

Traumatic Brain Injury: Analysis of Functional Deficits and Posthospital Rehabilitation Outcomes

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ABSTRACT

Background: Advances in emergency medicine, both in the field and in trauma centers, have dramatically increased survival rates of persons sustaining traumatic brain injury (TBI). However, these advances have come with the realization that many survivors are living with significant residual deficits in multiple areas of functioning, which make the resumption of a quality lifestyle extremely difficult. To this point, TBI has recently been characterized as a chronic disease. As with other chronic diseases, TBI is often causative of persistent disabling symptoms in multiple organ systems. Therefore, posthospital residential rehabilitation programs have emerged to treat these symptoms with the goal of helping these individuals regain function and live more productive and independent lives. **Purpose:** This study examined the nature and severity of residual deficits experienced by a group of 285 brain-injured individuals and evaluate the efficacy of posthospital residential rehabilitation programs in treating those deficits. **Method:** Participants consisted of 285 individuals who had sustained a TBI and, due to multiple residual deficits, were unable to care for themselves, necessitating admission to residential posthospital rehabilitation programs. All participants were evaluated at admission and discharge on the Mayo-Portland Adaptability Inventory–Version 4 (MPAI-4). The MPAI-4, developed specifically for persons with acquired brain injury, measures 29 areas of function often affected by TBI. **Results:** From the 29 skills evaluated, the 12 most often rated as causing the greatest interference with function were identified. Of these skills, the cognitive deficits including memory, attention/concentration, novel problem solving, and awareness of deficits were highly correlated with disruption in performing everyday societal roles. The impact of treatment for reducing the level of disability in these areas was statistically significant, $t(284) = 17.43$, $p < .0001$. Improvement was significant even for participants admitted more than 1 year postinjury, $t(78) = 8.05$, $p < .0001$. **Conclusions:** Skill deficits interfering with reintegration into home and community are highly interrelated and should be treated with the understanding that progress in one area may be dependent on change in

another area. Cognitive skills including memory, attention/concentration, novel problem solving, and awareness of deficits were highly correlated with measures of overall functional outcome. Posthospital programs using a multidisciplinary treatment approach achieved significant reduction in disability from program admission to discharge. The benefits of these programs were realized even for the most chronically-impaired participants.

KEYWORDS: *traumatic brain injury, Mayo-Portland Adaptability Inventory–Version 4, posthospital residential rehabilitation programs, acquired brain injury*

Introduction

It is well known that traumatic brain injury (TBI) often leads to residual impairments that persist well beyond the hospital level of care. Residual complications may include physical, cognitive, emotional, behavioral, and functional symptoms.¹ In the acute stage of recovery (0–6 months), dramatic improvements may occur but not equally for all categories of symptoms. For instance, physical improvements often occur earlier than cognitive improvements. Emotional features are often blunted for the initial 6 months of recovery due to impaired insight and awareness, then become more prominent in the chronic phase of recovery (>6 months) as an individual experiences the impact of residual deficits on everyday functioning. Over the past decade, reports have documented the need for Soldiers who have sustained a TBI to have extensive care to help them reintegrate into their former roles at home and in the community.²

This type of extensive care is provided by posthospital comprehensive TBI rehabilitation programs. Under the direction of a physician, these programs typically offer physical, occupational, speech, and psychological therapies to treat the residual deficits following TBI. Evaluation of the effectiveness of these programs, however, has been limited due to a lack of standardized functional outcome measures. To address this problem, Malec and

Lezak developed the Mayo-Portland Adaptability Inventory (MPAI).³ Now in its 4th version, “the MPAI-4 was designed to assist in the clinical evaluation of individuals during the postacute/posthospital period following acquired brain injury (ABI), to assist in the evaluation of rehabilitation programs designed to serve these people, and to better understand the long-term outcomes of ABI.”³ Because of the instrument’s strong reliability and validity data, the MPAI-4 can provide a clear indication of the problems experienced by TBI survivors and the effectiveness of posthospital programs in treating those problems. Therefore, the MPAI-4 was selected for use with participants in this study.

The purpose of this study is 2-fold. The first objective is to describe the nature and severity of the problems experienced by today’s TBI survivors after hospital care within the United States. Those studied were within a facility-based, posthospital level of care requiring supervision for all activities. The second objective is to evaluate the efficacy of residential posthospital brain injury programs in reducing disability and improving independent functioning.

Methods

Subjects

The total sample consisted of 416 neurologically impaired individuals (e.g., traumatic, cerebrovascular, tumor, anoxic, etc.) referred to NeuroRestorative, a large provider of posthospital comprehensive rehabilitation care with community-based facilities located throughout the United States. From that total sample, 285 participants who met the criteria of sustaining a TBI (closed and open trauma) were included in the study. Table 1 presents the causes of the traumatic injuries for the current sample. The most frequent cause of injury was automobile accidents (38%) followed by falls (23%). Closed head injury was the primary diagnosis for 274 cases, and

Table 1 Cause of Injury

Injury Cause	Percentage (N = 285)
Automobile accident	38
Falls	23
Motorcycle	10
Gunshot	5
Hit by flying object	5
Assault	4
Pedestrian hit by car	3
Bicycle	2
Blast injury	2
Other (not specified in record)	8

11 cases suffered open brain trauma. The average age at admission was 41 years (standard deviation [SD] = 14.7 years, range = 15–79 years). Most of the participants were male, accounting for 82% of the sample. The onset of injury to admission averaged 27 months (SD = 60 months, range = 1–437 months). The average length of stay in the treatment facilities was 20 weeks (SD = 37 weeks, range = 1–485 weeks).

Rehabilitation Treatment

Each participant within the NeuroRestorative active neurorehabilitation program received physical therapy, occupational therapy, speech therapy, recreation, counseling (based on need), case management, and medical management provided by nursing and physicians specializing in physical medicine and rehabilitation. Posthospital rehabilitation integrates a traditional therapeutic regimen with applied life skills incorporating residential skill building (e.g., cleaning, kitchen use), money management, community application of skills and integration (e.g., shopping, leisure activity, volunteering), and social skills acquisition. Behavioral analysis was also provided for cases requiring more extensive modification to reduce inappropriate behaviors and increase positive replacement behaviors. On average, 3 hours of traditional rehabilitation was provided with an additional 6–8 hours of life skills acquisition including community integration. Weekends incorporated time in the community to develop leisure and social skills. Treatment team management and physician review were provided biweekly, and nursing was provided daily for medication management and medical needs assessment. Twenty-four-hour activities of daily living assistance was provided for those with greater physical impairments and/or cognitive impairments requiring extensive cues/redirection.

Measure

Participant functioning was assessed on the MPAI-4 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 3 subscales: Ability Index, Adjustment Index, and Participation Index. Each index has an average of 50 and an SD of 10 points. The MPAI-4 and its 3 subscales (Abilities Index, Adjustment Index, and Participation Index) offer measures with highly-developed and well-documented psychometric properties. Person reliability studies for the MPAI-4 range from 0.78 to 0.88³. 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. Table 2 shows the 29 items on the MPAI-4 as distributed within the indices.

Table 2 MPAI-4 29 Items by Index

Abilities Index	Adjustment Index	Participation Index
Mobility	Anxiety	Initiation
Use of hands	Depression	Social contact
Vision	Irritability, anger, aggression	Leisure skills
Audition	Pain and headache	Self-care
Dizziness	Fatigue	Residence
Motor speech	Sensitivity to mild symptoms	Transportation
Communication	Inappropriate social Interaction	Paid employment
Attention/concentration	Impaired self-awareness	Other employment
Memory		Managing money and finances
Fund of information		
Novel problem solving		
Visuospatial abilities		

Procedure

Each participant was evaluated on admission by the NeuroRestorative multidisciplinary treatment team composed of physicians, nursing, physical therapy, occupational therapy, speech therapy, counseling/psychology, case management, and cognitive rehabilitation specialists. Once individual evaluations were completed, each participant was then evaluated with the MPAI-4 within 30 days of admission by treatment team consensus. Discharge MPAI-4s 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 diagnosis on admission.

Results

The first aim of the study was to determine the nature and severity of the problems experienced by TBI survivors after hospital care. This was done using simple frequency counts across all levels of the 5-point rating scale for each of the 29 items. Table 3 shows the 12 skills most frequently rated in the severe range of functioning

on admission for the participant sample. To be included in this list, the skill had to be rated as severely interfering with performance for at least 20% of the participants. The 4 skills most frequently cited as being severely impaired were residential independence (51.9%), money management (49.1%), leisure and recreation (40.4%), and social contact (34.4%). Each of these skills are within the Performance Index and largely dependent on items on the Abilities and Adjustment Indices. To more closely evaluate these relationships, Pearson correlations were calculated among the 12 items. Table 4 shows these correlations. As revealed in that table, the majority of items are highly correlated with cognitive functions contributing to adjustment and participation. With family relationships removed, 109 of 110 Pearson correlations were statistically significant and were greater than or equal to $r(284) = 0.22, p < .05$, 2-tailed. The correlation between awareness and mobility was non-significant. This result shows that performance on the skills is highly interrelated so that deficits in one area are associated with difficulty in many others.

The second objective of this study was to evaluate the efficacy of posthospital brain injury programs in reducing disability and improving independent functioning. The most common confound faced by clinicians and researchers examining program effectiveness is "time or spontaneous recovery." It has long been reported that the rate of recovery declines dramatically following 6 months post injury, and certainly by 1 year.⁴ Given that a randomized clinical trial is not feasible in treatment facilities, statistical control for chronicity (onset to admission) was seen as the next best option and was used in 2 ways in the current study. First, onset to admission was regressed on participation discharge *T*-scores. The participation *T*-score was used as the dependent variable because it provides a good measure of independent functioning. Second, improvement was tested using the Wilcoxon *z*-test for participants admitted more than 1 year post injury. One year was selected as the cutoff because it was considered a conservative measure of chronicity.

The first analysis revealed that participants admitted before 6 months post injury improved significantly more on the participation *T*-score (admission to discharge difference) than those admitted later ($r = 16.5, p < .05$). A post-hoc least significant difference (LSD) analysis revealed that after 6 months post onset, improvement did not vary as a function of time even at $p < .05$. In the second analysis, the participants admitted after 1 year post injury showed significant improvement on 11 of the 12 MPAI-4 items from admission to discharge, Wilcoxon *z* tests greater than or equal to $z = -1.98, p < .05$. The only item not achieving statistically significant change was "family relationships." However, this area approached significance at $p < .07$. Thus, even the more chronic

Table 3 Distribution of Admission MPAI-4 Ratings for the Most Severely Impaired Skills

MPAI-4 Skills	Severe Problem: >75% Interference	Moderate Problem: Interferes 25%–75% of the Time	Mild Problem: Interferes 5%–24% of the Time	Mild Problem– No Interference: May Use Assistive Device or Medication	No Problem
Residence (level of independence in the home)	51.9	30.9	13.7	2.1	1.4
Money management	49.1	32.3	13.0	3.9	1.8
Leisure and recreational activities	40.4	35.1	15.4	3.5	5.6
Social contact	34.4	34.0	19.3	8.1	4.2
Novel problem solving	31.9	34.0	22.8	7.0	4.2
Impaired self-awareness	31.2	30.9	21.1	11.2	5.6
Memory	27.4	41.8	21.8	6.3	2.8
Initiation	25.3	30.9	22.1	13.0	8.8
Attention/concentration	23.5	40.4	20.7	11.9	3.5
Family relationships	22.8	35.8	21.8	11.6	8.1
Mobility	22.5	22.1	17.2	21.8	16.5
Self-care	21.4	19.6	22.8	18.6	17.5

Notes: Numbers indicate the percentage of the 285 participants who were rated in each severity category (on the MPAI-4 scale, severe = 4, moderate = 3, mild = 2, mild without problems = 1, and none [no problems] = 0).

Table 4 Correlations Among MPAI-4 Most Severely Rated Skills

MPAI-4 Skill	1	2	3	4	5	6	7	8	9	10	11	12
1. Mobility	—	0.24	0.23	0.24	0.10	−0.04	0.34	0.23	0.33	0.71	0.46	0.30
2. Attention/concentration	0.24	—	0.59	0.64	0.51	0.24	0.46	0.37	0.43	0.34	0.45	0.44
3. Memory	0.23	0.59	—	0.63	0.48	0.09	0.49	0.33	0.35	0.30	0.37	0.40
4. Problem solving	0.24	0.64	0.63	—	0.62	0.22	0.55	0.48	0.48	0.36	0.43	0.48
5. Awareness	0.10	0.51	0.48	0.61	—	0.26	0.51	0.48	0.45	0.31	0.36	0.39
6. Family relations	−0.04	0.24	0.09	0.22	0.26	—	0.12	0.27	0.25	0.01	0.07	0.10
7. Initiation	0.34	0.46	0.49	0.55	0.51	0.12	—	0.49	0.54	0.48	0.39	0.45
8. Social contact	0.23	0.38	0.33	0.48	0.48	0.27	0.49	—	0.62	0.33	0.41	0.31
9. Leisure	0.33	0.44	0.35	0.48	0.45	0.25	0.54	0.62	—	0.42	0.51	0.38
10. Self-care	0.71	0.34	0.30	0.36	0.31	0.01	0.48	0.33	0.42	—	0.55	0.47
11. Residence	0.47	0.45	0.38	0.44	0.36	0.07	0.39	0.41	0.51	0.55	—	0.53
12. Money management	0.30	0.44	0.40	0.48	0.39	0.10	0.45	0.31	0.38	0.47	0.53	—

Notes: Coefficient values in bold are significant ($p < .05$).

participants benefited from the posthospital comprehensive rehabilitation programs.

The ensuing analyses were conducted on the total sample of 285 participants. Improvement on the 12 most severely rated skills was statistically significant at the $p < .001$ level. Table 5 shows the Wilcoxon z significant levels and the number of cases improving for each skill. Next, to evaluate improvement on the overarching outcome goal of participation in societal roles, a comparison of admission and discharge Participation T -scores was

made. The difference between these scores was statistically significant, $t(284) = 17.43$, $p < .0001$, indicating a positive reduction in overall disability experienced in the performance of everyday activities. This difference was significant even for the more chronic participants who were admitted at least 1 year after injury $t(78) = 8.05$, $p < .0001$.

Discussion

In 2009, the Brain Injury Association of America published a position paper in which the authors characterized

Table 5 Functional Improvement From Admission to Discharge on 12 MPAI-4 Subscales Rated Most Severely Impaired at the Time of Admission

	Mobility	Attention/ Concentration	Memory	Problem Solving	Awareness of Deficits	Family Relationships
No. improving	157 (55%)	144 (51%)	156 (54%)	134 (47%)	131 (46%)	103 (36%)
	Initiation	Social Contacts	Leisure Activity	Self-care Skills	Residence Skills	Money Management
No. improving	138 (48%)	140 (49%)	164 (58%)	158 (55%)	164 (58%)	138 (48%)

Notes: All Wilcoxon Z tests were significant at $p < .0001$. The percentages reflect the participants of the total sample who improved on that subscale.

TBI as a “chronic disease” rather than a “single event or final outcome.”⁵ Essential to this conceptualization is the fact that TBI disrupts neurological functioning, resulting in deficits that remain with the individual, at least in some ways, throughout life. It is estimated that more than 3 million persons in the United States are living with significant disability resulting from a TBI.⁶ The first objective of this study was to identify the nature and severity of those deficits. Consistent with previous literature,⁷ the present study found that cognitive skills were among the most severely impaired of the 29 MPAI-4 items. Cognitive functions including memory, attention/concentration, novel problem solving, and awareness of deficits were highly correlated with the ability to care for oneself, engage in leisure activities, and interact socially with friends. Consequently, posthospital rehabilitation programs should make treating these deficits a major focus of intervention in order to maximize positive outcomes. Each of the facilities in this study employed specialists (e.g., speech pathologists, occupational therapists, psychologists) to address cognitive deficits.

The second objective of this study was to evaluate the efficacy of residential posthospital brain injury programs in reducing disability and improving independent functioning. First, consistent with the results of recent research by Hayden et al.,⁸ we found that persons receiving posthospital rehabilitation within the first 6 months of injury showed the greatest improvement from admission to discharge in the 12 most severely impaired skills. However, even the most chronic participants (onset to admission of longer than 1 year) experienced statistically significant improvement, including improvement in persistent cognitive deficits. Perhaps even more important, improvements in these skills were associated with a reduction in disability with regard to participation in societal roles for both the acute and chronic groups. The current findings debunk the notion that rehabilitation effectiveness stops following 6 months of neurological recovery. Chronically impaired participants (> 1 year post injury) reduced overall disability as a result of continued comprehensive rehabilitation efforts.

Because of the most recent theatre operations for the military, many United States Soldiers have returned with TBIs and associated complex residual deficits. The current results illustrate the benefits of posthospital residential rehabilitation and offer hope for persons struggling with the problems caused by TBI. Given that, subsequent research should focus on the specific nature, intensity, and duration of treatments to optimize these benefits.

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Disclosures

Dr. Lewis currently serves as the director of Clinical Outcomes Services and as Georgia state clinical director for NeuroRestorative. Dr. Horn currently serves as the deputy director of Clinical Outcomes Services and Florida State clinical director for NeuroRestorative. The authors have no other disclosures.

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