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Physical Therapy Management and Recovery of an Individual with a Severe Traumatic Brain Injury: A Case Report

Kristen Bolen
University of Iowa

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Kristen Bolen

DPT Class of 2018
Department of Physical Therapy and Rehabilitation Science
The University of Iowa

Abstract

Background: Traumatic Brain Injury (TBI) leads to long lasting effects on health and quality of life. The prognosis following a TBI is unique and often unpredictable. While research is beginning to study the impact of rehabilitation on outcome following TBI, there is minimal good quality evidence in the literature on what the most effective rehabilitation interventions are for the TBI population**. Case Description:** The patient is a 35-year-old man who suffered a severe traumatic brain injury after falling off a bicycle. He was diagnosed with a right subdural hematoma and a left sided fracture through mastoid air cells. He received a right craniectomy for evacuation of a subdural hematoma and a left lateral cerebellar craniectomy with evacuation of an epidural hematoma. During his inpatient rehabilitation stay the patient participated in interventions including: functional mobility, gait training, complex balance training, coordination and agility, dual task training, and return to work tasks. **Outcome Measures:** The patient received physical therapy interventions for 60 minutes, 5 days a week, for a total inpatient rehabilitation length of stay of 64 days. The main outcome measures utilized with the patient included: Berg Balance Test, 6 Minute Walk Test, and High-Level Mobility Assessment Tool. **Discussion:** The patient demonstrated significant improvement in mobility during his stay in an inpatient rehabilitation facility, despite multiple medical complications and negative prognostic factors. This case report provides preliminary support for the use of a comprehensive rehabilitation program for severe TBI. Future research is needed on the outcomes following severe TBI and to establish standards for rehabilitation decision-making.

Keywords: Traumatic brain injury; neurology; physical therapy; rehabilitation

Background

Traumatic brain injury (TBI) is defined as a “bump, blow, or jolt to the head that disrupts the normal function of the brain”.[1] It has been reported that TBI effects around 1.7 million individuals in the United States every year, with over 50,000 of those injuries resulting in death.[2] Significant long-term deficits persist after traumatic brain injuries. In fact, 43% of individuals who are hospitalized following a TBI have a disability related to the injury one year later.[1]

TBI severity is commonly rated using the Glasgow Coma Scale (GCS). The GCS consists of three subcategories: eye opening, verbal response, and motor response.[3] Each of these is scored for a total score ranging from 3-15, where lower scores indicate greater severity of coma and impaired consciousness. Eye opening is scored on a scale of non-testable to 4, based upon the level of stimulus required for the individual to open their eyes. Verbal response is scored on a scale of non-testable to 5, and documents any audible verbalizations the individual makes and grades them based upon proper orientation. Motor response is graded on a scale of non-testable to 6, based upon the individual’s response to physical stimulation provided via fingertip pressure, trapezius pinch, or pressure at the supraorbital notch. According to the Center for Disease Control, TBI severity can be differentiated as severe (scores of 3-8), moderate (9-12), and mild (13-15).[1] A motor response score of less than 6 has also been utilized to classify individuals as a severe TBI. The GCS assessment form can be found at the following link: https://www.glasgowcomascale.org/downloads/GCS-Assessment-Aid-English.pdf?v=3.

Researchers have attempted to establish prognostic factors that would indicate the probable outcome a patient will have following a TBI. Initial GCS (motor score specifically), age, and pupil reactivity at admission have been reported to be the most common predictor variables analyzed.[4] It has also been found that considering CT characteristics, hypotension, hypoxia, and laboratory values (glucose and hemoglobin), increases the accuracy of prediction.[5] Specifically, factors which suggest a positive outcome six months following injury include: younger age[2,4,5], higher initial GCS score[4,5,6], fewer days on ventilation[2], shorter post traumatic amnesia[2], shorter ICU stay[6], shorter total hospital stay[6], and presence of an epidural hematoma on CT[5]. Factors suggesting a negative outcome include: increase in age[4,5], GCS motor scores of 1 or 2[4], lack of pupillary reactivity[4,5], presence of hypoxia[4,5], presence of hypotension[4,5], CT images displaying mass lesions/increased intracranial pressure/subarachnoid hemorrhage[4,5,6], high glucose levels[5], and low hemoglobin values[5].

The majority of patients with TBI discharge home from acute care.[7] Yet several reports identify improved functional gains with higher doses of therapy and intensive rehabilitation programs.[8,9] This indicates a discrepancy between the standard model of care that exists versus evidence supporting greater levels of intervention. Furthermore, there is minimal good quality evidence in the literature on what the most effective interventions are for the TBI population. While spontaneous recovery is an accepted concept that occurs in brain injury[10], the mechanisms of how this occurs and how this relates to rehabilitation and outcomes as a whole is still poorly understood. While research is increasing on the underlying mechanisms and treatments for traumatic brain injury, it still falls behind what is known about other neurological injuries. As with most forms of brain injury, including stroke, anoxic injury, or another non-traumatic acquired mechanism, each case is unique which makes the outcomes often very unpredictable. Thus, therapists often have to rely on limited evidence to develop treatment interventions for patients with TBI.

Accordingly, this case presents a description of a patient with severe TBI. It documents his initial presentation and the unique interventions that were chosen as part of a comprehensive rehabilitation program. Collectively, the case then provides an example of a successful outcome that was initially unexpected based upon the patient’s initial presentation.

Case Description

The patient was a 35-year-old Asian male who suffered a severe TBI after falling off a bicycle, without wearing a helmet. He was diagnosed with a right subdural hematoma with a subfalcine herniation and a left sided fracture through mastoid air cells. At the scene of the trauma, the patient scored an 8 on the Glasgow Coma Scale (GCS), as assessed by emergency responders. Eye opening was a 3, verbal response was a 1, and motor response was a 4. The patient underwent a right craniectomy for subdural hematoma evacuation and a left lateral cerebellar craniectomy with evacuation of epidural hematoma. He had a tracheostomy placed until 15 days post-injury and a percutaneous endoscopic gastrostomy (PEG) tube placed until 20 days post-injury. He was in acute care for thirty-nine days and was then admitted to an inpatient rehabilitation facility specializing in brain injuries, located in the Midwest. The patient received physical therapy in the acute care setting, however, the details of these services are unknown. Upon initial admission to inpatient rehabilitation, this individual was immediately readmitted to acute care due to medical instability. He had a consistent respiratory rate over 35 breaths per minute (bpm), and his oxygen saturation was falling below 91% on 4L of oxygen. He remained in acute care for twelve days and was then re-admitted to the rehab facility.

For the craniectomy, a portion of the patient's skull, also known as a bone flap, was removed on the right side. This was done to evacuate the subdural hematoma in order to reduce intracranial pressure. Decompressive craniectomies are most frequently indicated with acute subdural hematomas.[11] The bone flap was left out after removing the hematoma in case of increased brain swelling post-operatively. Thus, when the patient was admitted to the inpatient rehabilitation facility, he still did not have his bone flap put back in place. The patient would undergo another surgery at a later date to put the bone flap back, once brain swelling was minimized. Because there was a portion of the patient's brain that did not have skull surrounding it, the patient was at increased risk of suffering another brain injury if he were to fall and hit his head. Thus, the patient had to wear a protective helmet whenever he was out of bed.

The patient's re-admission after becoming medically stable was the date that he received his initial physical therapy evaluation and will be considered his admission day for the remainder of this case report.

The patient was married and a father of two boys, whom he was riding his bike with at the time of injury. Interestingly, his wife had previously suffered a brain injury in a car accident several years prior. She had no prolonged physical deficits; however, she continued to have some mild impairments with higher order thinking and memory. At times this was a complicating factor to the patient's recovery because his wife was not consistently compliant with the orders that were provided. Prior to injury, the patient was enrolled in a HVAC training program at a local community college. His desired outcomes were to return home with his family independently, return to school, and to return to playing sports with his kids.

Examination

When initial examination was performed, the patient required dependent assistance of two for bed mobility. Per the lifting restrictions for nursing at this facility, the patient required the use of a Hoyer lift to transfer because he was dependent on assistance. The patient required maximum assistance for seated balance and maximum assistance of two people for static standing balance. See Table 1 for more detailed definitions of the levels of assistance.

A general neurological screen was performed finding impaired: light touch, left great toe proprioception, a moderate coordination deficit, and grade one spasticity in the left gastrocnemius muscle according to the Modified Ashworth Scale. The patient scored between 4 and 5 out of 5 bilaterally on all lower extremity manual muscle testing, with slightly increased strength on the left compared to the right lower extremity. Despite having relatively intact lower extremity strength bilaterally, this did not carryover to functional mobility as evidenced by the high level of assistance required.

The primary goal established by the physical therapist following initial examination was for the patient to tolerate upright positioning in a tilt in space wheelchair. He had minimal tolerance for sitting upright because he would experience large, symptomatic decreases in blood pressure. For example, five days after initial examination, the patient's blood pressure measured at 100/46 after inclining the head of bed. It further dropped to 91/52mmHg after completing a stand pivot transfer. On day 6, the patient experienced heaving, nausea, and dizziness after sitting for five minutes. During this first week, the patient tolerated 30 minutes in the tilt in space wheelchair at best, however his tolerance was inconsistent.

Table 1 Definition of assistance based upon percentage of patient involvement

Level of Assist	Definition
Dependent	Patient performs <25% of task
Maximal Assistance	Patient performs at least 25% of task
Moderate Assistance	Patient performs at least 50% of task
Minimal Assistance	Patient performs at least 75% of task
Contact Guard Assistance	Tactile cues or guidance, hands on the patient
Standby Assistance	No physical assistance, within arm reach
Independent	No physical assistance or verbal cues

Intervention

This patient was seen for physical therapy services in the inpatient rehabilitation setting, while also receiving occupational therapy, speech therapy, and recreational therapy services during his episode of care. Co-treatment sessions between therapy disciplines were a frequent occurrence at this facility. At the beginning of the episode of care, the patient commonly had PT and OT co-treatment sessions to work on functional mobility and activities of daily living (ADLs) concurrently. As the patient progressed, PT and speech therapy co-treatment sessions were used on occasion to challenge dual tasking, secondary to cognitive motor interference.

The patient was seen for 8 to 12 sessions of physical therapy per week. Most commonly he was seen for two thirty-minute sessions per day, Monday through Friday. Occasionally he would be seen for an additional thirty-minute session on a Saturday. Due to the set-up of the rehabilitation facility, the patient was usually seen by one physical therapist and one physical therapist assistant (PTA) per day. The individual was consistently compliant with participation in physical therapy and usually only missed a session if he had a doctor's appointment out of facility or another scheduling conflict. The interventions began by working on upright tolerance and functional mobility, then gradually progressed to more complex tasks including gait training, complex balance training, coordination, dual task activities, and return to work tasks.

Week 1

During the first week following initial evaluation, treatment sessions focused on building upright tolerance and progressing independence with functional mobility. The bed was progressively inclined during sessions as tolerated or the tilt table was used to progress towards a standing position, with dependent assistance. Table 1 documents the patient's vital signs during the first trial he completed using the tilt table. He presented with low blood pressure at baseline that further decreased initially when inclining the table without compensation in the heart rate. Along with objective drops in blood pressure, the patient also reported nausea and dizziness, and presented with occasional heaving. During this time the patient progressed to performing a supine to sit transfer with moderate assistance and a stand pivot transfer to a standard wheelchair with moderate assistance.

Table 2 Data from tilt table trial completed 6 days after day of admission

Position	**Blood Pressure** (mmHg)	**Heart Rate** (bpm)	**Time passed in each position** (minutes)
Supine	94/55	75	
	89/53	84	5
10 degrees	91/56	83	
	83/57	87	7
20 degrees	93/56	86	
	87/55	86	4
30 degrees	88/59	86	

Weeks 2-5

During this period of treatment, the patient made rapid progressions in mobility. After requiring moderate assistance for a supine to sit transfer and blood pressures dropping to 68/42 mmHg at a 50-degree incline on the tilt table at the end of week one, the patient completed a sit to stand transfer with minimal assistance and then walked 3 ft. two times with minimal assistance at the beginning of week two. His ambulation distance progressed steadily, increasing from 80 ft, to 120 ft, to 270 ft at the end of week 2. While performing ambulation trials, the patient demonstrated minimal awareness of losses of balance, with the tendency to fall posteriorly and to the left. The patient demonstrated a forward flexed posture when ambulating with moderate manual cues provided to facilitate improved hip and trunk extension. The patient required manual and verbal cues to facilitate anterior weightshift and improved upright and midline posture. He was also provided maximal verbal and tactile cues for proper sequencing of lower extremity advancement. Standing balance training was also initiated in week two. The patient performed standing with minimal assistance while dribbling a basketball 2 minutes at a time, and repeated this 4 times.

Fifteen days following his initial evaluation (end of week two), and two months following initial injury, signs of infection were present in his scalp wound with visible mesh present where the bone flap was removed. He had Klebsiella pneumonia at his incision site, and was re-admitted a second time to acute care for four days to treat the infection. When the patient returned to the inpatient rehab facility, the doctors ordered him to not where his helmet until further notice, in order to prevent further infection.

When the patient was re-admitted to the inpatient rehabilitation facility during week three, he demonstrated progress from where he was at week two. He completed bed mobility and seated static balance with standby assistance. He required contact guard to minimal assistance for sit-to-stand transfers and ambulated 200 ft twice, with contact guard assistance to minimal assistance. Because the patient was ordered to not wear his protective helmet, he was at increased risk for further injury if he were to fall without his helmet donned. Therefore, nursing orders were updated at this time requiring nursing staff (RN, CNAs) to use assistance of two for all transfers. Nursing was also not allowed to assist the patient with ambulation, the patient was only allowed to ambulate with physical therapy. This was done as a safety precaution, despite the patient's improving independence with mobility. With physical therapy, he was allowed to be assisted by only one person. Per facility policy, physical therapists were deemed as more skilled and trained in assisting patients in a safe manner, thus explaining the discrepancy in the orders between disciplines.

During week three, the patient completed the Berg Balance Test for the first time. The Berg Balance Test has been validated for use with the TBI population (SEM=1.65, excellent test-retest reliability ICC=0.99).[12] He scored a 27/56, 17 days after his initial evaluation, indicating he was at high risk for falls. Treatment was then progressed to challenging gait on uneven surfaces, opposed to the straight and flat surface of the facility hallways. The patient began ambulating up to 1000 ft at a time, ambulating over curbs, across grass, and on inclines on the outdoor grounds surrounding the facility, requiring contact guard assistance. During these trials, the patient demonstrated rigid upper extremities with minimal arm swing. To facilitate arm swing, verbal cues were provided and with the use of walking sticks in bilateral upper extremities were added. The walking sticks were held horizontally by the patient in each hand, and the physical therapist held the opposite end of the sticks and moved them in a reciprocal pattern to provide a reciprocal arm swing in coordination with the lower extremities.

Throughout weeks three and four, dynamic balance tasks were also performed using a railing along a long straight hallway to provide a safe environment for challenging balance. Activities included side stepping in both directions, grapevine (lateral step followed by cross over step, alternating anteriorly or posteriorly), backwards walking, and tandem walking (walking heel to toe to challenge narrow base of support). Dyna discs (balance cushions of varying compliancy) were utilized to provide varying surfaces for challenging dynamic balance. The Berg Balance Test was repeated twice during week 4, day 22 and day 26. While usually this test would not be administered so frequently, the patient was progressing rapidly and the physical therapist wanted to demonstrate that the patient had improved balance with minimal fall risk, so that the nursing orders could be updated to allow the patient to ambulate with nursing. The patient's progress with walking tolerance and endurance was being limited by these orders since he had the ability to walk with contact guard assistance but could only practice for up to 60 minutes a day when he had physical therapy. On day 22 the patient scored a 33/56 on the Berg Balance Test, indicating he was still at a fall risk. By day 26, the patient scored a 52/56. At this time, the physical therapist deemed the patient safe to walk with nursing staff without his helmet donned.

Orders were not updated however until the patient had a follow up appointment for his incision with the neurosurgeon during week 5. On day 31 after initial evaluation, the patient was cleared to wear his helmet whenever he was ambulating. At that time, the patient was also cleared by the physical therapist to ambulate with nursing staff and his wife with contact guard assistance, and standby assist of 1 for transfers.

Weeks 6-9

At the beginning of week six, the use of the patient's standard wheelchair was discontinued secondary to his independence with functional mobility and safety now that he was permitted to wear his helmet. Treatment began to focus on increasing endurance, improving gait mechanics, dual tasking during gait, agility and coordination drills, and introduction to return to work skills. Over the course of this treatment period, the patient utilized the elliptical exercise machine to challenge endurance and coordination. Time was progressed from 5 to 15-minute durations, progressed from bilateral upper extremity support to no upper extremity support, and performed backward and forward. Preliminary evidence from a clinical trial provides support that an elliptical training program focused on progressing speed and resistance, leads to improvements in balance, dual task performance, and improved HiMAT scores.[13]

The treadmill was also initiated in week six to work on gait mechanics, specifically focusing on improving gait speed and facilitating bilateral reciprocal arm swing. In week six, the patient ambulated at 1.5 to 1.8 mph. A 3% incline was used to bias the patient into dorsiflexion for improved left lower extremity clearance. By week seven, the patient achieved 2.0 mph on the treadmill. However, carryover was assessed by ambulating in the hallway and an immediate decrease in speed was observed upon stepping off of the treadmill. During week eight, the patient ambulated at 2.4 mph on the treadmill, continuing to benefit from cues to increase clearance of his left lower extremity. Verbal cues to avoid making a “scuffing” noise were provided, which the patient demonstrated improvement with.

During ambulation trials, the patient enjoyed engaging in conversation with the physical therapist. However, whenever the patient began to speak, he stopped walking. He demonstrated what is termed “cognitive motor interference”. This concept has been explained in the literature to be due to the fact that the areas of the brain that control gait speed are interlinked with networks in the brain that control higher-level cognitive functions, including the prefrontal cortex.[14] Because of this, spatio-temporal parameters of gait such as decreased speed, cadence, and stride length, as well as increased stride time and stride variability, are influenced by dual tasking. Literature shows preliminary evidence that dual task training may improve gait, balance, and cognition in individuals with neurologic disorders.[15] Specifically, one systematic review found that in patients with brain injury who received dual task training, including cognitive tasks paired with gait, demonstrated improved gait velocity and stride length.[15]

Dual task training was implemented throughout weeks six to nine to train the patient’s ability to continue walking with the same mechanics, while engaging in a conversation or performing a cognitive task. During some sessions the physical therapist facilitated this activity alone, and during other sessions co-treatments with speech therapy were utilized, enabling the physical therapist to focus solely on the patient’s ambulation and safety. While ambulating in the hallways of the facility, the patient performed wayfinding. He was given a destination in the building to find (e.g. therapy gym, nurse’s desk, dining room, etc.). Initially he was given one at a time. In week seven, memory recall was added to the task and he was given two to three destinations at time then asked to navigate to each without reminders. During the first attempt of this task the patient had frequent stopping and decreased gait speed compared to baseline, however by week nine the patient demonstrated improved gait speed, less frequent stopping, and required fewer verbal cues to assist with memory recall.

Dual task training was also performed while completing obstacle courses, which provided greater challenges with balance. Obstacle courses consisted of variations of dyna discs, stepping over low obstacles (e.g. canes), stepping up onto a raised surface, and the balance beam. One cognitive task frequently performed simultaneously was categorical word finding. The physical therapist provided the patient a category (e.g. animals, foods, states, etc.) and the patient was asked to list off as many examples as he could while completing the obstacle course. In most attempts, the patient paused from completing the course to come up with an appropriate word. He would also demonstrate decreased accuracy and speed while completing the course, compared to when performing the obstacle course without the cognitive task. Alternatively, the patient was given a memory recall task with playing cards; the physical therapist would show the patient 3-5 playing cards in a set order at one end of the obstacle course and when the patient got to the opposite end he was given the cards and asked to place them in the correct sequence.

Other interventions performed in the final weeks were return to work tasks and agility drills to progress towards the patient's goals of returning to work and playing sports. Return to work activities were selected based upon what the patient reported his duties were. Activities performed included climbing a ladder (with and without a weighted vest to simulate wearing a backpack), carrying a weighted laundry basket, crawling with a weighted vest, and strengthening in a quadruped position. During week six, jogging was initiated. It was initially trialed using an overhead gait system so the patient was supported in a harness and the amount of weightbearing could be adjusted; in this case it was done for safety. The patient did not attain a true jog at this time. Verbal cues and visual demonstration were provided but he continued to demonstrate an increased walking speed when given the command to jog. The harness was removed and the patient attempted jogging over ground. Contact guard assist was provided, but patient continued to not attain a true jog. By the end of week eight, the patient demonstrated jogging with contact guard to stand by assist, with a true flight phase. During week nine the patient improved to performing jogging with stand by assistance while dribbling a basketball on asphalt for 25 ft bouts, repeated five times.

Outcomes

The patient was discharged from the inpatient rehabilitation facility nine weeks and two days after his initial evaluation. He was discharged to be independent at home with outpatient therapy services provided in the same facility as inpatient rehabilitation, twice per week. At discharge, the patient had not yet received his bone flap. He was scheduled to have surgery approximately three weeks after discharge. Follow up was made with his outpatient therapy team whom reported that the patient's surgery was successful with no immediate complications. Additional follow-up was not available beyond this final surgery.

The patient made an excellent recovery, achieving independence with functional mobility, and achieving his and his family's goal of being independent at home. At discharge the patient was jogging while dribbling a basketball with stand by assistance, achieving another goal of his to return to playing sports with his kids. The therapy team made attempts to contact the patient's HVAC training program to assist the patient with making the return to school/work, however they did not respond by his discharge. While the patient demonstrated proficiency during therapy activities designed to resemble return to work activities, it is unknown if the patient achieved his goal of returning to his training program or if working as an HVAC technician will be a manageable job for his physical skill level.

Table 3 provides the patient's required assistance level at discharge, relative to initial assessment. He continued to require stand by assistance for upright mobility as a safety precaution due to his absent bone flap. The patient scored a 52/56 on the Berg Balance Test one-month prior discharge, indicating a significantly reduced risk for falls. The test was not reassessed at discharge due to already coming close to maxing out on the test and time constraints. The 6 Minute Walk Test (6MWT) was completed three times during his episode of care to assess endurance and gait speed. The 6MWT has an excellent test re-test reliability for the TBI population (ICC=0.94-0.96).[16] On day 32 the patient ambulated 286.6 m, day 46 he ambulated 422.4 m, and on day of discharge the patient ambulated 538.62 m. A reference equation from the literature was used to calculate the normative value for a healthy male adult this patient's size: $6MWD = (7.57 x height\ cm) - (5.02\ x\ age) - (1.76\ x\ weight\ kg) - 309$.[16] Based upon this, to return to what his baseline value likely was, the patient was expected to ambulate approximately 682 m (using an estimation of the patient's height and weight, which were not known exactly). The patient performed slightly below this value at his best, although he demonstrated significant improvement during his length of stay.

The High-Level Mobility Assessment Tool (HiMAT) was used to assess the patient's higher-level mobility skills. This test has been found to have excellent test-retest reliability and excellent inter-rater reliability in the chronic TBI population, but is considered to also be appropriate to use during the acute stages following TBI if the patient can ambulate without assistance.[17] This assessment was also found to have moderate content validity with the motor FIM, although the HiMAT has less of a ceiling effect.[18] At discharge, the patient scored 26/54 on the HiMAT. He scored a 21/54 when he first completed the test 24 days prior, during week 6. While he demonstrated a five-point improvement, which is above the minimal detectable change[17], the patient was considered to have remaining deficits with higher level mobility. This may indicate potential limitations or safety concerns that may be present when performing more complex tasks such as sports with his kids or work duties. His main limitations on this assessment included hopping, bounding, skipping, walking on toes, and gross limitations in speed. The HiMAT assessment form can be found at https://www.sralab.org/sites/default/files/2017-06/HiMAT.pdf.

Table 3 Functional Mobility Outcome at Discharge vs. Initial Evaluation

Activity	Level of Assist	
	Discharge	**Initial**
Bed Mobility	Independent	Dependent x2
Seated Balance	Independent	Maximal assistance
Sit-to-Stand Transfers	Standby assistance	Dependent with Hoyer lift
Gait	Standby assistance	Non-ambulatory, tilt-in-space w/c
Standing Balance	Standby assistance	Maximal assistance of 2
Stairs	Standby assistance, reciprocal step pattern and 1 handrail	Not assessed

The TBI EDGE task force performed a review of numerous outcome measures to determine the most evidence based and useful measures to assess patients with TBI.[19,20] They determined measures that are either "recommended" or "highly recommended" for use with the TBI population in either the inpatient or outpatient setting. According to their findings, the Coma Recovery Scale-Revised (CRS-R) and the Moss Attention Rating Scale are the two measures highly recommended for patients in inpatient. The CRS-R would not have been appropriate with the patient in this case report because he did not have a disorder of consciousness. The Moss Attention Rating Scale would have provided an objective measure to assess this patient's difficulty with attention, as it takes into consideration a patient's ability to dual task. While the scale may be performed by any therapy discipline, attention deficits and higher order thinking were monitored and assessed by the speech therapist and not the physical therapist, despite some overlap in treatment interventions.

The 6 Minute Walk Test was chosen for the patient to track gait speed and endurance. The test is designed to be a measure of endurance only; thus the 10 Meter Walk test may have been a more optimal outcome to more accurately assess gait speed. The patient did have impairments in both endurance and gait speed following his injury. The 10 Meter Walk test likely would have showed a more rapid gait speed than what was calculated from the 6 Minute Walk Test, because it requires a shorter distance to ambulate so endurance would be factored out.

Finally, a subjective outcome measure was not completed by the patient. A subjective measure such as "Quality of Life after Brain Injury" or the "Patient Health Questionnaire", which are both recommended by the EDGE for patients in inpatient care with TBI, would have been beneficial to assess how the patient perceived his recovery and current level of function. This may have provided greater insight into how well his goals were achieved during his inpatient rehabilitation stay. Furthermore, a subjective measure would help with optimizing patient care to give an indication if the patient needed any specific services after discharging from inpatient rehabilitation.

Discussion

Currently, there is not a specific standard of care that has been established for traumatic brain injury. No recommendations for rehabilitation interventions specifically have been provided in the clinical practice guideline for this population. Instead, the clinical practice guideline focuses on the medical management of TBIs.[21] This may be attributed to the high amount of variability that exists under this broad diagnosis, as well as lack of research available. Nevertheless, according the APTA's PTNow clinical summary, all of the interventions listed as recommended for the traumatic brain injury population were utilized with the patient in this case report.[2] Furthermore, a systematic review by Hellweg and Johannes found strong evidence that more intensive rehabilitation programs lead to earlier functional abilities.[22] According to their review of the literature, they also provided a strong recommendation for task-oriented repetitive training.[22] Time spent in more complex therapeutic activities has also been found to lead to better outcomes.[13] Thus, while there is not strong evidence to guide the specific implementation of rehabilitation in TBI population, the literature supports the effectiveness of the use of physical therapy as a whole.

Based upon the patient's presentation at the scene of injury and at admission to inpatient rehabilitation, a more unfavorable outcome likely would have been predicted for this patient. According to the literature, a readmission to acute care during inpatient rehabilitation stay is associated with longer lengths of stay in rehab and decreased likelihood of discharging home.[24] Thus, the patient's infection that readmitted him to acute care was one complicating factor to his recovery. Based upon the prognostic factors for outcome following TBI found in the literature, the patient in this case possessed both negative and positive factors. The patient's positive factors were a relatively young age of 35 years old, the presence of an epidural hematoma on CT, and pupillary reactivity bilaterally. Negative factors the patient possessed were hypoxia, hypotension, and a mass lesion on CT (subdural hematoma). His GCS could be considered positive or negative as some studies consider a score of less than 12 a negative factor, others consider only a score of 1 or a 2 as a negative factor. Furthermore, the patient's hemoglobin and glucose lab values are unknown, so they could not be considered for determining prognosis. According to one prognostic calculator found in the literature, the patient had a 39% likelihood of an unfavorable outcome and a 19% likelihood of mortality.[5]

Nevertheless, the patient described in this case made an excellent recovery, achieving the majority of his goals and most importantly discharged to be independent at home, 64 days after his initial physical therapy evaluation at the inpatient rehabilitation facility. The patient provides an example of the positive outcomes that can happen from spontaneous recovery combined with comprehensive rehabilitation, despite having multiple negative prognostic factors. Once he became medically stable, the patient demonstrated rapid progress to become independent with functional mobility. However, there were still impairments present that may have hindered this positive of a recovery if they were not assessed and then treated appropriately. Addressing coordination, return to work skills, community integration, and cognitive-motor interference were all less commonly used practices of care that may have contributed to his recovery. While all traumatic brain injuries have extremely different presentations and prognoses, this case documents a positive outcome following severe TBI and provides an overview of interventions that could be utilized with other individuals who have suffered from a similar neurological injury. Future research is needed to establish standards and guidelines for rehabilitation decision-making in the TBI population, along with higher quality studies to provide stronger evidence for specific interventions. Furthermore, additional research on the outcomes following TBI would be beneficial to better establish accurate prognoses in order to better educate families and to better guide physical therapy plans of care. However, this case report provides preliminary support for the use of a comprehensive rehabilitation program for severe TBI.

References

1. Centers for Disease Control and Prevention. Traumatic Brain Injury & Concussion. https://www.cdc.gov/traumaticbraininjury/severe.html. Updated March 30, 2017. Accessed December 7, 2018.
2. Madsen J, Roberts H, Wagner R, Meyer J, Furman R, Johnson K. APTA PTNow Clinical Summary. Traumatic Brain Injury in Civilian and Military Populations. https://www.ptnow.org/clinical-summaries-detail/traumatic-brain-injury-in-civilian-military-popula. Published August 25, 2017. Accessed December 7, 2018.
3. Teasdale G. Institute of Neurological Sciences NHS Greater Glasgow and Clyde. https://www.glasgowcomascale.org/downloads/GCS-Assessment-Aid-English.pdf?v=3. Published 2015. Accessed December 7, 2018.
4. Perel P, Edwards P, Wenzt R, Roberts I. Systematic review of prognostic models in traumatic brain injury. *BMC Medical Informatics & Decision Making.* 2006; 6:38.
5. Steyerber EW, Mushkudiani N, Perel P, et al. Predicting outcome after traumatic brain injury: a development and international validation of prognostic scores based on admission characteristics. *PLOS Medicine.* 2008; 5(8): e165.
6. Vedantam A, Robertson CS, Gopinath SP. Clinical characteristics and temporal profile of recovery in patients with favorable outcomes at 6 months after severe traumatic brain injury. *Journal of Neurosurgery.* 2018; 129(1): 234-240.
7. Asemota AO, George BP, Cumpsty-Fowler CJ, Haider AH, Schneider EB. Race and insurance disparities in discharge to rehabilitation for patients with traumatic brain injury. *Journal of Neurotrauma.* 2013; 30(24): 2057-2065.
8. Cifu DX, Kreutzer JS, Klakowsky-Hayner SA, Marwitz JH, Englander J. The relationship between therapy intensity and rehabilitative outcomes after traumatic brain injury: a multicenter analysis. *Archives of Physical Medicine and Rehabilitation.* 2003;84(10):1441
9. Gordon WA, Zafonte R, Cicerone K, Cantor J, Brown M, Lombard L, Goldsmith R, Chandna T. Traumatic brain injury rehabilitation: state of the science. *Archives of Physical Medicine and Rehabilitation*. 2006;85(4):343-82.
10. McGinn MJ and Povlishock JT. Chapter 5: Cellular and molecular mechanisms of injury and spontaneous recovery. *Handbook of Clinical Neurology*. 2015; 127(3): 67-87.
11. Kolias AG, Adams H, Timofeev I, et al. Decompressive craniectomy following traumatic brain injury: developing the evidence base. *British Journal of Neurosurgery.* 2016; 30(2): 246-250.
12. Newstead AH, Hinman MR et al. Reliability of the Berg Balance Scale and balance master limits of stability tests for individuals with brain injury. *Journal of Neurological Physical Therapy.* 2005; 29(1):18-23.
13. Damiano D, Zampieri C, Ge J, Acevedo A, Dsurney J. Effects of rapid-resisted elliptical training program on motor, cognitive and neurobehavioral functioning in adults with chronic traumatic brain injury. *Experimental Brain Research*. 2016; 234(8):2245-2252.

14. Al-Yahya E, Dawes H, Smith L, Dennis A, Howells K, Cockburn J. Cognitive motor interference while walking: a systematic review and meta-analysis. *Neuroscience and Behavioral Reviews.* 2010; 35(2011):715-728.
15. Fritz NE, Cheek FM, Nichols-Larsen DS. Motor-Cognitive Dual-Task Training in Neurologic Disorders: A Systematic Review. *Journal of Neurological Physical Therapy.* 2015;39(3):142-153.
16. Shirley Ryan Ability Lab. Rehabilitation Measures Database: 6 Minute Walk Test. https://www.sralab.org/rehabilitation-measures/6-minute-walk-test. Updated April 26, 2013, Accessed December 7, 2018.
17. Shirley Ryan Ability Lab. Rehabilitation Measures Database: High-Level Mobility Assessment Tool. https://www.sralab.org/rehabilitation-measures/high-level-mobility-assessment-tool. Updated January 17, 2013. Accessed December 7, 2018.
18. Williams G, Robertson V, Greenwood K, Goldie P, Morris ME. The concurrent validity and responsiveness of the high-level mobility assessment tool for measuring the mobility limitations of people with traumatic brain injury. Arch Phys Med Rehabilitation. 2006; 87(3):437-42.
19. McCulloch et al. TBI EDGE outcome measures for in-and outpatient rehabilitation. http://www.neuropt.org/docs/tbi-edge/tbi-edge-rehab-1-page.pdf?sfvrsn=4aedf834_2. Published 2013. Accessed December 7, 2018.
20. McCulloch K et al. Outcome measures for persons with moderate to severe traumatic brain injury: recommendations from the American Physical Therapy Association Academy for Neurologic Physical Therapy TBI EDGE Task Force. *Journal of Neurologic Physical Therapy*. 2016; 40(4):269-280.
21. Carney N, Totten AM, O'Reilly C, et al. Guidelines for the Management of Severe Traumatic Brain Injury, 4th Edition. *Brain Trauma Foundation*. Published September 2016.
22. Hellweg S and Johannes S. Physiotherapy after traumatic brain injury: a systematic review of the literature. *Brain Injury*. 2008; 22(5): 365-373.
23. Horn SD et al. Traumatic Brain Injury Patient, Injury, Therapy, and Ancillary Treatments Associated with Outcomes at Discharge and 9 Months Post discharge. *Archives of Physical Medicine and Rehabilitation.* 2015; 96(8): S304-S329.
24. Hammond FM. Readmission to an acute care hospital during inpatient rehabilitation for traumatic brain injury. *Archives of physical medicine and rehabilitation.* 2015; 96(8):S293-S303.

