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CASE REPORT



Intensive, functional training leads to optimal outcomes in a young woman post brain stem hemorrhage due to cerebral cavernous malformation

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ABSTRACT

Purpose: Cerebral cavernous malformations (CCMs) can cause intracranial hemorrhages and account for 5–15% of all cerebral vascular malformations. The purpose of this retrospective case report is to describe the unusual motor recovery of a young woman following a large hemorrhage of a previously unknown brainstem CCM, otherwise not reported in the literature. **Case Description:** The patient was a 29-year-old female who presented with severe hemiparesis on the left 6 weeks after a first-ever hemorrhage. She had demonstrated minimal improvement in her motor recovery to date, was dependent on a walker for ambulation, and had no distal left upper extremity function. An intensive evidence-based plan of care over 6 weeks included progressive task-specific strengthening, treadmill training, and dynamic balance training. **Outcomes:** The patient achieved complete motor recovery, indicated by improvement from 23/66 to 64/66 in the Fugl-Meyer Upper Extremity Subscale score and from 12/30 to 30/30 in the Functional Gait Assessment. She returned to independent ambulation with functional gait speeds and kinematics. **Discussion:** This case report demonstrates an unusual clinical course of unexpected full recovery in a young woman after a large brainstem CCM after an intensive 6-week course of physical therapy. Other patients with a similar presentation after CCM may benefit from an intensive plan of care. Clinicians should be aware of the possibility of unusual recovery in this population as not to limit expectations for recovery.

ARTICLE HISTORY

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KEYWORDS

cerebral cavernous malformation; hemorrhagic stroke; physical therapy

Background

Cerebral cavernous malformations (CCMs) can cause an intracranial hemorrhage (ICH) and account for 5–15% of all cerebral vascular malformations (Morrison and Akers, 2016). Defined as a cluster of enlarged capillary channels lacking mature cell wall elements, CCMs can occur throughout the central nervous system and are often undiagnosed until symptoms present. Genetic mutation is the only risk factor for developing a CCM and it can be either hereditary or sporadic (Morrison and Akers, 2016). Several autopsy and magnetic resonance imaging (MRI) review studies have reported the prevalence of CCM between 0.4% and 0.6% in the general population (Gross and Du, 2016; Smith and Scott, 2010). The incidence of this vascular disorder is more accurately described as a detection rate given its spontaneous course and has been reported at 0.39% in the United States (Del Curling, Kelly, Elster, and Craven, 1991).

Gross and Du (2016) reported a history of hemorrhage to be the only significant risk factor specific to individuals recovering from CCMs for experiencing a

future bleed with a risk ratio of 3.73 at the 95% confidence interval. The authors of this systematic review did not find any correlation in the literature for sex, location, size, and multiplicity of the malformation, and association with developmental venous anomalies as risk factors for hemorrhage.

Symptoms of a CCM primarily manifest between the second and fifth decades of life and feature various clinical presentations including seizures, headaches, cerebral hemorrhage, and/or focal neurologic deficits (National Organization of Rare Disorders, 2016). However, hemorrhage of a CCM does not always lead to symptom presentation and as many as 40% of individuals are clinically asymptomatic, even in the presence of a CCM. The prospective risk for hemorrhage of an un-ruptured CCM is approximately 0.4–0.6% per patient-year; whereas, the risk for re-bleeding of a previously ruptured CCM ranges from 4.5–22.9% per patient-year (Gross and Du, 2016). Given the dynamic nature of CCMs (Morrison and Akers, 2016), the potential for deficits can change over time. Therefore, routine imaging is recommended to monitor for new

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lesions and early detection of hemorrhages for any person with known CCMs.

In a prospective investigation of functional outcomes in 331 subjects who did not receive surgical or rehabilitative treatment after brainstem CCM, 81% of survivors lived independently, 92.7% improved or stabilized, and only 28.7% of patients completely recovered (Li et al., 2014). The significant prognostic factors for a favorable outcome were no prospective hemorrhage from the date of initial diagnosis of a CCM, younger age, and small lesion size. Additionally, a literature review of CCMs concluded that female patients typically had a worse prognosis than males (Mouchtouris and Chalouhi, 2015). Surgical management of a CCM has also shown favorable results with 84–89.7% of individuals achieving improved or unchanged long-term functional outcomes (Li et al., 2013). However, surgery had inherent risks with 16–26.9% of patients experiencing permanent morbidity and a 0.8–1.5% mortality rate (Gross et al., 2013; Li et al., 2013). Therefore, patients should be managed according to their individual presentation (Batra, Rigamonti, and Rigamonti, 2012).

There is paucity in the literature on the influence of rehabilitation on functional outcomes in this population. Therefore, limited information is available to date to guide physical therapy (PT) treatment and prognosticate motor outcomes in this special population. Given the similarities in clinical manifestations of individuals with CCM to those experiencing a stroke, principles of rehabilitation following stroke were used as the foundation for the interventions described in this report. Rehabilitation following stroke has proven to be a valuable part of the recovery process with benefits including improved quality of life and functional outcomes (Winstein et al, 2016). The literature was applied with caution, however, as the majority of this research details rehabilitation from stroke caused by other mechanisms than a hemorrhagic CCM. The purpose of this retrospective case report of an episode of care is to describe the unusual recovery of a young woman presenting with focal neurological deficits following a large hemorrhage of a brainstem CCM. To our knowledge, this is one of few descriptions of motor outcomes following PT intervention for an individual with this diagnosis.

Case description

Patient history

The subject of this study was a 29-year-old female research analyst who presented after experiencing her

first-ever hemorrhage of an unknown CCM located in her brainstem. Magnetic resonance imaging and computed tomography scanning revealed a primary hemorrhage of a brainstem CCM (Figure 1), along with 15 additional asymptomatic CCMs in multiple locations throughout her brain. A timeline of the individual's condition can be found in Figure 2. There was no family history for CCM hemorrhage, but imaging had not yet been performed to rule out asymptomatic CCMs in her family members. Despite 12 pack-years of smoking cigarettes, her medical history was otherwise uneventful.

Five days prior to her hospital admission, she experienced initial symptoms of a pressure headache, double vision, and sensitivity to light during a day hike. Her condition slowly worsened over the next 5 days and she lost voluntary control of her left upper extremity (UE) and lower extremity (LE), leaving her unable to ambulate. At that time, the subject was admitted to the intensive care unit where she received intravenous corticosteroids and inpatient PT. She was released from the hospital to home after a 1-week stay with a 2-week course of oral corticosteroids. She was independent with bed mobility, transfers, and ambulation with a front-wheeled walker (FWW) and left ankle foot orthosis. The individual reported no significant improvements in her mobility in the 5 weeks between hospital discharge and the episode of care described within this report.

The initial encounter took place at a University outpatient clinic 6 weeks after her onset of symptoms. The individual was evaluated and subsequently seen for PT twice weekly for 6 weeks. Her treatment at this clinic was supplemented with 30 min of PT and occupational therapy every other week at a conventional outpatient clinic. Speech therapy was not recommended for this individual.

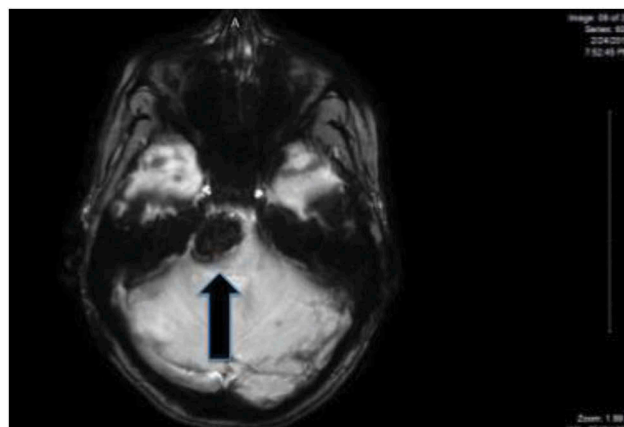


Figure 1. MRI of brainstem hemorrhage.

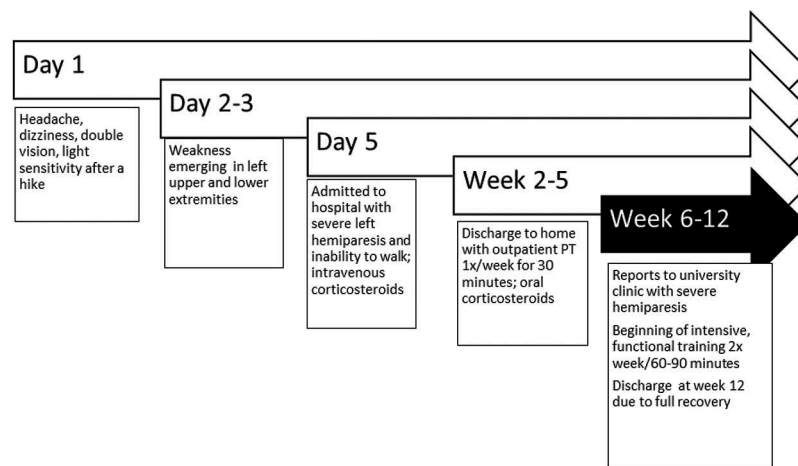


Figure 2. Timeline of patient's condition.

At the time of evaluation, the subject lived independently in a single-story home, used a FWW for community ambulation, and worked 30 h/week. Her work was clerical in nature and required short distance ambulation as well as data entry. Outside of work, her most frequent social activities were having dinner with friends and getting her nails done. Her prior level of function included full independence in all aspects of functional activity and a weekly exercise routine using calisthenics. Her physician had discharged her from all medications after the 2-week course of oral corticosteroids. The individual's primary concerns were left-sided hemiparesis and decreased activity tolerance causing inability to use her left side during activities of daily living (ADLs). Her goals for PT were to type 40 words/min, perform ADLs at her premorbid level, ambulate independently, and improve her endurance for all physical activities. This case report does not fall under the purview of Institutional Review Board oversight at California State University Sacramento.

Systems review

The subject's cardiopulmonary system was unremarkable based on objective measurements: resting blood pressure was pre-hypertensive at 130/70 mm mercury, resting heart rate was 73 beats/min, and resting respiratory rate was 15 breaths/min. The neuromuscular and musculoskeletal systems were impaired based on medical diagnosis, observation, and examination data listed in Table 1. The integumentary system was unimpaired based on observation and patient report. Her language communication, affect, cognition, and learning were unimpaired based on observation and patient report. Mild hoarseness of

voice had resolved at the time of initial encounter based on patient report. The participant stated no abnormalities with urogenital or gastrointestinal systems. She weighed 62.6 kg and stood 162 cm, with a body mass index of 23.7.

Examination test and measures

The examination was organized by the International Classification of Functioning (ICF) Model (Cieza et al., 2002).

Body structure and function

The Modified Ashworth Scale (MAS) is a reliable and valid measure used to assess resistance to passive movement about a joint with varying degrees of velocity (Katz, Rovai, Brait, and Rymer, 1992; Kaya et al., 2011). The positive and negative likelihood ratios for the MAS are 6.25 and 0.54, respectively (Malhotra et al., 2008).

Somatosensory testing was conducted for light touch, pinprick, proprioception, and kinesthetic sense. A cranial nerve assessment was also conducted. Vestibular system integrity was examined using the Modified Test of Sensory Integration and Balance.

Manual Muscle Testing (MMT) (Hislop and Montgomery, 1995) was used to assess voluntary strength using manual resistance from the clinician with the subject in a standardized position. The grading system uses an ordinal scale from 0 to 5, with 5 representing full strength and grades 0–4 indicating varying degrees of muscle weakness. The Minimal Detectable Change (MDC) associated with MMT is a change of at least one full grade (Cuthbert and Goodheart, 2007). The individual's cerebellar motor function was assessed

Table 1. Examination baseline data and outcomes.

Test	Baseline data		Discharge data		MCID/MDC
Gait Observation	<ul style="list-style-type: none"> • Trendelenburg sign during L mid-stance • L knee hyperextension during mid-stance • L toe drag during initial swing • L arm swing less than R • L stance phase less than R • L step length greater than R 		<ul style="list-style-type: none"> • No visible hip drop • No visible L knee hyperextension • No visible L toe drag • Symmetrical upper extremity swing • Symmetrical stance phase and step length • Independent walking 		NA
Modified Ashworth Scale	Joint Elbow	L Flex: 1 Ext: 1+	No spasticity found		NA
	Wrist Fingers Ankle	Flex: 1 Flex: 3 PF: 2			
Manual Muscle Test	Joint Shoulder	L Abd: 2-/5 Flex: 1+/5	Joint Shoulder	L Abd: 4/5 Flex: 4/5	MDC = 1
	Elbow	Flex: 1+/5 Ext: 3/5 Sup: 3/5	Elbow	Flex: 5/5 Ext: 5/5 Sup: 4/5	
	Wrist	Flex: 2/5 Ext: 1/5	Wrist	Flex: 4/5 Ext: 4/5	
	Hip	Flex: 4-/5 Ext: 4/5 Abd: 4/5	Hip	Flex: 5/5 Ext: 5/5 Abd: 5/5	
	Knee	Flex: 3/5 Ext: 4-/5	Knee	Flex: 3+/5 Ext: 5/5	
	Ankle	DF: 1/5	Ankle	DF: 5/5 PF: 3/5	
Hand Held Dynamometer	0 lbs with L hand		20 lbs with L hand		*MCID = 13.6lbs
6-Minute Walk Test	296 m with SBA, ankle brace, and FWW		488 m independently		*MCID = 34.4m
Fugl-Meyer Upper Extremity Subscale	23/66		64/66		*MCID = 5.25
Nine Hole Peg Test	Unable to attempt with hemiparetic side		28 s; faster than uninvolved side		*MDC = 32.9s
Functional Gait Assessment	15/30; SBA with ankle brace		30/30; independent gait without ankle brace		*MCID = 4.2
10-Meter Walk Test	SBA with ankle brace		Independent gait without ankle brace		*MCID = 0.16 m/s
	Self-selected: •0.58 m/s		Self-selected: •1.25 m/s		
	Fast speed: •0.78 m/s		Fast speed: •1.6 0m/s		
Stroke Specific Quality of Life Scale	161/245		245/245		Value not determined
Bike riding	Patient unable to ride a bicycle		Patient able to ride a bicycle independently		NA
Bimanual Typing	Patient unable to perform bimanual typing		Patient able to perform bimanual typing at premorbid level, > 40 wpm		NA

NA = not applicable; R = right; L = left; MCID = minimal clinically important difference; MDC = minimal detectable change; Flex = flexion; Ext = extension; Abd = abduction; PF = plantarflexion; DF = dorsiflexion; Sup = supination; lbs = pounds; SBA = stand by assist; m = meter; FWW = front wheeled walker; s = seconds; m/s = meter per second; wpm = words per minute

* MCID/MDC met

using coordination testing as able given the amount of initial hemiparesis on her left side.

Passive range of motion was performed to assess the subject's joint integrity and presence of limitations secondary to decreased motor function and subsequent tissue shortening.

A hand-held grip dynamometer is a valid and reliable device used to assess palmar grip strength (Bertrand et al., 2007; Boissy et al., 1999). The participant was seated with shoulder in neutral and elbow at 90° flexion and asked to squeeze the handle with the measurement recorded in kilograms (kg). The Minimal Clinically Important Difference (MCID) for the grip

dynamometer is 6.2 kg for the affected, non-dominant side with an effect size of 0.59 indicating a moderate improvement in patients with stroke (Lang, Edwards, Birkenmeier, and Dromerick, 2008).

The Fugl-Meyer Upper Extremity Subscale (FMUES) is a reliable and valid tool used to assess the subject's UE functional strength and mobility (Platz et al., 2005; Shelton, Volpe, and Reding, 2001). A maximum score of 66 includes only motor components with the clinically important difference of 5.25 for patients with chronic ischemic stroke and values for components of the instrument ranging from 4.25 to 7.25 (Page, Fulk, and Boyne, 2012).

The 6-Minute Walk Test (6MWT) is a reliable and valid tool used to measure the individual’s submaximal muscular and aerobic endurance (Eng, Dawson, and Chu, 2004). Impairments in walking endurance were determined using normative data from healthy individuals with similar demographics. The MCID at the 95% confidence interval (MCID₉₅) of the 6MWT for individuals with chronic stroke was used to determine change for this patient at 34.4 m (Tang, Eng, and Rand, 2012). The patient’s gait was assessed via observational gait analysis during overground walking with and without an assistive device.

Activity limitations

The Nine Hole Peg Test (9HPT) is a reliable instrument used to assess finger dexterity with UE function (Chen et al., 2009). The MDC at the 95% confidence interval (MDC₉₅) for the 9HPT for individuals with acute and chronic stroke is 32.8s for the more affected side and 6.2s for the less affected side (Chen et al., 2009). A moderate effect size has been reported at 0.66 between 1 and 6 months post stroke (Beebe and Lang, 2009).

The Functional Gait Assessment (FGA) is a reliable and valid 10-item test assessment of postural stability and dynamic balance during walking tasks (Lin et al., 2010). The MDC₉₅ is 4.2 for subjects with acute stroke with a moderate effect size of 0.54 (Lin et al., 2010).

The 10-Meter Walk Test (10MWT) is a reliable and valid tool to examine walking speed in m/s over a 10-m distance (Flansbjerg et al., 2005). The MCID₉₅ for comfortable walking speed is 0.16 m/s for patients with acute

stroke (Tilson et al., 2010). Walking speed has shown predictive value in determining the level of community ambulation with household ambulators walking < 0.4 m/s, limited community ambulators walking between 0.4 m/s and 0.8 m/s, and community ambulators walking > 0.8 m/s (Bowden, Balasubramanian, Behrman, and Kaut, 2008). These values correlated significantly with steps walked in a day to determine level of ambulation with a Pearson’s correlation coefficient 0.687 (Bowden, Balasubramanian, Behrman, and Kaut, 2008).

This individual’s needs for durable medical equipment and home modifications were assessed based on patient report and safety requirements.

Participation restrictions

The Stroke Specific-Quality of Life Scale (SS-QOLS) is a valid patient reported questionnaire assessing physical and psychosocial domains (Teixeira-Salmela et al., 2009). A high score of 245 indicates better functioning. The responsiveness of each domain is mild to strong with effect sizes ranging from 0.20 to 0.83 (Williams et al., 1999). Patient-specific outcomes including riding a bicycle and work-related bimanual typing were also used to measure change.

Examination findings

The complete list of baseline examination data can be found in Table 1 and a problem list based on ICF categories can be found in Figure 3.

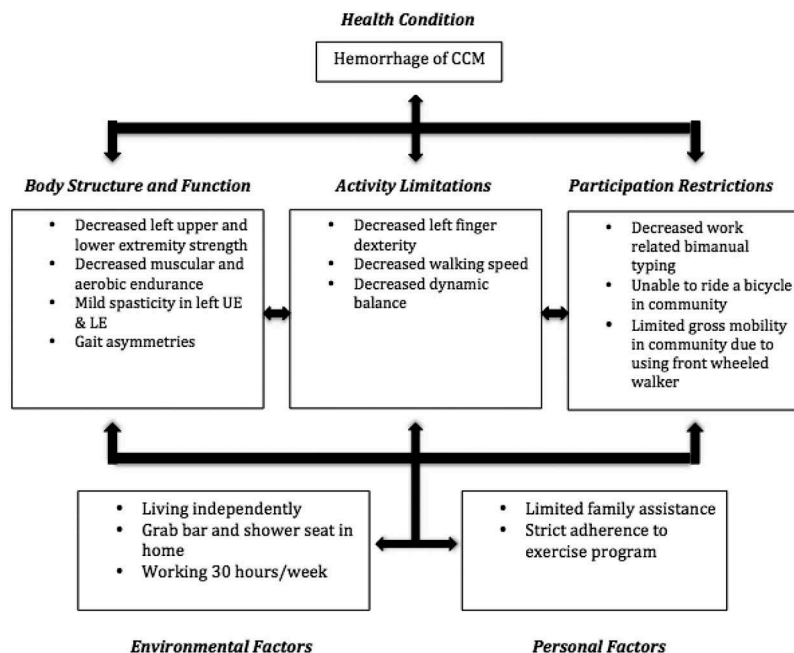


Figure 3. ICF problem list.

Body structure and function

The participant exhibited gait abnormalities including lack of dorsiflexion during initial swing, left knee hyperextension in mid-stance, a positive Trendelenburg in left mid-stance, decreased step length with the right LE, and decreased stance time on the left LE. Spasticity was mild throughout the patient's proximal upper and lower extremities on her left side, with little resistance to passive movement and attainable range of motion that was comparable to her uninvolved side. She had increased spasticity distally that was most notable in her finger flexors and ankle plantarflexors, with MAS scores of 3 and 2, respectively. During great physical effort, the patient exhibited a flexor synergy in her left UE and an extensor synergy in her left LE.

The patient exhibited weakness that was more severe in her left upper than her lower extremity and progressively worse proximal to distal. Complete results of her MMTs and grip strength measurements can be found in [Table 1](#). She was unable to actively form a grip or register a reading on her left with a hand-held dynamometer. She scored a 23/66 on the FMUES indicating decreased strength and mobility of her left UE. Her right UE showed no deficits and age-appropriate strength.

She was able to ambulate 296 m on the 6MWT, requiring stand by assist (SBA), a FWW, and an ankle brace, demonstrating decreased muscular and aerobic endurance. Compared to healthy females of similar age, height, and weight, her result is 58% below the predicted ambulation distance in 6 min (Enright and Sherrill, 1998).

Examination of the patient's cranial nerves, cerebellar and vestibular function, and sensation to light touch, pinprick, proprioception, and kinesthetic sense revealed no deficits.

Activity limitations

The patient was unable to perform the 9HPT with her left UE due to her inability to perform a functional reach and grasp to pinch and lift the pegs. She was able to complete the task in 29 s with her uninvolved upper extremity.

During the FGA, she required SBA while wearing her ankle brace to achieve a score of 15/30, indicating a large fall risk when not using her FWW. She exhibited greatest difficulty with specific items of narrow base walking, backward stepping, and walking while making head turns. The patient was able to utilize a stepping strategy, with occasional minimal assistance, to maintain her balance when necessary.

She required SBA during walking without an assistive device and used a front-wheeled walker (FWW) for

long distance ambulation. She used a hand splint for stretching, an ankle brace for stability, and it was her choice to no longer use an over the counter solid ankle foot orthosis (AFO) despite having only trace movement of left dorsiflexors.

Her self-selected walking speed based on the 10MWT was 0.58 m/s, while her fast walking speed was 0.78 m/s. Respectively, these values are 58% and 69% below the age-adjusted norms for healthy individuals (Bohannon, 1997). She required SBA and wore her ankle brace during the tests.

Participation restrictions

The result of the SS-QOLS was 161/245, or 66%. Areas she felt were most affected included her personality, energy levels, mobility, and arm function. The patient was not able to ride a bicycle in her community, nor could she perform bimanual typing at her premorbid level and used only her right hand for unilateral typing. These limitations also affected her ability to perform activities of daily living with her left arm at home, including dressing and grooming. At home, she used a grab bar and shower seat to assist with activities of daily living. She also transitioned her vehicle from manual to automatic transmission.

Diagnosis and prognosis

The PT diagnosis was left hemiparesis resulting in decreased work-related bimanual typing, decreased gross mobility at work and in the community, an increased fall risk when taking steps without the FWW, and the inability to ride a bicycle in the community. The patient's initial return to work was reduced to 30 h/week. Her self-selected walking speed was adequate for household ambulation, but even her maximal walking speed was sufficient only for limited community ambulation.

The patient's positive prognostic factors included no history of hypertension, no heavy alcohol use, no diagnosis of hypocholesterolemia, no prospective hemorrhage since this first bleed, intact sensation, and young age (Ariesen, Claus, Rinkel, and Algra, 2003; Li et al., 2014; Mouchtouris and Chalouhi, 2015).

Negative prognostic factors were her current hemorrhage, history of smoking, presence of multiple dormant CCMs, non-measurable grip strength, and female sex (Ariesen, Claus, Rinkel, and Algra, 2003; Coupar et al., 2012; Heller et al., 1987). The current hemorrhage and presence of other CCMs increased her risk of having a future hemorrhage, potentially influencing her recovery. Her inability to register a grip strength measurement at 6-week post-hemorrhage decreased the

likelihood of UE functional recovery. Based on her MRI, the magnitude of the lesion would have been considered large and thus decreased her likelihood of significant recovery.

Her ambulatory status at time of initial encounter was encouraging for future walking improvements. However, given she was 6-week post hemorrhage without improvement, the expectation for significant functional return was not optimal.

Intervention

Treatment application

No treatment protocols have been established for individuals recovering from a CCM. Descriptions of various interventions can be found in [Table 2](#). Therefore, PT interventions and principles (Kleim and Jones, 2008; Winstein et al, 2016) used in stroke rehabilitation were drawn upon to design the plan of care described for this patient. She was seen twice weekly for 60 to 90 min totaling 14 treatment sessions and was prescribed a daily progressive home exercise program. Her blood pressure, heart rate, and rating of perceived exertion were monitored throughout the sessions and found to respond appropriately to the given activity performed.

The treatment protocol included intensive, progressive resistance, and task-specific functional training interventions targeting the subject's impairments and activity limitations. Treatment aimed to improve the patient's unilateral weakness was prescribed by utilizing resistance exercises using body weight, bands, and manual resistance performed until fatigue. Initial resistance was determined effective to elicit strength gains based on her performance and perception of difficulty with the exercise. Interventions for improving her balance deficits were task-specific and progressed by decreasing stability while increasing mobility. Exercise protocols including variations of the treatment principles have resulted in improvements in strength and functional ability for patients with acute stroke, though typically of older age (Duncan et al., 2003; Outermans et al., 2010).

Treadmill training was incorporated to improve the patient's observed gait deviations and her muscular and aerobic endurance deficits, as has been seen with ambulatory patients post stroke (Mehrholtz, Pohl, and Elsner, 2014; Polese et al., 2013). The program included in this episode of care was 10–15 min, 2×/week, at progressive speeds ranging 0.63– 1.34 m/s per hour, with inclines reaching a 5% grade. The patient initially used her right UE for support by holding the handrail and able to incorporate her left UE for support at later sessions. She was encouraged to gradually decrease this support

over time by increasing reciprocal arm swing. No unweighting of the patient using a harness was utilized.

Treatment progression

The patient's presentation evolved throughout the episode of care as she made rapid improvements in her functional ability. Therefore, the interventions were prescribed according to her need at each particular point to address specific impairments and limitations. Her home program was developed to integrate the combined interventions prescribed during the entire episode of care to ensure consistency with addressing each impairment and limitation. She was educated about her recovery and the importance of preventing learned non-use of her left upper extremity in particular. She was encouraged, as part of her home program, to incorporate her left upper extremity during all ADLs and work activities despite the potential for frustration during completion of a task.

Direct interventions were initially focused on a progression away from using assistive devices by addressing lower extremity weakness, decreased gait speed, and fall risk. Progression of the exercises included a gradual increase in exercise volume as the patient improved with performance and tolerance. Initially, strengthening exercises were performed for 2–3 sets of 5–10 repetitions. Volume was increased over time to 4–5 sets of 10–15 repetitions in order to meet the patient's improvements with strength and tolerance.

Within the first 2 weeks, she progressed from a FWW to a single point cane. By 3rd week, she exhibited independent gait without an assistive device for all ambulation within the community. At this point, treatment sessions were shifted to enhance the return of strength and function in her left upper extremity and progress balance interventions.

During the 3rd and 4th weeks of PT, the patient's grip strength increased from zero to 10 pounds with the hand-held dynamometer and exhibited adequate strength to raise her left UE above her head, which she was not able to do just a few weeks earlier. Functionally, she was able climb stairs with step over pattern and no assistance and walked on the treadmill at increasing speeds. Interventions to maximize finger dexterity and UE functional strength were progressed using hand therapy resistance bands and manual resistive techniques, including proprioceptive neuromuscular facilitation. Balance interventions were progressed based on decreasing her base of support while increasing the mobility of her lower extremities, which included narrow-based walking and lunges.

The 5th and 6th weeks of PT were focused on maximizing her function and refining skills during physical

Table 2. Example interventions during plan of care.

IMPAIRMENT	INITIAL INTERVENTION: 2–3 sets of 5–10 repetitions	PROGRESSION: 4–5 sets of 10–15 repetitions
Impaired Gait Mechanics, Decreased Muscular and Aerobic Endurance, Decreased Walking Speed	Treadmill training for 10 minutes at the beginning of each session. Treadmill speed began at 1.4mph and zero incline. Patient was cued with verbal commands to actively control left dorsiflexion, end range knee extension, increase right step length, and increase arm swing. BP, HR, and RPE were monitor before, during, and after walking.	Treadmill time increased to 15 min each session. Treadmill speed incrementally increased to 3.0 mph and 5% incline based on patient comfort, performance, and need for UE support. Dual task training included by adding conversation and small head turns in different directions.
Decreased Lower Extremity Strength	Plantarflexor and dorsiflexor strength addressed by repeated toe taps and heel-raises in sitting until fatigue. Therapist applied tactile cues to calf musculature for feedback about muscle contraction. Body weight squats against exercise ball performed until fatigue. Patient instructed to maintain center of mass in midline. A mirror was used to provide feedback. Hip hikes performed in standing with left foot placed on step. Patient instructed to lower right hip and return by contracting left hip abductors. Hamstring curls in standing by bringing heel of foot toward buttocks. Patient instructed to maintain stationary thigh throughout movement. Stair climbing one flight of stairs at the end of each session. Began with step-to-step pattern using handrail and led with involved LE for 25% of the steps.	Standing heel raises with decreased UE support. Tactile cueing to left calf musculature to facilitate contraction. Manually resisted dorsiflexion in supine with concurrent straight leg raise. Patient instructed to maintain dorsiflexion against resistance while performing straight leg raise until performance decreased. Lunges and single leg squats in parallel bars as needed for balance. Therapist provided instruction to maintain proper mechanics throughout motion. Bridging in supine with tactile facilitation. Stair climbing with reciprocal step pattern.
Decreased Upper Extremity Strength	Weight bearing exercises through UE in sitting with hand on mat by shifting weight onto left side and returning to midline. Manual resistance UE PNF Diagonal-2 flexion pattern using rhythmic initiation with assistance given as tolerated. Scapular squeezes with depression in sitting. Tactile cues for muscle contraction. Patient instructed to hold for 5 s and relax.	Quadruped on floor mat resisting perturbations from therapist. Decreasing base of support to one hand with continued perturbations. Resistance bands performed in UE PNF Diagonal-2 pattern. Also used in forward flexion, scaption, and abduction planes. Scapular squeezes in prone with increasing lever arm by adding UE flexion.
Decreased Finger Dexterity	Hand therapy activities with magnets, marbles, clips, and play-doh. She performed object manipulation within one hand by finding items in a rice bucket.	Grip strengthening was performed with resistance bands for opposition, flexion, extension, and abduction.
Decreased Dynamic Balance	Balance board with visual feedback for weight bearing between left and right sides. Patient performed squats while maintaining center of mass in midline. Patient walked with head turns and arm movements to challenge mobility with instability. Static standing on unidirectional balance board.	Stepping activities to challenge base of support and limits of stability while patient moved cursor on monitor to correct location. Walking progressed to lunges and lunges progressed to crossover stepping while still performing head turns and arm movements. Movements attempted with eyes open and eyes closed to further challenge balance systems. Patient instructed to maintain neutral board position while adding arm movement perturbations. Progressed to moving board into dorsiflexion and plantarflexion with controlled motion. Patient performed riding a 2-wheeled bicycle outside with stand by assist, including turning, stopping, and increasing speeds. Instructed on safety when mounting and dismounting the bicycle.

activities. Treadmill speeds were increased to 3.0 miles/h with inclines reaching a 5% grade. The patient was safely re-trained in riding a bicycle independently in an open environment.

Outcomes

A complete list of outcomes can be found in [Table 1](#).

Body structure and function

During the episode of care, the patient improved from severe left hemiparesis to make substantial strength improvements. Her gait efficiency improved and she exhibited symmetrical swing and stance phases,

concentric dorsiflexion during initial swing, eccentric dorsiflexion control during terminal swing, eccentric control at the knee during loading response, and an absent Trendelenburg sign during left mid-stance. There was no detectable spasticity and she had full voluntary and selective control of her left side with no visible synergistic movements.

She significantly increased her strength scores based on MMTs and grip measurements, exceeding the MDC on the majority of the follow-up measurements. Her FMUES score progressed from 23/66 to 64/66 and surpassed the MCID of 5.25. She was able to move through full range of motion with side-to-side equality. Her 6MWT improved by 192 m of independent gait without an assistive device and exceeded the level of

meaningful change of 34.4 m. Despite achieving a meaningful change, she remained 31% below her predicted value compared to healthy counterparts (Enright and Sherrill, 1998).

Activity limitations

At initial evaluation, the patient had been unable to attempt the 9HPT with her left side. At discharge assessment, the score of her involved side exceeded that of the right UE and met the MCID of 32 s. Her FGA improved from 15/30 with SBA to 30/30 independently and exceeded the MCID of 4.2, indicating no fall risk.

Self-selected walking speed improved from 0.58 m/s with SBA to 1.25 m/s independently and fast walking speed improved from 0.78 m/s with SBA to 1.60 m/s independently, indicating a functional community ambulation speed. Each value exceeded the MCID of 0.16 m/s; however, she was 10% below comfortable walking speed and 37% below fast walking speed compared to healthy individuals of similar age (Bohannon, 1997).

Participation restrictions

The patient improved her SS-QOL score from 161 to 245, the maximum score, indicating full recovery of her overall quality of life. She was able to ride a bicycle independently and performed bimanual typing at her pre-morbid level.

In summary, from the initial encounter to the discharge assessment, this patient made marked changes across all outcome measures and exceeded all available MCIDs. She resumed all social interactions, ADLs, and functional activities. Despite remaining below her predicted values for walking speed and endurance, she was no longer limited with her mobility in all environments.

Discussion

This case report illustrates the unexpectedly positive functional outcomes of a patient participating in PT following hemorrhage of a brainstem CCM. To our knowledge, this is the first publication describing the outcomes following an episode of care of PT for an individual following such an event.

The untreated functional outcomes of individuals with hemorrhagic CCMs have been described, with almost 30% of those in the study experiencing complete functional recovery (Li et al., 2014). Individuals achieving that level of success were of younger age and

experienced no prospective hemorrhage during their observation period. The same was true for the patient in this report who had received PT intervention. Despite female patients with a CCM typically having a worse prognosis (Mouchtouris and Chalouhi, 2015), the current patient exceeded the expected degree of functional recovery and substantially lessened the time frame of recovery compared to individuals in the available published studies.

Typically, the initial degree of motor impairment following a stroke predicts the course of subsequent motor return (Hendricks, Van Limbeek, Geurts, and Zwartz, 2002; Jorgensen, Nakayama, Raaschou, and Olsen, 1999). In a seminal study, Heller et al. (1987) found that non-measurable grip strength in the first 24 days following a stroke indicated the absence of useful arm function at 3 months. A more recent systematic review confirmed that initial measures of upper extremity function were the most significant predictor of functional outcome after stroke (Coupar et al., 2012). They also concluded that intact sensation was a positive indicator of UE recovery. The patient in this case report did not register grip strength until the 8th week after hospital discharge and her sensation was intact. Based on her lack of early return and initial motor presentation, there was limited expectation of future upper extremity recovery, despite having no sensory impairments. Contrary to these expectations, by the 12th week after discharge, she had full functional ability in her upper extremities. This unexpected recovery pattern may be explained by this patient's relatively younger age and the type of cerebral vascular incident compared to the subjects represented in the Coupar et al. (2012) review.

Evidence strongly supports the use of intensive, progressive resistance, and task-specific training to improve outcomes for strength and function after stroke. In a randomized controlled study (Outermans et al., 2010) of 44 patients 2 to 8 weeks after stroke, participants performed a high-intensity exercise protocol consisting of 45-min sessions three times a week for 4 weeks, which was comparable to the volume of exercise performed by the patient in this report. Improvements beyond clinical significance were achieved on the 10MWT and 6MWT for this group of subjects. Additionally, progressive resistance and functional exercises utilizing body weight and resistance bands improved stroke recovery for a group of subjects 30–150 days post stroke in areas of balance, walking endurance and speed, and upper and lower extremity function (Duncan et al., 2003). Interestingly, subjects with higher baseline scores on upper extremity functional measures experienced the most improvement,

with average baseline scores of 45/66 on the FMUES for those who eventually improved. This was contrary to the patient in the present report, whose baseline score was 23/66 and went on to achieve higher success on the FMUES than those in the study.

Conversely, a systematic review (Salter, Musovic, and Taylor, 2016) consisting of five trials and a total of 350 participants found that although progressive resistance training was safe within the first 3 months after stroke, there was no significant improvement in strength or activity compared to conventional therapy. The review comprised protocols including lower intensity exercises with higher repetitions, which might not have been adequate stimulus to elicit the desired strength improvements. In addition, the severity of impairment for patients within the first 3 months after stroke might limit the effectiveness of progressive resistance exercises due to safety concerns and appropriateness of the exercise. There was no concern about the appropriateness of high-intensity strengthening exercises for the current patient. She had no comorbidities that would limit the effect of these exercises, such as cognitive deficits or unusual vital sign response to activity. She initially demonstrated her ability to perform the exercises at a lower level that would allow sufficient progression of resistance throughout the plan of care. Lastly, her youth and background of being a relatively active individual prior to her CCM rupture made this type of program desirable.

In conjunction with the resistance-training program, treadmill training was prescribed as a means of providing a functional and task specific intervention. A systematic review (Polese et al., 2013) of nine studies and 977 participants 1.6 to 27 months after stroke reported treadmill training without body weight support resulted in faster walking speeds and greater walking distance when delivered to ambulatory patients after stroke. Another systematic review of 16 studies consisting of 823 participants of various demographic characteristics who experienced strokes of various origins found treadmill training without body weight support to be most beneficial for patients who were ambulatory and within 3 months of their recovery (Mehrholz, Pohl, and Elsner, 2014). The authors demonstrated benefits of treadmill training as a safe and effective intervention. The latter article also reported difficulty suggesting what influence different frequencies, durations, and speeds may have for producing desired results. In spite of her different age and stroke etiology, the current patient improved her walking speed and distance beyond the reported mean improvements of the subjects in these treadmill studies when prescribed a similar treatment protocol.

The patient in this case report experienced minimal progress during the 6-week period between discharge from the acute care hospital and initial assessment in the outpatient setting. Following a 6-week intensive outpatient PT program, testing indicated that this individual had returned to her premorbid functional status 3 months after the initial hemorrhage. The timeline of recovery seen here occurred at an unusually rapid pace when compared to those with untreated functional outcomes following hemorrhage of a CCM, with complete recovery occurring for those individuals on average at 4.1 months and as late as 18 months (Li et al., 2014). It is unclear whether those individuals had a similar period of stagnation followed by full recovery to the patient in this report. The exact course of rehabilitation, if any, these patients may have received is also unknown.

Compared to other individuals with ICH due to various causes, the subject in this report also differs. Given that initial severity of motor impairments determines future functional recovery and ICHs are associated with greater initial motor impairments (Kelly et al., 2003), the outcome of patients with an ICH is generally not optimal (Jorgensen, Nakayama, Raaschou, and Olsen, 1995). The patient in this report was consistent with this presentation given the severity of her initial motor impairments, highlighted by her inability to walk unassisted, and a lack of voluntary movement in her left upper extremity. The difference between the current patient and those detailed in the literature is the degree of recovery she achieved, returning to full functional ability, and even riding a bicycle within a relatively short period of time. In addition, her functional recovery in her upper extremity exceeded expectations given her initial degree of flaccidity (Coupar et al., 2012).

In a study of 44 individuals following rupture of CCM, the most common symptoms reported were cranial nerve deficits, hemiparesis, hemisensory loss, and cerebellar symptoms in that order. Headaches were not typically the predominant complaint and of the 25% with midbrain lesions, 37% of those had corticospinal tract involvement (Hauck, Barnett, White, and Samson, 2009). The patient described in this report deviated from this presentation. She experienced the less common symptoms of hemiparesis and headaches, without involvement of more common structures such as sensory tracts or cerebellum, and only very early mild cranial nerve involvement that affected her speech initially. Furthermore, a smaller lesion size has been linked to improved prognosis (Li et al., 2014). Based on the MRI for the current subject (Figure 1), the large lesion size would not have predicted the level of recovery she ultimately achieved.

There was almost certainly a natural and spontaneous neurological recovery that occurred during this episode of care which differed from those detailed in the available literature. The 6 weeks of stagnation in her recovery this patient experienced was an unusual course compared to typical patterns seen after stroke. After this period, she experienced rapid and vast gains in her functional ability that could not be attributed solely to her PT program. It is unclear the degree to which her recovery was attributed to spontaneous improvement or her rehabilitation program.

Conclusion

While spontaneous recovery may account for some of this patient's improvements, the significant progress that occurred specifically after the 6-week intensive PT program is noteworthy. The literature supporting the use of intensive, progressive resistance, and task-specific functional training interventions following a stroke is clear; when it can be safely administered, it is an effective way to improve strength and function for these individuals. The outcomes presented were unusual compared to the progression of stroke recovery typically seen (Jorgensen, Nakayama, Raaschou, and Olsen, 1999), highlighted by a 6-week delay in improvement from severe paresis to full functional recovery. To our knowledge, this is the first case describing the functional outcomes through PT for an individual following brainstem hemorrhage of a CCM. Subjects with similar diagnoses and presentations may progress in similar patterns and clinicians should be aware of that possibility so to not limit expectations of recovery.

Declaration of Interest

The authors declare no conflicts of interest.

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