4	66% / 34%	154

the greatest cost in post-hospital care per person. Now it is imperative to analyze and develop evidence-based guidelines related to a neurological continuum of rehabilitation care.

2. Acquired brain injury

Many persons with moderate to severe acquired brain injury are unable to live independently after inpatient discharge. However, with appropriate post-hospital services, they can improve enough to live more independently at home and engage in productive activity (Langlosis, Rutland-Brown & Wald). The current research supports that clinically meaningful improvements can be demonstrated any time after injury, as opposed to only appreciating gains within the first year of recovery (Hayden, Plenger, & Bison, 2013; Lewis & Horn, 2013). Currently, rehabilitation services are most accessed from a hospital system with length of stay approximating 2-3 months total following injury with limited funding for care options at discharge. However, much of the recovery process occurs after the initial 6 months of injury (Horn & Lewis, 2014). Natural healing does not contribute thereafter, rather improvement is driven by behavioral experience and intervention (Hayden et al., 2013; Johnston & Lewis, 1991; Lewis & Horn, 2013; Nudo, 2003). As such, post-hospital services have been developed with the purpose of restoration of independence over a gradual period of time providing appropriate medical, behavioral, and social supports to sustain and enhance quality of life (Horn & Lewis, 2014).

The following sections will describe the nature and purpose of programming along the post-hospital rehabilitation continuum. For each level of the continuum, data will be presented to answer two questions: (1) Is post-hospital rehabilitation effective in reducing disability resulting from acquired brain injury at the moderate to severe levels? (2) What are the variables that predict functional outcome?

3. Methods

3.1. Subjects

The data consisted of 1276 participants from a multi-site study (discharged from 40 post-hospital programs) across the eastern and central United States. All programs were part of a for-profit network of care for brain injured adults. Multiple program types contributed data to the total sample. These programs included active neurorehabilitation, neurobehavioral intensive, day treatment, and supported living (with rehabilitative care). The demographic characteristics of the total sample are presented in Table 1.

3.2. Program types

3.2.1. Active neurorehabilitation

The need for active post-hospital neurorehabilitation is well established (Cope, 1991; Hayden et al., 2013; Johnson & Lewis, 1991; Lewis & Horn, 2013 Malec & Brasford, 1996). These types of residential programs first appeared in 1977 and were referred to as community re-entry or transitional living following an educational rather than a medical model of care. The purpose of this level of care is to teach and promote generalization of functional skills (e.g. safe ambulation, problem solving, compensatory memory strategies, effective interpersonal communication, self-care, and money management) assisting patients with return to their home resuming productive pre-vocational or vocational activities. Though patients are medically stable, these programs are typically overseen by a Medical Director, most often a Physiatrist. They are staffed with Physical, Occupational, and Speech Therapists. Psychological services are often also provided (Lewis & Horn, 2013). Functional return and use of effective compensatory strategies are the focus of treatment plans. The community is often the context for therapeutic activities. Typically, patients enter six months to one year post-injury, though research indicates that participation in these programs within 3–6

months of injury results in the greatest gains (Hayden et al., 2013; Lewis & Horn, 2013).

The neurorehabilitation group consisted of functional outcomes for 808 participants receiving active rehabilitation. Most of these participants were male (76%). The average age was 43.5 years (range = 16–82 years). Average length of stay was 129 days with an average of 660 days duration from onset of injury to admission for post-hospital care. These participants were comprised of TBI (71%), cerebrovascular accident (13%), anoxia (5%), tumor (2%), medical/disease and (9%).

3.2.2. Neurobehavioral intensive

Persons with significant behavioral dyscontrol after TBI require intensive neurobehavioral rehabilitation from a skilled clinical team, because the most severe kinds of behaviors can result in potential danger to self and/or others. Behavioral dyscontrol includes: poor impulse control, explosive outbursts, poor planning and judgment, limited or poor self-awareness, verbal and physical aggression. This program type teaches patients how to use skills in context, using community outings and productive activities, rather than traditional therapies only. The short-term goal is to stabilize behavior with repeated learning trials so that patients can move to less restrictive, functionally-based settings. The long-term goal is for patients to achieve socially appropriate behavior and self-managing skills so they can return home or live in the community with minimal to no supervision. This group tends to be injured longer than the typical neurorehabilitation patients, with time between onset of injury to admission often averaging greater than five years (Lewis & Horn, 2014).

The neurobehavioral intensive group was comprised of 122 adults with acquired brain injury who were discharged from six programs across five states. Eighty three percent of the neurobehavioral intensive sample were males. The average age was 38 years (range = 17–77 years). The average length of stay in the program was 294 days. The average number of days from onset of injury to admission within a post-hospital care program was 2,448 days, which was considerably lengthier than the neurorehabilitation program. Diagnoses included TBI (82%), cerebrovascular accident (1%), anoxia (10%), tumor (2%), and medical/disease (5%).

3.2.3. Day treatment

The day treatment model has shown efficacy for continued rehabilitation improvement and is often completed following post-hospital residential neurorehabilitation care (Malec & Brasford, 1996). This type of program offers structured educational activities and therapies from 4–6 hours per day, 3–5 days per week. In this study the multidisciplinary teams included psychologists or mental health counselors, physical, occupational, and speech therapists. Participants lived at home with family or in supported community dwellings. Participants did not require 24-hour supervision by any treatment program or family. Treatment aimed to improve and generalize cognitive skills including initiation, attention, concentration, self-awareness, problem solving, and organization.

Day treatment group was comprised of 146 brain injured adults. Seventy one percent of the group was male. The average age was 42 years (range 16–73 years). The average program duration was 153 days. The average length of time from onset of injury to admission into the day treatment program was 1,080 days. The sample was comprised of TBI (65%), cerebrovascular accident (17%), anoxia (6%), tumor (2%), and medical/disease (10%).

3.2.4. Supported Living programs

Supported Living programs do not typically provide active restorative rehabilitation services. This program type provides a safe living environment, maintenance of patient's health (e.g., glucose and blood pressure monitoring), and prevention of decline through monitoring daily health needs (cognitive and physical exercise and challenge; Horn & Lewis, 2013). Participants are often involved in maintaining activities of daily living, residential skills improvement (e.g., cooking, cleaning, and laundry), multiple recreational and leisure activities, and prevocational activities focusing on quality of life and generalization of community skills.

The Supported Living group within this study was comprised of 86 subjects from residential facilities throughout 23 states. Participants in the supported living group accounted for 7% of the total discharges within the current study. The group consisted of 80% male and 20% female participants. The average age was 45.7 years (range = 23–74 years). Gender differences revealed 80% male and 20% female. The average length of stay was 348 days. The average length of time from onset of injury to admission within a supported living program was 2,555 days. The diagnostic categories included TBI (79%), cerebrovascular (5%), anoxia (8%), tumor (5%), and medical/disease (3%).

3.3. Measure

Participant functioning was assessed using the Mayo-Portland Adaptability Inventory-4 (MPAI-4; Malec & Lezak, 2008) at the time of admission and time of discharge from the treatment facilities involved in the study. Specifically, the MPAI-4 consists of 29 items rated from 0 to 4 on a 5-point scale, where 0 represents no limitations and 4 represents a severe problem interfering with activity more than 75% of the time. Raw scores on the 29 items are converted to T-scores within three subscales: Ability Index, Adjustment Index, and Participation Index. Each index has an average impairment T-score of 50 and a standard deviation of 10 points. The T-score interpretation is inverted so that higher scores reflect greater disability. The MPAI-4 and its three subscales (Ability, Adjustment, and Participation Indices) offer well developed and documented psychometric properties. Pearson Reliability studies for the MPAI-4 range from 0.78 to 0.88 (Malec & Lezak, 2008). The MPAI-4 provides a comprehensive evaluation of the cognitive, physical, and behavioral sequelae following neurological injury. Additionally, the Participation Index provides a measure of the final common outcome aim – societal participation. The measure can be completed by family members, individual professionals, rehabilitation professionals, and comprehensive treatment team consensus.

3.4. Procedure

Participants were evaluated upon admission by each program's multidisciplinary treatment team comprised of physicians, nursing, physical therapy, occupational therapy, speech therapy, counseling/psychology, case management, cognitive rehabilitation specialists, and facility-based life skills teachers. Once individual discipline assessments were completed, each participant was then evaluated using the MPAI-4 within 30 days of admission by treatment team consensus. Discharge MPAI-4 s were completed in a similar fashion within the final week of the participant's stay. The results of the evaluations were then compiled into a national database. The study participants were selected from that national database based on their program type upon admission.

A repeated measure multivariate analysis of variance (MANOVA) was provided to evaluate change scores with Abilities, Adjustment, and Participation Indices from admission to discharge. Efficacy of programming was determined by using this statistical approach.

Regression analyses were conducted to determine the MPAI-4 variables that best predicted functional outcome at discharge for each group. The participation T-score was used as the dependent variable in each of the regression analyses because it provides a measure of independent functioning. In cognitive neuroscience, there are five primary areas of cognitive functions with executive functions falling at the highest and most complex level. The primary reason executive functions are the highest level is because this system requires functioning and interaction of the other systems to produce cognitive, behavioral, communication and physical functioning to meet daily challenges (Godefroy, 2003; McDonald, Flashman & Saykin, 2002). The success of the interaction is based on the success of this system operating efficiently and effectively. Measuring the various primary and secondary functions of the frontal system is possible through the use of portions of the MPAI-4. The Abilities Index includes mobility, verbal communication, and novel problem solving. The Adjustment Index includes neurobehavioral components identified as Irritability-Anger-Aggression, Impaired Social Interaction, and Impaired Awareness. The Participation Index measures the functional generalization of skills including Initiation, Self-Care and Residence (functional living skills). As such, these variables were used in the regression analyses as predictors of outcome. Other variables included were length of stay, length of time from onset of injury to admission, and age.

Stepwise multiple regression was the primary method used to identify the best set of predictor variables from those listed above. The stepwise multiple regression analysis searches for predictive relationships within a data set but is prone to overestimation of the statistical significance between variables yielding results that may be sample dependent (Type 1 error). To reduce this risk, each group was randomly divided into two independent sub-groups. The predictor variables were entered into the equation for the first independent sub-group. To validate the results of the stepwise regression, the significant predictor variables were then entered into a Hierarchical Regression using the second independent sub-group. This procedure was followed for each program type with the exception of supported living. Protection against Type 1 error was achieved in the other three groups by stepwise regression followed by the hierarchical regression because of adequate sample size. However, due to the smaller sample size for supported living ($n = 86$), the procedure for this group followed hierarchical regression only. For

Table 2
Prediction of participation T-score at discharge for *neurorehabilitation* participants

Predictor Variable	Stepwise Regression			Hierarchical Regression		
	R-Square Added	Cumulative R-Square	Final Beta	R-Square Added	Cumulative R-Square	Final Beta
Initiation	0.361***	0.361	0.329***	0.283***	0.283	0.221***
Self-care	0.110**	0.471	0.187***	0.160***	0.443	0.283***
Residence	0.017**	0.488	0.138**	0.018***	0.461	0.118**
Inappropriate Social	0.012**	0.501	0.119**	0.035***	0.496	0.193***
Mobility	0.011**	0.511	0.136**	0.005*	0.501	0.09*
Verbal Communication	0.006*	0.517	0.096*	0.013**	0.513	0.124**

*$p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

further review procedures for controlling for Type 1 error using multiple regression, the reader is referred to Cohen and Cohen (1975).

4. Results

4.1. Active neurorehabilitation

Effectiveness. Program effectiveness was evaluated by examining differences in MPAI-4 T-scores from admission to discharge. A Repeated Measures Multivariate Analysis of Variance revealed a significant pre-post main effect $F(1,807) = 959.3$, $p = .0001$. Ratings on each of the three MPAI-4 T-scores were significantly improved from admission to discharge. The mean admission and discharge scores were: 55 vs 47 for abilities, 47 vs 41 for adjustment, and 56 vs 48 for participation. Given the chronic nature of this population (average onset from injury to admission of 22 months), these considerable gains are strongly supportive of the benefits of post-hospital neurorehabilitation in reducing disability caused by brain injury.

Predictive findings. The sample of 808 neurorehabilitation participants was then randomly divided into two independent groups using SPSS Version 22. The first analysis, stepwise multiple regression, identified six significant predictors of discharge participation T-score: initiation, self-care (activities of daily living), residence (managing a home environment), inappropriate social interaction, mobility and verbal communication, $R^2 = 0.52$, $F(6,358) = 63.98$, $p < .0001$ (adjusted $R^2 = .509$). Of those variables, **Initiation** predicted the largest portion of variance in discharge participation T-score (adjusted R^2.361). **Self-care** skills at admission increased the prediction of discharge outcome by 11%. The validation hierarchical regression with those six variables entered was also significant ($R^2 = .513$, $F(6,395) = 69.32$, $p < .0001$). Each of the six variables increased the multiple R to its final level of .513 (adjusted $R^2 = 0.506$). Again initiation and self-care skills at admission were the strongest predictors. Table 2 displays the predictive findings for the two analyses.

4.2. Neurobehavioral intensive

Effectiveness. Program effectiveness was evaluated by examining differences in MPAI-4 T-scores from admission to discharge. A Repeated Measures MANOVA revealed a significant main effect for Abilities, Adjustment, and Participation T-scores from admission to discharge, $F(1,121) = 7.19$, $p < 0.01$. On each subscale, participants showed significant improvement in function from admission to discharge. Mean admission and discharge scores were: Abilities 52 vs 47, Adjustment 49 vs 45, and Participation 56 vs 51. This improvement in functional again is noteworthy given the time from onset of injury to admission into the program was almost seven years.

Predictive findings. The sample of 122 was randomly divided into two independent sub-groups of 61 participants. A step-wise multiple regression analysis conducted with the first sub-group revealed that **Impaired Awareness and Self-care skills** predicted discharge participation T-scores, $R^2 = 0.50$, $F(2,49) = 24.53$, $p < 0.0001$, (adjusted R^2 .48) with **Impaired Awareness** accounting for 36% of the variance, and Self-care providing an additional 13.8%. A follow-up hierarchical regression with the second independent sub-group was completed with impaired awareness and self-care entered was also significant, $R^2 = 0.42$, $F(2,58) = 27.79$, $p < 0.0001$ (adjusted R^2 .40). In this analysis, self-care was the strongest predictor, accounting for 34% of the variance. Table 3 displays the beta weights, predictive contributions, and cumulative R^2 for the two analyses.

4.3. Day treatment

Effectiveness. Program effectiveness was evaluated by examining differences in MPAI-4 T-scores

Table 3
Prediction of participation T-score at discharge for *behavior intensive* participants

Predictor Variable	Step-wise Regression			Hierarchical Regression		
	R-Square Added	Cumulative R-Square	Final Beta	R-Square Added	Cumulative R-Square	Final Beta
Impaired Awareness	0.362***	0.362	0.508***	0.146**	0.146	0.387***
Self-care	0.138***	0.500	0.383***	0.344***	0.489	0.429***

**$p < 0.01$; ***$p < 0.001$.

Table 4
Prediction of participation T-score at discharge for *day treatment* participants

Predictor Variable	Step-wise Regression			Hierarchical Regression		
	R-Square Added	Cumulative R-Square	Final Beta	R-Square Added	Cumulative R-Square	Final Beta
Self-care	0.358***	0.358	0.523***	0.366***	0.366	0.379***
Initiation	0.138***	0.496	0.301***	0.127***	0.493	0.313**
Onset of injury	0.058**	0.549	0.206***	0.046*	0.536	0.176*
Irritability	0.034*	0.583	0.197*	0.034*	0.570	0.198*

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

from admission to discharge. A Repeated Measures MANOVA revealed a significant main effect for Abilities, Adjustment, and Participation Indices of the MPAI-4 from admission to discharge for the Day Treatment group, $F(1,145) = 105.9$, $p < 0.000$. Mean admission and discharge T-scores were: Abilities 51 vs 45, Adjustment 43 vs 38, and Participation 51 vs 44.

Predictive findings. The Day Treatment group ($n = 146$) was randomly divided into two independent sub-groups for regression analyses. The stepwise multiple regression analysis conducted on the first independent sub-group found that the admission variables of self-care, initiation, along with length of time of injury onset to admission, and irritability predicted discharge participation T-score, $R^2 = 0.58$, $F(4,65) = 22.68$, $p < 0.0001$ (adjusted R^2 .56). **Self-care** predicted 36% of participation T-score, with **Initiation** adding another 14% to the total variance. The follow-up hierarchical regression with those four variables entered was also significant, $R^2 = 0.57$, $F(4,62) = 20.5$, $p < 0.0001$ (adjusted R^2 .542). Validating the first finding, self-care ($R^2 = 0.37$) and initiation ($R^2 = 0.13$) also accounted for 50% of the variance in discharge participation T-score. Table 4 presents the predictive findings for day treatment.

4.4. Supported living

Effectiveness. Program effectiveness was evaluated by examining differences in MPAI-4 T-scores from admission to discharge. A Repeated Measures MANOVA revealed a significant main effect for Abilities, Adjustment, and Participation Indices of the MPAI-4 from admission to discharge for the Supported Living group $F(1,85) = 17.58$, $p < 0.001$. Mean admission and discharge T-scores were as follows: Abilities 52 vs 48, Adjustment 46 vs 44, and Participation 54 vs 52. As would be expected with chronic injury effects, these differences were not as great as observed within the active rehabilitation or within the neurobehavioral intensive groups, but nonetheless demonstrated statistical and functional improvement at program completion.

Predictive findings. To predict participation T-score at discharge for the supported living programs, predictor variables were entered into the regression equation in four hierarchical blocks only, due to sample size limitations. Length of time from onset of injury to admission was selected a priori in the first hierarchical block. This variable predicted 11.8% of the variance for discharge participation T-score. Admission items of initiation, self-care, and residence were entered by stepwise inclusion into the second block. Inclusion of these variables increased the multiple R to its final level of.659 (adjusted R-squared.637). **Self-care** made the greatest contribution to prediction of outcome adding 46.2% of the variance within the model. **Initiation** made the second greatest contribution within the block adding 9% to the total variance. The variables in the third block included mobility, verbal communication, novel problem solving. The variables in the fourth block included irritability, inappropriate social behavior, and impaired self-awareness. The third and fourth block variables did not improve the prediction significantly. Predictive findings for supportive living are summarized in Table 5.

Table 5
Prediction of participation T-score at discharge for *supported living* participants

Block number and Predictor	R-Square Added	Cumulative R-Square	Final Beta
1. Onset of injury	0.118**	0.118	0.216**
2. Self-care	0.462***	0.544	0.420**
Initiation	0.093***	0.637	0.292***
Residence	0.022*	0.659	0.179

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 6
MPAI-4 Predictors of outcome across program types

Program Type	Highest Predictor	Second Highest Predictor
Active Neurorehabilitation	*Initiation*	*Self-Care*
Neurobehavioral Intensive	*Impaired Self-Awareness*	*Self-Care*
Day Treatment	*Self-Care*	*Initiation*
Supported Living	*Self-Care*	*Initiation*

5. Discussion

The purpose of this research was to illustrate a post-hospital continuum of care for adults with moderate to severely acquired brain injury and to evaluate program effectiveness focusing on those variables most important for achieving functional independence. The need for rehabilitative care beyond acute hospitalization and acute rehabilitation is well established. Serious brain injury is now viewed as a chronic condition with residual deficits that can persist throughout one's lifespan, disrupting performance of the most basic functions necessary for a satisfying life. It is estimated that more than three million people in the United States are living with significant disability resulting from moderate to severe brain injury (Zaloshnja, Miller, & Langlosis, 2008).

A very positive finding of this study was that on average, participants in each of the four program levels realized meaningful reduction in disability from admission to discharge. As would be expected, those achieving the greatest gains were participants with the shortest length of time from injury to admission (average = 22 months) being treated in the active neurorehabilitation programs. Day treatment participants, with an average onset of injury to admission of almost 2 years, also appreciated meaningful and statistical gains with services. Typically, these two services fall in succession to help transition care. Therefore, when reviewing these two groups together, the results clearly demonstrate that each program shows positive differences from admission to discharge. Progressing from the active neurorehabilitation to day treatment also shows a reduction in the total number of variables that contribute to predictive outcome. This reduction enables a refined rehabilitation focus on those remaining variables that are essential for achieving functional independence and provides a rationale for a continuum of care.

Results from the neurobehavioral intensive and supportive living programs are particularly noteworthy. The behavior intensive participants had an average onset of injury to admission of 6.7 years, yet they demonstrated significant improvement on the MPAI-4 Abilities, Adjustment, and Participation T-scores from admission to discharge (mean LOS = 294 days). Similarly, supported living participants whose onset to admission averaged >7 years also showed statistically significant improvement on those measures (mean LOS = 348 days). These findings offer a definitive answer to the first question posed in this study: post-hospital rehabilitation is effective in reducing functional disability following moderate to severe brain injury, even with chronically injured individuals.

The second purpose of this study was to identify those variables that have the greatest impact on functional outcome at each level of care across the post-hospital continuum. An interesting finding was that different programs had different outcome predictors suggesting that there are distinct program types that can be identified using the MPAI-4 to characterize those differences. Further, within each group, there were two predictors accounting for up to 50% of the variance. These predictors become important when formulating rehabilitation planning for treatment outcomes. The surprising finding was the overlap of Self-care for all four groups investigated. Further, three of four groups had Initiation as a predictor as well (see Table 6). As noted earlier, executive functioning requires integration of other motor, sensory, cognitive, and behavioral systems. Initiation and Self-care are part of the executive function system and this may be one reason why these two variables are consistent across groups.

The active neurorehabilitation program had Initiation as the primary predictor. This group had the highest level of acuity, as defined by the least amount of time from injury onset to post-hospital admission, and by higher admission MPAI-4 Abilities Index T-scores. As such, initiating activity, cognitive skills, and productive behavior is often the focus of care. At this level of injury, the emphasis is focused on creating momentum toward greater independence. To move from a residential level of care to living in the community, participants then have to demonstrate adequate skills in self-care, which is not possible without cognitive and behavioral initiation.

The neurobehavioral intensive group had Impaired Self-awareness and Self-care as the primary predictors of outcome. At a functional level, the crux of the behaviorally intensive group is a limited understanding of their behavioral impact on self-regulation and interaction with others. This creates the greatest challenge when away from a structured milieu. As such, treatment programs may consider emphasizing self-awareness as a way to help participants manage with less structure.

In the day treatment group, like the active neurorehabilitation group, Initiation and Self-care were important predictors. However, the order of importance of those predictors was reversed in the day treatment group. Self-care was the strongest predictor of outcome; Initiation impairment may be reflective of higher acuity of injury in the active neurorehabilitation group.

The Supported Living group demonstrated improvement overall, which was contrary to prior research notions that the greatest proportion of recovery may occur within the first year (Selby, 2000). Rather, this group's improvement was likely reflective of the milieu provided in supported living programs and with the emphasis on health care stabilization for participants. It is interesting that self-care and initiation remain significant predictors of outcome >7 years post injury.

5.1. Limitations

Limitations of the study would include the unavailability of follow up data to investigate the durability of these changes following discharge. A second limitation was the sample size for supported living. As noted, this is a group that has very few discharges. It is possible that those that remained in the program may also show gains or possible losses based on medical management, but could not be investigated within the scope of this study.

6. Conclusions

In conclusion, the results of the study demonstrated evidence that improvement can be achieved at the post hospital care level even with an extensive length of time since injury, and differences with program type (e.g., active neurorehabilitation, neurobehavioral intensive, day treatment, supported living). There are differences in program groups that can be identified statistically by using the MPAI-4. The primary predictor of positive outcome for all programs was Self-care. In addition, Initiation was the second most common predictor of outcome, followed by impaired self-awareness for the neurobehavioral intensive group only. The results of this research may provide a systematic method to formulate intervention strategies to further enhance recovery along a continuum of care.

References

Brain Trauma Foundation (2007). Guidelines for the management of severe acquired brain injury. *Journal of Neurotrauma*, *24*(1), 1-106.

Center for Disease Control Health, United States (2013). *National Center for Health Statistics*. Hyattsville, MD.

Cohen, J., & Cohen, P. (1975). *Applied Multiple Regression/Correlation Analysis for the Behavioural Sciences*. Lawrence Erlbaum, Hillsdale.

Cope, N. D., Cole, J. R., Hall, K. M., & Barkans, H. (1991). Brain injury: Analysis of outcome in a post-acute rehabilitation system. Part I: General analysis. *Brain Injury*, *5*, 111-125.

Godefroy, O. (2003). Frontal syndrome and disorders of executive functions. *Journal of Neurology*, *250*(1), 1-6.

Hayden M. E., Plenger P., Bison K, et al. (2013). Treatment effect versus pretreatment recovery in persons with acquired brain injury: A study regarding the effectiveness of post-acute rehabilitation. *American Academy of Physical Medicine and Rehabilitation*, (4), 319-327.

Horn, G. J., & Lewis, F. D. (2013). Analysis of post-hospital rehabilitation outcomes. *Journal of Head Trauma Rehabilitation*, *28*(5), E 57.

Horn, G. J. & Lewis, F. D. (2014). A model of care for neurological rehabilitation. *Journal of Nurse Life Care Planning*, *14*(3), 681-692.

Johnston, M., & Lewis, F. D. (1991). Outcomes of community reentry programs for brain injury survivors. Part 1. Independent living and productive activities. *Brain Injury*, *5*, 141-154.

Langlosis, J. A., Rutland-Brown, W., & Wald, M. (2006). The epidemiology and impact of acquired brain injury: A brief overview. *The Journal of Head Trauma Rehabilitation*, *21*(5), 375-378.

Lewis, F. D., & Horn, G. J. (2013). Acquired brain injury: Analysis of functional deficits and post-hospital rehabilitation outcomes. *Journal of Special Operations Medicine*, *13*(3), 56-61.

Lewis, F. D., & Horn, G. J. (2014). Post-hospital brain injury rehabilitation: Comparison of neurobehavioral intensity and neurorehabilitation outcomes. *Archives of Physical Medicine and Rehabilitation*, (in press).

Malec, J. E., & Brasford, J. S. (1996). Post acute brain injury rehabilitation. *Archives of Physical Medicine and Rehabilitation*, *77*, 198-207.

Malec, J. F., & Lezak, M. D. (2008). The Mayo-Portland Adaptability Inventory (MPAI-4) for adults. *Child Adolescence Manual*, 1-84.

McDonald, B. C., Flashman, L. A., & Saykin, A. J. (2002). Executive dysfunction following traumatic brain injury: Neural substrates and treatment strategies. *NeuroRehabilitation*, *17*(4), 333-344.

Nudo, R. (2003). Adaptive plasticity in motor cortex: Implications for rehabilitation after brain injury. *Journal of Rehabilitation Medicine*, *41*, 7-10.

Selby, M. J. (2000). Overview of neurology. In: G. Groth-Marnat (editor). *Neuropsychological Assessments in Clinical Practice*. (John Wiley & Sons), pp. 48-93.

Zaloshnja, E., Miller, T., & Langlosis, J. (2008). Prevalence of long-term disability from traumatic brain injury in the civilian population of the United States. *Journal of Head Trauma Rehabilitation*, *23*, 394-400.