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Management of a Patient with Cavernous Malformation Surgical Repair at C7-T3: A Case Report

Thomas A. Koc[1, *], Jenna Tucker[1], Christopher Durante[2], Razija Hasanovic[1], Sara Gotthold[1], Timothy Marshall[1]

[1]School of Physical Therapy, Kean University, Union, United States of America

[2]Prostaff Physical Therapy, Nutley, United States of America

Email address:

Tkoc@kean.edu (T. A. Koc), JTucker@kean.edu (J. Tucker), Cdurante@prostaffpt.com (C. Durante), hasanovr@kean.edu (R. Hasanovic), gotthols@kean.edu (S. Gotthold), Marshati@kean.edu (T. Marshall)

[*]Corresponding author

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Abstract: *Background:* Cavernous malformations (CM) are rare vascular lesions occurring within the brain or spinal cord, managed using surgical and/or non-surgical interventions. Limited studies exist outlining physical therapy (PT) intervention guidelines or functional outcomes for individuals with CMs. *Objective:* This case outlines PT interventions that were used for a 35-year old female 6 weeks status post-surgical management of a C7-T3 spinal cord CM, and their impacts on the Timed-Up and Go (TUG), Five-Time Sit to Stand (5xSTS), and Observational Gait Analysis (OGA) functional outcome measures. *Case Description:* The patient participated in 41 visits of outpatient PT over 18.5 weeks focusing on compound and closed kinetic chain (CKC) interventions to improve lower extremity functional strength and coordination, gait and balance, endurance, agility, and core stabilization. *Outcomes:* TUG and 5xSTS times met the patient's goals by visit 23, three weeks into treatment. OGA demonstrated improvements with steadier ambulation, a decreased base of support, increased arm swing and trunk rotation, coordination and timing, and endurance over the 18.5 weeks of treatment. *Conclusion:* These findings suggest that compound and CKC interventions and gait training may have potential to improve functional mobility, standing balance, and gait quality in this patient with a spinal cord CM.

Keywords: Physical Therapy, Interventions, Outcomes

1. Background

Cavernous malformations (CMs) are rare vascular lesions that occur within the brain and/or the spinal cord [1, 2]. Spinal cavernomas have an incidence rate of 0.04–0.05% in the general population [3]. These vascular pathologies constitute 3–5% of all central nervous system lesions and account for approximately 5% to 15% of all spinal vascular malformations [3, 4]. The literature suggests a variety of possible risk factors associated with CMs including age, gender, and genetics [5-8]. CM-related symptoms most often appear between ages 30 and 40, with an increased incidence in females than in males [5].

The diagnosis of CM is identified with magnetic resonance imaging (MRI) [1, 2]. There is a wide variation in type and degree of neurological signs and symptoms, ranging from none to severe disability [1]. Two common signs include seizures and hemorrhages, with frequently reported symptoms of headache, double vision, weakness, and sensory disturbances [1, 8]. The reason behind the variability of the symptoms experienced with CM remains unknown, producing uncertainty in the progression of the condition [1].

Treatment options include surgery or symptom management, with the most important factors to decision-making being the doctor's opinion on surgery and availability of an expert surgeon, the degree of disability, and patient's fear of the disease progressing [1]. Surgeons report invasive procedures to be beneficial, but effective conservative treatment with no significant neurological deficits has also been documented [9].

Furthermore, conservative, or non-operative, management outcomes with CMs are widely variable, with some studies reporting better long-term outcomes after surgical management, and others reporting improvement or maintenance of baseline symptoms in 50% of patients treated conservatively [7]. The observed variability may be due to a lack of clinical guidelines available for surgical and non-surgical management of CM [9]. There are also limited studies outlining physical therapy (PT) intervention guidelines and reliable functional outcomes to manage the symptoms associated with post-surgical treatment of CM. Due to the variable nature of CM, there are few neurological conditions that consistently mimic its symptoms and presentation.

Despite the absence of clinical guidelines and evidence for PT and CM, the current literature shows that compound and closed kinetic chain (CKC) interventions improve function in populations with neurological deficits, similar to those who underwent a surgical repair of a CM. The purpose of this case report is to demonstrate the efficacy of a foundational PT management approach for a post-surgical C7-T3 spinal cord CM, and its impact on the Timed-Up and Go (TUG), Five-Time Sit to Stand (5xSTS), and Observational Gait Analysis (OGA) functional outcome measures.

2. Case Description

2.1. Participant

The patient was a 35-year-old female who reported bilateral lower extremity (LE) weakness (left > right), loss of pain and temperature at and below the T5 dermatome, and loss of vibratory sense in bilateral feet which progressively worsened over two years. The patient's MRI results concluded a C7-T3 spinal CM (Figures 1, 2, 3). Following surgery for a C7-T3 spinal CM, the patient spent 3 days in an inpatient hospital before being transferred to an acute rehabilitation facility for 5 days. She then received home PT for 3 weeks. The patient presented to outpatient PT 6 weeks following surgery for a C7-T3 spinal CM.

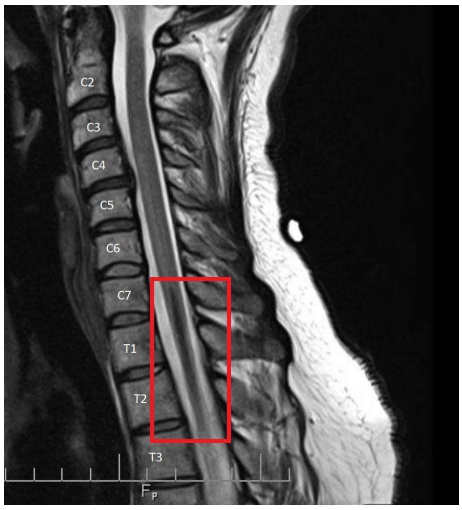

Figure 1. *T2 MRI - Sagittal view.*

Figure 2. *T2 MRI - Transverse view.*

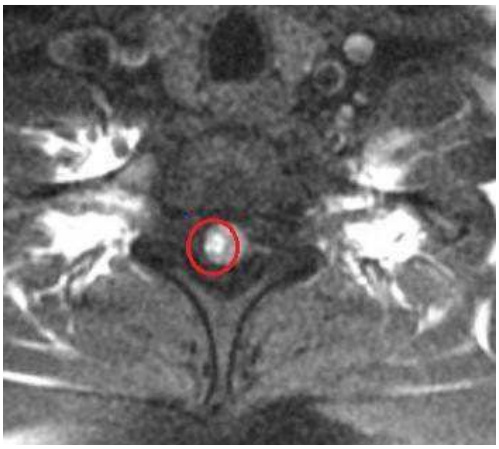

Figure 3. *T1 MRI - Transverse view.*

The authors disclose that this case report was conducted in accordance with the Declaration of Helsinki 1964 and sufficient informed consent was obtained from the patient, paying attention to the Health Insurance Portability and Accountability Act (HIPAA) of 1996.

2.2. Evaluation

During the PT initial evaluation (IE), 6 weeks post-surgery, the patient reported an increase in pain, symptoms (such as right knee buckling), and difficulty with static and dynamic balance, ambulation, stair negotiation, transfers (sit to stand), and sleeping. The patient's goals for therapy were to "reduce my fatigue, and improve my stamina and balance."

3. Tests and Measures

Outcome measures included the TUG, 5xSTS, and OGA. The patient was seen 2-3 times a week and re-evaluated on visits 12, 21, 28, 34, and 41 (at weeks 3, 6.5, 10.5, 16.5, and 18.5, respectively) for these functional outcome measures.

The TUG test is used to assess mobility, balance, walking ability, and fall risk in older adults [10]. Current literature has determined the TUG to be a valid and reliable outcome tool in the following populations: vestibular disorders,

Parkinson's disease, Alzheimer's disease and progressive dementia, brain injury, osteoarthritis, older adults and geriatric care, spinal injuries, and stroke [10]. The TUG is inexpensive, quick to perform, does not require significant space or additional staff training, and has normative reference values across the adult spectrum [11].

The 5xSTS provides clinicians with an objective measure of lower limb muscle strength [12]. It also provides a method to identify movement strategies an individual uses to complete transitional movements [13]. Current literature has determined the 5xSTS to be a valid and reliable outcome tool in the following populations: vestibular disorders, Parkinson's disease, multiple sclerosis, back pain, stroke, older adults and geriatric care, joint pain and fractures, arthritis, pulmonary diseases, cerebral palsy, and non-specific patient population [13]. The 5xSTS is inexpensive, typically takes less than five minutes to perform, and does not require any additional staff training [13].

OGA is often measured over a six meter distance, with one meter added before and after the six meter path to avoid recording acceleration and deceleration phases [14]. Specifically, assessing gait variability through observation becomes useful in identifying changes in ambulation that are due to pathological conditions or diseases [14]. The greater the variability seen with ambulation indicates reduced consistency and a more unstable gait pattern, leading to an increased risk of falls [14].

Table 1. *PT Treatment Focus and Interventions.*

	Treatment Plan	Specific Closed Kinetic Chain Interventions	Sets, Repetitions, Time
Visit 1 - 11 *(weeks 1-3)*	Lower extremity (LE) strengthening/coordination and core stabilization Gait and balance	Lateral Walks with Red Theraband Progressed to: Green Theraband Black Theraband W-Walks Pallof Press with Blue Theraband Boxing Lateral Step-Ups Eccentric Step-Downs TRX Squats Progressed to: Curtsy Squats Curtsy Squats with BOSU Incline Treadmill Gait Training with verbal cues for weight shift, heel strike, and base of support	2x for 4' 2x for 4' 8' 3 sets of 10 reps 3 sets of 10 reps 3 sets of 10 reps 8' (incline treadmill and gait training)
Visit 12 - 20 *(weeks 3-6.5)*	LE strengthening/coordination and core stabilization Strength and balance	Leg Press with 50 lbs Progressed to 65 lbs Bulgarian Splits Trap Bar Deadlifts Incline treadmill Upright Bike HIIT - targeting Quads Yoga Boxing Progressed by adding core challenges	3 sets of 8-20 reps 3 sets of 8-20 reps 3 sets of 8-20 reps 10' at 2.2 mph 6' 8' 8'
Visit 21 - 27 *(weeks 6.5-10.5)*	Compound LE movements Strength and Single LE balance	Leg Press with 85 lbs Progressed to 95 lbs Monster Walks with Black Theraband Pistol Squat Physioball Crunch Single Leg Romanian Deadlifts Single Leg Airex Ball Toss Forward Hops Kettlebell Sit-to-Stand with 35 lbs Walking Lunges Bulgarian Splits with 15 lbs	3 sets of 20 reps 4 cycles 3 sets of 10 reps 3 sets of 8 reps 30 reps 4 sets of 12 reps
Visit 28 - 34 *(weeks 10.5-16.5)*	Single and alternating LE balance and strength, and core activation Endurance and agility	Skateboarders Ladder Drills Kettlebell Sit-to-Stand with 10 lbs Progressed to 35 lbs by Visit 34 Eccentric Step-Downs Boxing Cat Camel Bird Dog Downward Dog Fire Hydrants Divero Crunch Stationary Lunges	3-4 sets of 8-10 reps 3-4 sets of 8-10 reps 15 reps 15 reps 3-4 sets of 8-10 reps 10' boxing 3 sets of 10 reps 3 sets of 10 reps 3 sets of 10 reps 3 sets of 10 reps

	Treatment Plan	Specific Closed Kinetic Chain Interventions	Sets, Repetitions, Time
Visit 35 - 41 *(weeks 16.5-18.5)*	LE and core strengthening/ balance Endurance and agility	Kettlebell Sit-to-Stand with 40 lbs Boxing Leg Press Side-Stepping BOSU: Squat Step-over Lateral Steps Corner Core Taps Elliptical Hip Flexor Stretch Agility Drills	10’ 30 reps 30 reps 30 reps 10 reps 10’ 6’

4. Diagnosis/Prognosis

The ICD-10 codes used to classify the patient’s diagnosis were: R26.9: Unspecified abnormalities of gait and mobility, R26.81: Unsteadiness on feet, and M62.81: Muscle weakness (generalized). The Physical Therapist determined the patient had a good prognosis for rehabilitation.

5. Interventions

During visits 1 to 11, weeks 1-3, treatment focused on improving LE strength, LE coordination, core stabilization, gait quality, and balance to address the patient’s primary goal of increasing stamina and balance (Table 1). Interventions included lateral and W walks, TRX squats, lateral step ups, eccentric step downs, boxing, incline treadmill, and gait training with verbal cues for weight shift, heel strike, and base of support (BOS) (Table 1).

In visits 12 to 20, weeks 3-6.5, the treatment plan was progressed to increase the challenge of LE strengthening and balance (Table 1). Interventions included weighted leg press, bulgarian splits, and trap bar deadlifts, upright bike, yoga, boxing with added core challenges, and incline treadmill training (Table 1).

By visits 21 to 27, weeks 6.5-10.5, compound LE movements and single LE balance were incorporated to facilitate activities required for higher level functional tasks (Table 1). New interventions included monster walks, pistol squats, kettlebell sit-to-stand, single leg romanian deadlifts, and single leg airex ball toss (Table 1). Previous interventions, like leg press, were progressed in weight (Table 1).

During visits 28 to 34, weeks 10.5-16.5, the treatment plan began to include dynamic LE balance and strength, progressive core activation, endurance and agility to progress the patient’s dynamic balance (Table 1). Added exercises included ladder drills and skateboarders. The patient continued with compound movements including walking lunges, bulgarian splits, and kettlebell sit-to-stands, and boxing. Elements of therapeutic yoga poses were also added, including downward dogs, bird dogs, cat-camels, and fire hydrants (Table 1).

By visits 35 to 41, weeks 16.5-18.5, the treatment plan continued to progress the challenge of LE and core strengthening and balance, as well as endurance and agility (Table 1). With these progressions, the patient was able to resume her prior level of functional mobility/activity. Added interventions included BOSU-integrated exercises to challenge her balance, including squats, step-overs, lateral steps, and corner-core taps. The elliptical and boxing were also integrated along with agility drills (Table 1).

Table 2. *Functional Outcome Measures.*

	Visit 1 - 11 *(weeks 1-3)*	Visit 12 - 20 *(weeks 3-6.5)*	Visit 21 - 27 *(weeks 6.5-10.5)*	Visit 28 - 34 *(weeks 10.5-16.5)*	Visit 35 - 41 *(weeks 16.5-18.5)*	Change
TUG (s)	9.46	6.37	Not Tested	Not Tested	Not Tested	3.09
5xSTS (s)	7.04	5.47	Not Tested	Not Tested	Not Tested	1.57
Observational Gait Analysis	Narrow BOS Ataxic Decreased arm swing and trunk rotation Pt. reports R knee buckling with ambulation	Increased medial-lateral sway causing unsteadiness Mild R-side Trendelenburg	Increased medial-lateral sway causing unsteadiness	Occasional Trendelenburg	Antalgic Decreased weight shift to R	Non-ataxic gait pattern Improved BOS Improved arm swing and trunk rotation Improved coordination and timing Improved endurance
Assistive Device	Rollator	None	None	None	None	None

(s) indicates seconds per test.

6. Outcomes

During visits 1 to 11, weeks 1-3, the patient presented with an ataxic gait pattern, narrow BOS, and decreased arm swing and trunk rotation (Table 2). The patient also self-reported right knee buckling during ambulation (Table 2). The 5xSTS score was 7.04 seconds and the TUG score was 9.46 seconds (Table 2). Throughout this time period, improved stability during gait was noted.

In visits 12 to 20, weeks 3-6.5, the patient presented with a narrow BOS, unsteady gait secondary to increased medial-lateral sway, and a mild right sided Trendelenburg (Table 2). Improvements in BOS, arm swing, and trunk rotation were noted (Table 2). During the re-evaluation at visit 12, her TUG time improved by 3.09 seconds. Her 5xSTS improved by 1.57 seconds (Table 2).

By visits 21 to 27, weeks 6.5-10.5, the patient continued to present with unsteadiness but normalized BOS, arm swing, and trunk rotation during ambulation (Table 2). Both her TUG and 5xSTS times improved and met the patient's goals when re-evaluated after the first 12 visits. (Table 2). OGA became the primary focus for documenting progress moving forward.

During visits 28 to 34, weeks 10.5-16.5, the patient presented with an occasional right Trendelenburg gait (Table 2). Progress was noted with coordination, timing, and endurance with ladder drills and boxing (Table 2).

By visits 35 to 41, weeks 16.5-18.5, the patient continued to present with an antalgic gait and decreased weight shift to the right (Table 2).

Through the course of her treatment, the patient improved and resultantly demonstrated a non-ataxic gait pattern, increased BOS, increased arm swing and trunk rotation, and improved coordination, timing, and endurance. The patient was able to tolerate all PT interventions and had no adverse or unanticipated events throughout her course of treatment.

7. Discussion

This is the first case report to document interventions and outcomes of a patient following a surgical repair of a C7-T3 spinal cord CM. The majority of the patient's interventions were centered around compound and CKC therapeutic exercise, neuromuscular re-education, and gait training. These categories included pre-gait activities and gait training, transfer training, strength, and balance and coordination. Over the course of 41 sessions (18.5 weeks), the patient demonstrated improvements with 5xSTS, TUG, and gait quality during the OGA. She met the 5xSTS and TUG goals by visit 12, however, continued to demonstrate improvements in gait quality until discharge.

The findings of this case report showed that dynamic compound and CKC exercises may offer individuals with spinal CM some introductory evidence for treatment strategies, which are consistent with previous research studies that investigated interventions and outcomes for participants with similar neurological functional deficits. Specifically, a recent study by Lotter et al., [15] has shown that functional walking gains are elicited from a variety of therapeutic activities. The most significant categories connected to locomotor dysfunction in patients with acute neurological injury include deficits in aerobic capacity, balance, and strength [15]. Lotter et al., [15] further suggest that stepping which varies in direction, intensity, and surface resulted in greater locomotor activation, walking gains, and balance confidence in patients with spinal cord injuries due to the specificity of the tasks. The addition of specific activities to locomotor training influenced greater walking outcomes and included: postural training, strength and transfer exercises, circuit training, and aerobic cycling or stepping programs [15].

CKC exercises have been shown to activate muscles in the paretic LE and improve balance in patients with chronic stroke [16]. Additionally, in a case study of lumbar spinal stenosis by Komatsu et al., [17] CKC exercises contributed to improvement of prolonged paralysis by increasing muscle strength and returning total motor function. When it came to functional balance, CKC exercises improved activation of the gastrocnemius and tibialis anterior when compared to the open kinetic chain group [17]. Brayall et al., [18] further suggested improved balance secondary to LE CKC exercises in patients with chemotherapy-induced peripheral neuropathy (CIPN). In attempting to correct strength and balance deficits, CKC movements may be a better treatment choice depending on patient ability and compliance. The current literature regarding CKC exercises suggest that the patient's improvements with functional mobility were greater due to these employed interventions [16-18].

Due to the lack of clinical guidelines and evidence in the present literature, the foundational approach outlined in this case may offer an option for the PT management of surgical spinal CM. Utilizing evidence that exists regarding interventions for populations presenting with similar functional limitations, such as spinal cord injury, stroke, lumbar spinal stenosis, and CIPN, the authors suggest that the approach outlined in this case is a safe and efficacious option for the management of spinal CM. It also serves as the basis for future research and development of management guidelines for spinal CM populations.

8. Limitations

There are several limitations for this report. First, although the TUG and 5xSTS were only completed during evaluations at visit one (week 1) and visit twelve (week 3) due to the goals being met, the report's ability to suggest any relationship between treatment and function is limited as a result. In order to determine the effectiveness of treatment on functional progress in future studies, it is necessary to conduct these tests throughout the entire course of treatment.

Additionally, the authors were not able to locate any research studies that showed reliability or validity for TUG

and 5xSTS tests for spinal CM. According to "Timed Up and Go" [10], the minimal detectable change (MDC) for spinal cord injury populations for the TUG was 10.8 seconds, with a smallest real difference of 30%.; however, no specific categories of spinal cord injuries were included. There were also no values reported for the minimally clinically important difference (MCID) for the 5xSTS or the TUG tests. Furthermore, OGA has shown moderate to poor reliability in neurological populations, specifically with stroke [19, 20]. McGinley et al., [21] reported an intra-rater agreement of 89.5% when observing only push-off phase of gait. However, inter-rater and intra-rater reliability of the OGA through the entire gait cycle has not been discussed in the literature.

The authors cannot generalize the interventions and outcome measures for other patients post surgery for a C7-T3 spinal CM. In addition, due to a change in the patient's insurance plan during the course of her treatment, PT treatments ceased, limiting collection of final outcome measures.

Future studies may be designed to determine: (1) the reliability of both the 5xSTS and TUG tests, (2) the MDC and MCID for the 5xSTS and TUG tests, (3) the intra-rater reliability of OGA throughout the entire gait cycle in patients with spinal CM, and (4) intervention protocols.

9. Clinical Relevance and Summary

The outcomes of this case report suggest that interventions that focus on CKC activities and compound movements had the greatest impact on improving functional mobility, standing balance, and gait quality. Although limitations exist, this is the first case report introducing interventions and strategies for improving functional outcomes in a patient status post-surgical repair of a C7-T3 spinal cord CM.

Disclosure of Interest

The authors report no conflict of interest.

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