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Progression of Functional Mobility Recovery after a Severe Traumatic Brain Injury: A Case Report

Karen Eilers
University of Iowa

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Karen Eilers

DPT Class of 2019
Department of Physical Therapy & Rehabilitation Science
The University of Iowa

Abstract

Background: Traumatic brain injuries (TBI) can be devastating events that can completely transform individuals' lives. Determining prognosis after a brain injury can be difficult to discern due to the countless variations in injuries and contributing factors that affect rehabilitation. There is no standard physical therapy treatment for addressing TBI's due to the complex integration of the motor cortex with many regions of the brain that impact recovery. **Case Description:** A 62-year-old male sustained a severe TBI resulting from a fall down the stairs. He was found to have a subarachnoid hemorrhage, subdural hematoma, right posterior cephalohematoma and resulting encephalopathy. He spent 4 weeks in acute care and 39 days in an inpatient rehabilitation hospital to improve his functional mobility. Interventions in inpatient rehab utilized neuromuscular electrical stimulation, the Ekso bionic walking device, and task-oriented functional mobility training to work towards his goal of discharging home with his wife. **Outcome Measures:** The Center for Medicare and Medicaid Services GG Codes for Functional Abilities and the Swedish Modified Version of Postural Assessment Scale for Stroke Patients were utilized to demonstrate the functional improvements made during this patient's inpatient rehabilitation stay. **Discussion:** Recovery progression from TBI is difficult to study and predict due to the significant fluctuations in injuries and length of recovery. Neuroplasticity following brain injuries is dependent on timing, the environment, and other concurrent therapies as well as the motivation and attention level of the patient. Multifaceted treatment approaches should be taken to increase likelihood of success. This case demonstrates that despite the low functional initial presentation after a severe TBI, patients can still make dramatic improvements.

Keywords: Physical Therapy; inpatient rehabilitation; traumatic brain injury; recovery; neuromuscular electrical stimulation; bionic walking device; task-oriented functional mobility training

Background (or Introduction)

Traumatic brain injuries (TBI) can be devastating events that can completely transform individuals' lives. There are approximately 52,000 fatal traumatic brain injuries annually, and 275,000 people in the United States are hospitalized for a traumatic brain injury every year.[1] The greatest number of TBI-related emergency department visits occur after individuals suffer a fall. This rate increased among adults aged 65 and older between 2002 and 2006 with a 46% increase in ER visits, 34% increase in hospitalizations, and 27% increase in deaths.[1] Brain injuries can vary in presentation based on severity and region of the brain that is injured. Due to the extreme variety and countless contributing factors that can play into an individual's rehabilitation, prognosis is often difficult to discern.

Extensive research has been done in animal models to assess prognosis, recovery, and beneficial therapeutic interventions for individuals that sustain a stroke. Evidence of recovery of function after stroke suggests that "task-specific practice" facilitates the greatest plasticity.[2] Due to similar presentation of mobility deficits following TBI and stroke as well as decreased evidence available for traumatic brain injuries, there have been many generalizations made from stroke evidence to carry over into treatment of TBI's. One study was done to compare the neuroplasticity after stroke in the same region of the brain as a controlled cortical impact model of TBI. Evidence showed that following the TBI model there was a decrease in dendritic density in surrounding areas as compared to an increase in plasticity and dendritic growth in that same area following stroke.[2] This difference in plasticity between the injuries indicates that carry over of rehabilitation strategies specific to stroke recovery may be less effective when completing them with individuals who suffered a TBI. Further research into beneficial rehabilitation therapies following the controlled cortical impact model of TBI showed greatest improvements in approaches that combined varied rehabilitation tasks.[2]

Traumatic brain injury recovery can be lengthy, unpredictable, and many times individuals are unable to completely return to their previous level of functioning. Approximately 33% of individuals who have suffered a traumatic brain injury require ongoing assistance with at least two activities of daily living.[3] The goal of inpatient rehabilitation physical therapy is to help the patient take the first big steps to returning to their previous level of functioning in order to safely return home. The focus is on bed mobility, transfers, and ambulation/wheelchair mobility in order to increase their independence with daily functioning, improve safety, and decrease the burden of care for their family members and caregivers. The purpose of this case report is to demonstrate rapid functional progress that can occur following multiple rehabilitation intervention techniques to target impaired motor planning after a severe traumatic brain injury.

Case Description

A 62-year-old male suffered a severe traumatic brain injury after a fall down the stairs. This fall resulted in a subarachnoid hemorrhage, subdural hematoma, right posterior cephalohematoma and resulting encephalopathy. Due to the instability and extent of his injuries, this individual spent four weeks in an acute care hospital. He was then transferred to a neurological inpatient rehabilitation hospital where he would receive further medical care and therapies. Upon admission he was dependent for all mobility. Due to his inability to initiate movements he was dependent for rolling in bed, laying down, and sitting up. Nursing and therapy staff completed dependent slideboard transfers in order to move him from one surface to another and complete daily cares. He required a tilt-in-space wheelchair for improved safety due to trunk instability and inability to sit with upright posture in a standard wheelchair. This individual had no active movement of his lower extremities and had minimal volitional upper extremity movements. He was able to make small amplitude reaches towards a target volitionally but was unable to complete any movement upon command. Due to his low level of functioning, standing and walking were unable to be assessed upon initial evaluation. He additionally had significant cognitive impairments and was only oriented to person. Due to these deficits in cognition and command following, sensation and strength were unable to be formally assessed. This patient and his family's ultimate goal was for him to return home with the hopes of being able to go back to farming.

He was followed by a physiatrist, neuropsychologist, case manager, social worker, nursing staff, speech therapist, occupational therapist, and physical therapist during his rehab stay.

Outcome Measures

One of the functional outcome measures that was used at initial evaluation and discharge to assess functional skills was the Center for Medicare and Medicaid Services (CMS) GG Codes for Functional Abilities. This measure requires documentation of the level of assistance for various mobility items including: rolling, sit to/from supine, sit to/from standing, transfers, ambulation, picking up an object, and wheelchair mobility. After completion of an item, it is scored from 1 to 6 with higher scores indicating less assistance needed. If the item is unable to be assessed, it is scored with another coded number based on the reasoning behind not assessing. [4] Table 1 displays the scoring and specific definition of each assistance level. Due to the recent implementation of the CMS GG Codes with trials beginning in January 2019 and full utilization in October 2019, the reliability is not yet known. While it is being used, the degree to which change is more within its expected error may not be clear.

Table 1. Modified from Center for Medicare and Medicaid Services Coding Table [4]

Code	Assistance Level	Description
6	Independent	Safely completes activity without assistance.
5	Set-up or clean up assistance	Requires assistance prior to or following activity but can complete activity safely and independently.
4	Supervision or touching assistance	Assistance provided throughout activity for verbal cues, touching, and/or contact guard assistance to complete the activity safely.
3	Partial/moderate assistance	Assistance required to complete the activity with helper providing LESS than 50% of the work.
2	Substantial/maximal assistance	Assistance required to complete the activity with helper providing MORE than 50% of the work.
1	Dependent	100% of the work is completed by the helper for the activity OR assistance of 2+ helpers
7	Patient refused	
9	Not applicable	Did not perform the activity prior to current situation
10	Not attempted due to environmental limitations (ex: lack of equipment, weather)	
88	Not attempted due to medical condition or safety concern	

One standardized assessment that was utilized to measure progress from initial evaluation to discharge from inpatient rehabilitation was the Swedish Modified Version of Postural Assessment Scale for Stroke Patients (SwePass). This measure was designed for stroke patients. However, based on this patient's very low functional level upon admission, it was utilized to quantify the level of assistance required for this patient's functional mobility. The SwePass assesses twelve items and ranks the individual from 0 to 3 based on the amount of support that is required to complete the task for a total of up to 36 points. A higher score indicates better postural control. A score less than 32 is indicative of being a fall risk.[5] The SwePass has high test-retest reliability.[6] Additionally it also has high interrater reliability.[7] The transitional movements that are assessed are: rolling supine to affected side, rolling supine to non-affected side, supine to sitting edge of bed, sitting without support, sitting to standing up, standing with support, standing without support, standing on non-paretic leg, standing on paretic leg, standing and picking up a shoe from the floor, sitting down from standing up, and sitting on edge of bed to supine.

Interventions

This patient spent 39 days in this inpatient rehabilitation hospital. During his inpatient rehabilitation stay, the patient received sixty minutes of speech therapy, occupational therapy, as well as physical therapy every day for a total of three hours, five days per week. As his cognition improved, he participated in daily brain injury education seminars with his peers, went on group outings with recreational therapy, and ate meals in the dining room with other patients. His physical therapy sessions varied from two 30-minute sessions per day to one 60-minute session depending on his attention span, endurance, and the focus of the session. Throughout his treatment we used a variety of modalities and treatment techniques to facilitate strengthening, improving motor control, coordination, cognition, transfers, and gait training. The specific physical therapy interventions that were selected for him based on his presentation and evidence for traumatic brain injury recovery were: neuromuscular electrical stimulation in a variety of methods, use of an Ekso bionic walking device, and task-oriented functional mobility training.

Neuromuscular electrical stimulation (NMES) is defined by Carson as "tetanic muscle contractions induced to assist or reinstate movement, thereby enabling an otherwise quiescent limb to be engaged in goal-directed actions."[8] Early on in his rehabilitation, utilizing NMES techniques to facilitate muscle activation and contraction was beneficial in his progression due to his inability to voluntarily activate his muscles with impaired motor planning. He completed squats on the Moveo tilt table facilitating lower extremity weight bearing with the use of bilateral quadriceps stimulation twice during the first week of his stay at inpatient rehabilitation. When completing squats again two weeks later, he was able to complete them independently without assistance required from the NMES.

We also utilized NMES on the Functional Electrical Stimulation (FES) bike with electrodes on bilateral quadriceps, hamstrings, gastrocnemius, and anterior tibialis. When set to the proper parameters, the bike stimulates tetanic contractions in a rhythmic reciprocal pattern to facilitate cycling with lower extremities. This motion is similar to walking but is safer for low level patients due to the seated positioning.[9] The FES bike still gives patients the freedom to actively overpower the movement using voluntary contraction and the stimulation is then lowered in a graded fashion based on the amount of active contraction the patient is providing. Figure 1 shows the progression of utilizing NMES during the cycling sessions. With his initial FES trial on day 6 of inpatient rehabilitation he could not complete any active muscle contractions and relied entirely on the NMES to facilitate the movement for the entire 30-minute session. On Day 11 and 13 of therapy he was only able to maintain active contractions for up to 30 seconds at a time sporadically throughout the 30-minute session. On Day 18 he actively pedaled 20 minutes of the 36 minutes. Therefore, he demonstrated progression past the need for NMES. He could complete repetitive rhythmic stepping on Day 24 utilizing the NuStep independently for 12 minutes without any NMES required.

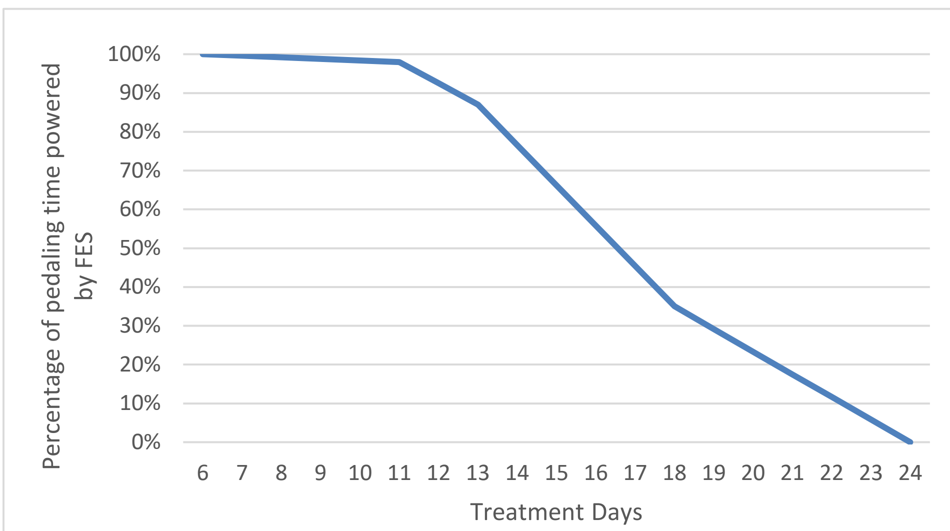

Figure 1. FES Cycling Sessions and amount of NMES assistance

Additionally, early on in therapy we utilized NMES in sitting and standing for improved muscle activation. This not only increased proprioception and awareness of postural muscles but assisted with motor relearning and motor planning for sit to stands, maintaining upright standing posture, and improving sitting balance and positioning. During his second week of therapy we stimulated erector spinae and rhomboids for upright trunk control as well as quadriceps and gluteus maximus for completing repetitive sit to stands. We adjusted the on/off settings and ramp in order to facilitate adequate timing and coordination of muscle contraction to complete the transition into standing. At 3.5 weeks, we utilized NMES on gluteus maximus for improved hip extension activation in standing in the parallel bars. We paired this activity with completing dynamic reaching up and forward to further facilitate full thoracic and hip extension, and though the patient was challenged and noted some discomfort with the stimulation, he responded well to the intervention. Throughout the various techniques using NMES, the patient was encouraged to voluntarily activate the specific muscles concurrently with the stimulation. The use of NMES and voluntary contractions is shown to accelerate recovery of muscle contractility and restore more functional abilities better than voluntary contraction attempts alone.[9] Electrical stimulation recruits motor units in order from large to small whereas voluntary muscle contraction recruits motor units from small to large. Therefore, the combination of both techniques can activate a substantial proportion of the muscle including both small and large motor units for strengthening. Additionally, electrical stimulation may be associated with elevating brain derived neurotrophic factor (BDNF) which plays an important role in promoting neuroplasticity.[8] This is key in facilitating recovery after a traumatic brain injury.

After the patient was able to demonstrate more active lower extremity activation in standing and gait trainers as well as 20 minutes in the standing frame with stable vital signs, we were able to initiate training with the Ekso Bionic Walking Device on Day 20. This device also uses repetitive reciprocal movement similar to the FES bike but provides external support in standing to bring the patient through the natural walking pattern. The increased practice and repetition with external support takes the patients through the normal gait pattern and prevents or reduces the likelihood of an individual developing compensation mechanisms in gait such as hip hiking, circumduction, steppage gait, and other abnormal gait strategies.[10] The support also allows the therapist to break down the gait cycle, and the patient can focus on one specific deficit at a time without having to think about all of the other elements of gait. This device also decreases the physical demand on the therapists as individuals with moderate to severe impairments often require maximal assistance for walking.[10] During this phase of rehabilitation this patient had difficulty weight shifting specifically onto the R leg, struggled to motor plan and initiate or maintain continuous stepping, was unable to achieve adequate hip and knee flexion to clear his stepping foot, and demonstrated circumduction in swing phase. The Ekso was utilized in six 60-minute sessions with the patient showing progression through the different levels of assistance modes programed in the device. Initially starting in a full motor-controlled mode, the device powered each step after the patient adequately weight shifted. Due to greater impairments on his right leg, the patient then completed several trials in right-affected mode which gave him freedom of his left leg to control stepping yet also provided the necessary increased assistance for right stepping and stance phase. Later he progressed to activating power assist only when he deviated from the natural stepping trajectory, requiring assist for increased step height or step length. Finally, he progressed to free mode which required him to control all phases of gait as if he was not wearing the device. During the final two sessions using the Ekso, the patient was challenged to walk backwards, complete lateral stepping, and walk forward against resistance for strength and coordination training.

The third category that was the primary focus of this patient’s therapy sessions in inpatient rehabilitation was task-oriented functional mobility training. This included repetition and breaking down of transfers, bed mobility, sit to stands, practicing standing balance, and manual wheelchair propulsion.

It also included gait training with various assistive devices progressing to less restrictive devices as the patient's strength and motor control improved. The focus of each session was chosen based on what the limiting factor was in preventing the patient from completing his functional movements safely. Due to his impaired cognition and high assistance level the first two weeks, his early sessions primarily focused on low level mobility in safe positions. This included practicing bed mobility, sitting balance on the edge of the mat, dependent standing in a standing frame, and use of the Rifton tram for body weight supported standing and early stepping. As he regained motor control and required less assistance, the focus of sessions became more dynamic. The patient was then able to be put in positions that challenged different muscles such as quadruped and tall kneeling. We were also able to incorporate standing balance training into sessions as he became stronger and more independent. Repetition and continuous practice of transfers remained a priority during therapy sessions and progressed to continued skill practice with nursing staff throughout the rest of the day with activities of daily living. These functional tasks were emphasized in order to allow the patient to be able to safely move positions and complete his daily cares when discharged home with his wife. As shown below his assist level for transfers decreased dramatically around his 3rd week of therapy. Gait training progressed from using the high support Rifton tram to parallel bars to a specialized bilateral platform walker. Eventually he progressed to use of a front wheeled walker which was both safe and practical for continued use when discharged home.

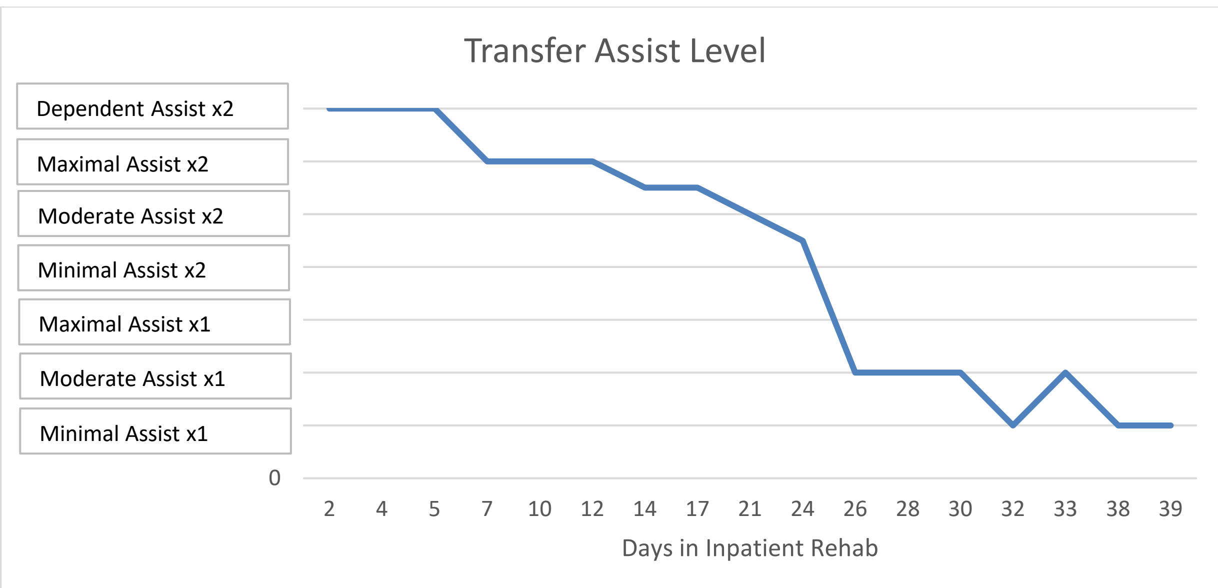

Figure 2. Required assist level for transfers throughout therapy progression.

Outcomes

After significant improvements in mobility, the patient and his family decided to transfer to an inpatient rehabilitation hospital closer to home to ease the burden on his family before finally discharging home. The patient transferred two weeks prior to his initial scheduled discharge date. Accordingly, the discharge data described here was for his discharge to the second facility, not discharge to home.

See Table 2 below for assistance level for the Functional Abilities GG Codes. Upon discharge, the patient was alert and oriented x4 but still demonstrated decreased safety awareness and insight into his injury, impairments and limitations, and continued need for assistance. As shown below in Table 2, this patient arrived at the neuro inpatient rehab facility completely dependent and many of the items were unable to be assessed due to his very low level of functioning. After 39 days in this inpatient rehabilitation hospital he was able to complete bed mobility with standby assist requiring no physical touching only verbal redirection and cuing due to his impulsivity and decreased safety awareness. He was able to progress in completing sit to stands and transfers requiring the assistance of one person to do 25% of the work, also known as minimal assistance, due to his continued impairments of motor planning, coordination, and safety. The patient progressed to utilizing a front wheeled walker requiring minimal assistance to ambulate 200 feet. He also progressed from using a tilt-in-space wheelchair at initial evaluation being dependently pushed because of his inability to maintaining trunk control and upright posture to a much less restrictive manual wheelchair which he was able to self-propel 220 feet with bilateral upper and lower extremities and supervision for safety cues and environmental awareness. Ambulation on unlevel surfaces, curb/stairs, and picking up an object continued to not be able to assess at discharge due to concerns for his safety because of his continued impairments with motor planning in less advanced tasks.

Table 2. Functional Abilities GG Codes at initial evaluation and discharge evaluation.

1	2	3	4	5	6
Dependent	Substantial/max	Partial/moderate	Supervision/touching	Setup/cleanup	Independent

Functional Skill	Initial Evaluation	Discharge
Rolling	Dependent	Stand by Assist
Supine to/from Sit	Dependent	Stand by Assist
Sit to Stand	Not assessed	Min Assist
Stand to Sit	Not assessed	Touching Assist
Transfer	Dependent (slideboard)	Min Assist (stand pivot) with FWW
Car Transfer	Not assessed	Min Assist with FWW
Ambulation (level)	Not assessed	Min Assist, 200 feet with FWW
Ambulation (unlevel)	Not assessed	Not assessed
Curb/Stairs	Not assessed	Not assessed
Picking up object	Not assessed	Not assessed
Wheelchair	Not assessed	Supervision, 220 feet

Progression with the SwePass also improved as shown in Table 3. Upon initial evaluation this patient scored 8 / 36 which shows significant fall risk and demonstrates the high level of assistance required for the various movements outlined in the table below. The patient improved 14 points by discharge, which showing notable improvement in these skills. He was able to advance his functional skills to independent or only needing one person to assist him, which was then a feasible mobility level for him to discharge home with a caregiver. However, he still scored 10 points below the cutoff level of 32/36 demonstrating continued significant risk for falling. Especially with his enduring insight impairments and impulsivity, safety and fall prevention were monitored closely and remained top priority through the end of his inpatient rehab stay. We provided education to both the patient and his wife on tactics to maintain safety for everyone involved.

Table 3. SwePass at initial evaluation and discharge.

Activity	Initial Evaluation	Discharge
Rolling	1 person assist	No help
Supine to Sit	1 person assist	No help
Sit without support	Cannot	Can sit for 5 minutes
Sit to stand	Cannot	1 person assist
Stand with support	Cannot	1 person assist
Stand without support	Cannot	10 seconds and leans on 1 leg
Single Leg Stance	Cannot	Cannot
Stand pick up	Cannot	Cannot
Stand to sit	Cannot	1 person assist
Sit to Supine	1 person assist	No help
Total Score	**8 / 36**	**22 / 36**

Discussion

This patient provides one example of how well a patient can progress through inpatient rehabilitation physical therapy with a severe traumatic brain injury. Each brain injury is different, and therefore each recovery should be individualized. Another case report of an individual with a severe traumatic brain injury demonstrated that progression to independent ambulation took 11 months with extensive therapy.[11] A study of 116 patients with severe traumatic brain injuries over a 32-month period found that 73.3% of people achieved independent gait by 5 months postinjury.[12] Of those patients 82% achieved this milestone by 2 months post injury and 95% achieved independent ambulation by 3 months.[12] Comparing to this specific case report, this patient advanced to minimal assistance for ambulation around 2.5 months post-injury with continued progress expected at the subsequent inpatient rehabilitation site as well as after final discharge to home with outpatient physical therapy services. This evidence of varying lengths of recovery demonstrates how significant the fluctuations between traumatic brain injuries and their progression can be. Therefore, making predictions for initial prognosis and developing a "standard" for therapy following TBI can be quite challenging, if not impossible. Motor networks are highly integrated with many other systems throughout the brain and body. Cognition, working memory, motor planning, language, motivation, and error detection are all areas that when impacted by a brain injury can significantly affect progression through therapy.[13] Depending on the area affected by the brain injury, this should dictate the patient progression with treatment. Multi-faceted treatment approaches improve likelihood of successful outcomes.[13]

Recovery from brain injury requires the brain to adapt; this process is known as neuroplasticity. Neuroplasticity is defined by Wolpaw as the nervous system's ability to reorganize its structure, function, and connections by responding to intrinsic and extrinsic stimuli.[14] Plasticity is dependent on timing, the environment, and other concurrent therapies as well as the motivation and attention level of the patient. One example of targeting neuroplasticity is specific skill training with individuals and observing their subsequent clinical gains. As the behavioral outcomes improve, the brain plasticity is increased.[14]

Throughout development as a fetus, specific proteins involved in neural growth are high, and the brain is at its highest level of plasticity and ability to adapt when we are young. Similarly after injury, a lot of evidence has shown that there is an upregulation of those proteins involved in neural growth that can guide recovery.[15] Genes that promote and inhibit neuronal growth are turned on/off post-injury mimicking typical neural development. Therefore there is thought to be a limited time period to maximize neuroplasticity following injury.[15] Early rehabilitation following traumatic brain injuries has been shown to have positive results decreasing length of stay and resulting in greater functional outcomes for ambulation and independence.[16] However, based on the medical complexities with these injuries, patients commonly have unstable intracranial pressure, cerebral blood flow, and cerebral perfusion pressures which are often barriers to implementing early rehabilitation.[16]

For this patient specifically, early on in his therapy at the inpatient rehabilitation facility, his cognitive impairments were the biggest barrier to completing therapies specifically to target plasticity. He had significant attention limitations and required nearly continuous redirection initially. As he emerged from his brain injury, he was able to focus more on the motor control aspect of therapy, and we saw more notable changes in his progress. Length of post-traumatic amnesia is one of the best prognostic indicators for individuals after TBI.[16] Around week three at the inpatient rehab facility, this patient showed notable cognitive changes and improvements in memory, which coincided with great improvements shown in regards to his gross motor skills and mobility.

Task-specific practice and motor “relearning” have been shown to be essential proponents to promote neuroplasticity.[2] Behavioral experiences have been shown to change both the structure and function of neural tissue in both healthy and injured brains.[15] Therapeutic interventions should focus to maximize neuroplasticity in patients to facilitate recovery. Utilizing a variety of individualized interventions to target each patient’s specific limitations can result in positive outcomes for patients.

Brain injuries are life changing events and the road to recovery can be challenging and tedious with some impairments enduring for years. The recovery process can be unpredictable with many ups and downs along the way. This case report was able to demonstrate that despite the severity and initial presentation of a brain injury, patients can make dramatic recoveries.

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