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Physical Therapy Management of Bilateral Knee Contractures Using Serial Casting in a Medically-Complex Rehabilitation Patient: A Case Report

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Abstract

Background: Serial casting is a technique that is used to improve muscle length and increase range of motion in joints that are limited by contractures. While it is typically utilized in pediatric populations including but not limited to cerebral palsy, club foot, and idiopathic toe walking, serial casting can also be used to treat adults with brain injury, spinal cord injury, and stroke. The purpose of this case report is to highlight the use of serial casting as part of a comprehensive rehabilitation process to treat a medically-complex adult. **Case Description:** Patient A was a 50-year old male who was admitted to inpatient rehabilitation following a series of multifaceted medical events. His diagnoses included both neurological and orthopedic components, including a brain injury, spinal cord involvement, and a total hip arthroplasty. **Intervention:** Patient A was seen by a physical therapist for 30-60 minutes, five days per week for six-and-a-half months. During this extensive rehabilitation period, the patient was treated with a variety of interventions, including serial casting. The primary goal of serial casting was to increase his bilateral knee range of motion (ROM) to improve his ability to perform functional activities, including walking and negotiating stairs. **Outcome Measures:** The outcome measures used to monitor progress included measuring range of motion, the 6 Minute Walk Test (6MWT), the Timed Up and Go (TUG), and the Modified Ashworth Scale. **Discussion:** The serial casting intervention was performed unilaterally with the goal of increasing the patient's ability to participate in therapy and functional activities. We found that the patient improved knee extension ROM bilaterally even though only one leg was casted using this technique, suggesting that stretching and positioning alone also likely significantly influence ROM.

Keywords: Serial casting; joint contractures; brain injury; neurological rehabilitation; physical therapy; rehabilitation

Background

Joint contractures are debilitating impairments that can significantly affect a person's ability to function. Contractures in the upper extremity joints can cause individuals to have difficulty completing activities of daily living (ADLs), including dressing, feeding, bathing, and toileting. Lower extremity contractures can be even more limiting of one's independence as they can affect a person's ability to safely walk, negotiate stairs, transfer, sit, and balance. Joint contractures are grouped into three categories based on etiology: congenital contractures (arthrogryposis), chronic diseases or trauma-related contractures, and contractures caused by prolonged immobility.[1] In a joint affected by contracture, the skin, muscles, tendons, ligaments, and joint capsule become shortened and lose their elasticity.[2] Conditions that may lead to joint contractures include serious burns, osteoarthritis, stroke, brain injury, spinal cord injury, total knee arthroplasty, diabetes, inflammatory conditions like rheumatoid arthritis, and other diseases including muscular dystrophy, cerebral palsy, and diseases of the central nervous system including polio, multiple sclerosis, and Parkinson's disease.[1] Often, joint contractures develop as a result of significant inactivity or immobilization, which leads to shortened sarcomeres, an influx of connective tissue and fat, and a subsequent decrease in elastic tissue.[2,3] In fact, it has been reported that greater than one-third of individuals who remain in the ICU for two weeks or more develop a joint contracture in a major joint (shoulder, elbow, hip, knee, or ankle).[3,4] Furthermore, joint contractures are associated with higher rates of mortality after discharging from the ICU.[4]

Brain injury and spinal cord injury are two neurological conditions in which patients may develop joint contractures. Whether the joint contracture arises from spasticity related to the neurological impairment itself, or whether it develops secondary to immobilization in the acute phase of recovery, joint contractures greatly impact rehabilitation in this patient population. Spasticity, a velocity-dependent increase in muscle tone during a passive stretch, occurs as a result of damage to upper motor neurons and an overactive stretch reflex.[5,6] Spasticity is also referred to as a type of muscle hyperactivity.[6] Following severe brain injury, patients may develop spasticity and increased muscle tone that can lead to a loss of range of motion of the involved joints. In the lower extremities, the muscle groups most commonly affected by spasticity include the hip adductors, knee flexors, muscles that invert and plantarflex the ankle, and muscles that extend the big toe.[2] A randomized controlled trial by Verplancke, et al. suggests that passive range of motion at the ankle is lost within 14 days following a severe brain injury.[7] This rapid rate of loss of range of motion highlights the clinical importance of considering a variety of techniques for managing joint contractures.

Patients presenting with joint contractures can be treated by several different healthcare disciplines with a variety of interventions, depending on the patient's specific diagnosis, the setting in which the patient is being treated, the patient's age, and other factors. Due to the cognitive and behavioral challenges that affect the ability of patients with neurological conditions, especially traumatic brain injury (TBI), to follow directions and/or tolerate certain interventions, traditional management of spasticity and secondary joint contractures may be difficult.[6] Research suggests that botulinum toxin A (Botox) is an effective and safe treatment intervention for managing focal spasticity in patients with neurological conditions. In fact, Botox is recognized as the gold standard intervention for treating spasticity.[5] While side effects are extremely rare, patients may develop iatrogenic botulism, or botulism-like syndrome, which is a serious complication of the spread of botulinum toxin A throughout the body. Iatrogenic botulism typically causes widespread weakness, dysphagia, and respiratory distress.[8] The risks of developing these, and other side effects, including muscle atrophy, increase with more frequent injections of the toxin in a shorter time period.[5] The positive effects of botulinum toxin A injections may last up to 2-3 months, at which time the patient may safely receive a second injection into the same muscle. However, research suggests that injecting a muscle that has a physiologically altered composition, including the presence of fibrosis, fat, or tendon retraction as seen in joint contractures, can reduce the duration of the positive effects on that muscle.[5] Thus, due to the specific frequency guidelines and the uncertainty of the duration of botulinum toxin A on muscles that have physiologically altered compositions, it is important to consider additional treatments, like serial casting, to use as

adjunct interventions to traditional physical therapy and medical management of joint contractures in neurological populations.

While it is typically utilized in pediatric populations including but not limited to cerebral palsy, club foot, and idiopathic toe walking, serial casting can also be used to treat adults with stroke, spinal cord injury, and brain injury. However, there is limited research available discussing the implementation of serial casting as an intervention for a complex rehabilitation patient with chronic bilateral knee joint contractures. The purpose of this case report is to highlight the use of serial casting as part of a comprehensive rehabilitation process to treat a medically-complex adult.

Case Description

The patient was a 49-year old (at the time of initial evaluation) African American male who was admitted to inpatient rehabilitation following a series of complex medical events. His diagnoses included both neurological and orthopedic components, including a brain injury, spinal cord involvement, and a total hip arthroplasty. This patient was selected for this case report in order to highlight serial casting as an adjunct treatment to traditional physical therapy techniques as an option for addressing bilateral chronic knee flexion contractures.

Patient A's medical journey began when he fell in his home approximately two months prior to entering the rehabilitation facility and he shattered his right pelvis. He was alone at the time of the incident and he was unable to get help for four days. After four days of lying on the floor, he was found and taken to the hospital where he was diagnosed with a fractured right pelvis in addition to spastic quadriparesis and hydrocephalus with cord compression. A ventriculoperitoneal (VP) shunt was placed in his brain to treat the hydrocephalus. The patient experienced atrial fibrillation following surgery and he was treated with an anticoagulation regimen as his cardiac function was declining. He continued to experience progressive spastic paresis leading to significant lower extremity impairment. The patient was transferred to the neurosurgery unit where he underwent surgery to remove an arachnoid cyst from C7-T12 that was causing cord compression. The patient developed metabolic encephalopathy from hyponatremia and he was treated aggressively. He was transferred to an inpatient rehabilitation facility, but his healthcare team was concerned about his health status, so they transferred him back to the hospital. Spinal fluid cultures revealed that the patient had developed cryptococcal meningitis. The patient's shunt was externalized, and he was immediately started on aggressive treatment to eliminate the infection. After treating the meningitis, Patient A had a new shunt placed and his cognition began to improve. The patient then had a right total hip arthroplasty to replace his fractured pelvis. During his stay at the hospital, the patient developed bilateral decubitus ulcers on his hips and a massive ulcer on his left calcaneus. The patient was admitted to a Midwest inpatient rehabilitation facility approximately six months after his initial VP shunt placement. At the time of admission, the patient required assist for upper extremity dressing, and he was completely dependent for lower extremity dressing and toileting. Patient A was unable to ambulate upon admission.

Prior to these acute medical events, Patient A was independent with upper extremity dressing and ambulation with an assistive device, as he had developed weakness in bilateral lower extremities secondary to the cord compression. He was also working full-time prior to these events. Patient A had a history of smoking. He had seven children, the youngest of whom was three years old at the time of his inpatient rehabilitation, and she lived in a different Midwest state with her mother. The patient expressed that he wanted to be able to support his children, especially the youngest, following discharge. At the initial evaluation, the patient stated that his biggest goal was to "walk out of here". In addition, he stated that he wanted to return to working full-time. Patient A was living with his brother in Iowa at the time of the initial fall. However, while he was at the rehabilitation facility, the patient worked with his therapists, social worker, and case manager and as a team, they decided that he would discharge to his sister's house in a different Midwest state. The sister's house had 12 steps to get to the bedrooms and the only bathroom in the house. Thus, the patient needed to be able to negotiate steps safely in order to discharge to this location.

Patient A was at the neurological rehabilitation center for a total of 6.5 months. While he was there, the patient received three or more hours of therapy each day, 5-6 days per week. His therapy included physical, occupational, speech, recreational, music, and group therapy sessions. He received 10-12 physical therapy sessions (30 minutes/session) each week. His rehabilitation also included community outings to stores, parks, and the state fair, as well as aquatic therapy (after his wounds completely healed).

Examination

At the time of admission, the patient was evaluated by each member of the rehabilitation team: a physical therapist, occupational therapist, and speech pathologist, in addition to the medical team. The physical therapist evaluated his functional mobility, pain level, balance, sensation, proprioception, coordination, endurance, tone, spasticity, range of motion, and strength. **Functional Mobility**: The patient required up to maximum assistance for bed mobility, especially with assisting the patient with his hip precautions following the total hip arthroplasty. The patient completed transfers using a slide-board and minimum assistance. He was unable to ambulate or attempt stairs at the time of the initial evaluation. The patient was in a standard wheelchair with pressure relieving cushions and a hip abductor pillow to improve hip alignment and positioning. He used bilateral upper extremities to propel the wheelchair and he initially require minimum assistance with wheelchair mobility. **Pain**: The patient presented to inpatient rehabilitation reporting 5/10 pain with activity, especially related to the muscle spasms in his bilateral lower extremities and due to the wounds on his bilateral hips and left heel. **Balance**: The patient required stand-by assist for static seated balance and contact guard assist for dynamic seated balance. For static standing balance, the patient required maximum assistance and he was dependent for dynamic standing balance. **Sensation**: Light touch was impaired bilaterally, and the patient had decreased sensation in bilateral lower extremities below the knee. **Proprioception**: Proprioception of bilateral lower extremities was within normal limits. **Coordination**: The physical therapist was unable to asses coordination at the time of evaluation secondary to other functional limitations. **Endurance**: The patient required at least 3-4 rest breaks in a thirty-minute session of mild activity. **Tone**: Severe deficit in muscle tone reported in bilateral knee flexors, bilateral hip flexors, and bilateral hip adductors. **Spasticity**: The therapist was unable to formally test spasticity at initial evaluation secondary to significant muscle guarding.

Table 1. Bilateral Lower Extremity Range of Motion at Initial Evaluation

	Right LE	Left LE	Normal Reference Values
Knee Extension	Lacking 60 degrees	Lacking 35 degrees	0 degrees
Hip Extension	*See below	*See below	15 degrees hyperextension
Hip Flexion	90 degrees (hip precautions)	WNL	125 degrees

*Unable to attain hip extension measurement; significant tightness in bilateral hip flexors noted
**Note: significant muscle guarding with ROM, tone, and spasticity assessment
WNL = within normal limits

Table 2. Bilateral Lower Extremity Strength Assessment at Initial Evaluation

	Right LE	Left LE
Ankle DF	2-/5	2-/5
Knee Flexion	2-/5	2-/5
Knee Extension	2-/5	2-/5
Hip Flexion	1/5	1/5
Hip Extension	1/5	1/5
Hip Abduction	1/5	1/5

Intervention

During the patient's first three months of intensive rehabilitation, physical therapy interventions primarily focused on improving the patient's ability to perform bed mobility, transfers, and wheelchair mobility with a decreased level of assistance in order to promote as much independence, or modified independence, as possible. The physical therapists also focused on increasing the patient's tolerance to upright posture using devices such as an EasyStand and an Arjo. The patient trialed ambulation with an Arjo for support and he worked with his physical therapists to gradually decrease the amount of support that he needed. He also worked on stair negotiation, initially using bilateral handrails to pull himself up and descending the stairs backwards for safety and he progressed to descending the stairs in a forward direction. The physical therapists also focused on prolonged stretching to address the patient's bilateral knee and hip flexion contractures. The prolonged stretching interventions included positioning the patient in supine with a bolster under his ankles and positioning the patient in prone to promote knee and hip extension, in addition to passive stretches performed by the physical therapist. Patient A made significant progress in four months of rehabilitation in the areas of bed mobility, transfers, ambulation, and upper extremity strength. However, he continued to be limited by bilateral hip and knee range of motion deficits and significant lower extremity weakness. During the final two months of rehabilitation, the physical therapy team focused their interventions on improving range of motion and lower extremity strength in order to work towards the patient-identified goals.

Three months into his rehabilitation, the patient received his first dose of botulinum toxin A (Botox) injections into bilateral lower extremities. The goal of the Botox injections was to decrease the spasticity in specific lower extremity muscles. When injected with Botox, the isolated muscle becomes chemically denervated by inhibiting the release of acetylcholine, leading to a decrease in muscle activity.[9] The physical therapists initiated serial casting of the patient's knees following the Botox to promote increased range of motion while his muscles were in a decreased state of hyperactivity. The physical therapist made multiple clinical decisions related to serial casting in order to increase success of the intervention. First, the therapist decided to cast the first knee as soon as possible following the Botox injections. Second, the therapist decided to cast only one knee at a time, as bilateral casting would restrict the patient's mobility while he had the cast on. With a unilateral knee casted, the patient was still able to complete stand-pivot transfers with modified independence. The therapist casted the knee immediately following an hour-long aquatic therapy session in which the patient was immersed in a warm therapeutic pool and he was engaging in stretching and strengthening exercises in the water. Finally, the therapist decided to cast the same knee three times consecutively with 5-7 days between casting sessions. The goal of casting the same limb was to maximize ROM gains in at least one limb, with the long-term plan of eventually casting the second limb.

Serial casting is a technique that is used to gradually increase range of motion of a joint through the consecutive application of multiple casts in a short period of time. The main goals of serial casting are to decrease spasticity and reduce joint contractures. There are two options for casting material: plaster and fiberglass. In this clinical example, the physical therapist used fiberglass casting material as it is light-weight, it dries quickly, and it is a strong material.

To begin the casting procedure, the patient completed a transfer to the mat table and he was positioned in supine with his ankles elevated on a bolster. He was encouraged to relax and perform quad sets to increase the available stretch so that the cast could be applied at end-range. The therapist added over-pressure as the patient performed quad sets in order to maximize the stretch. A foam block was placed between his ankles as he had significant resting adductor tone and the therapists wanted to create space between his legs during the casting procedure. The patient was wearing shorts so that the therapists would have direct access to his skin for casting. Patient A had a history of skin breakdown that led to deep wounds on his bilateral hips and his left heel. Therefore, prior to casting, the skin was checked thoroughly by the therapist to ensure that the cast would not be placed over an area with any sign of breakdown. To further protect the integrity of the patient's skin, a thin cast liner was placed over the entire area that was going to be cast, from mid-femur to mid-tibia. Next, the therapist applied foam padding over all bony and tendinous prominences, including the patella, femoral condyles, tibial tuberosity, anterior crest of the tibia, and the hamstring tendons. The whole area was then covered with soft casting cotton to fill in the open spaces and even out the entire surface that was going to be casted. This additional padding under the length of the cast ensured that all areas were equally protected. The next step was to apply the cast. Two packages of four-inch fiberglass casting were used to create the serial casts. While wearing gloves, the therapist submerged the roll of casting material under hot water to activate the material. The therapist then quickly applied the cast starting approximately one centimeter away from the proximal aspect of the padding in order to ensure that the sharp edge of the fiberglass cast would not touch the skin directly. The cast was then wrapped in layers so that about fifty percent of the previous layer was covered by the distal layer. The therapist did not add any stretch/pull to the cast as it was applied. Once the first layer of casting material was completed, the therapist rinsed the second roll in hot water and repeated the previous steps. However, this time, the therapist applied the cast starting from the distal aspect and moved proximally. The therapist palpated both ends of the cast to check for sharp edges and folded any sharp edges over while the cast was still pliable. The patient maintained his position in supine as the cast dried so that he would not change the angle of the cast by allowing his knee to flex. The therapist drew two parallel lines on the cast as markers for where the staff would need to cut the cast in the event that the patient needed immediate removal of the cast after normal PT hours. This was important as the cast would later be made into a bivalve splint to be worn at night, and the cuts needed to be specific so that the splint would be easy to don and doff by the patient and/or care-takers. Once the cast was dry, the patient completed a transfer back to his wheelchair. A slide-board and a pillow were placed under his left leg to improve the patient's comfort and safety in his wheelchair (see **Figure 1)**. The therapist changed the patient's transfer orders from independent from wheelchair level to stand-by assist in case the patient needed any additional assistance while he had the cast on.

Figure 1. Photo demonstrating the patient's left knee casted and supported in the wheelchair with a slide-board and pillow.

In addition to serial casting, during his daily 30-minute physical therapy sessions, the patient received a variety of traditional physical therapy interventions. These included sustained stretches with the patient positioned in supine and prone to target different muscles, especially bilateral hip flexors and bilateral knee flexors. The physical therapists performed soft tissue mobilization and joint mobilizations on his affected muscles and joints. The patient also participated in gait training with

various assistive devices on variable surfaces, balance training, and aquatic therapy in a heated pool, during which he received similar treatments to his land-based therapy (i.e. stretching, gait training, and balance).

Outcomes

The primary outcome measures used in this case report were range of motion (ROM) measured with a long-arm goniometer, Six-Minute Walk test (6MWT), the Timed Up and Go (TUG), and the Modified Ashworth Scale. The inter-rater and intra-rater reliabilities are >0.99 and >.98, respectively, for long-arm goniometry. The minimum significant difference for long-arm goniometry is 10 degrees.[10] As part of Patient A's inpatient rehabilitation, one therapist performed his initial evaluation and another performed his discharge evaluation, including Range of Motion (ROM) measurements. These measurements were taken using a standard long-arm goniometer and with the patient in supine on a mat table with his shoes removed (see **Figure 2**). The patient's left knee ROM was also recorded before and after applying the serial casts.

Figure 2. The patient is positioned in supine and he is performing a quad set to demonstrate his active ROM at discharge.

Table 3. Left Knee Extension ROM Measurements Before and After Serial Casting

Casting Day Compared to Initial Evaluation	Total Time Wearing Cast	Pre-casting ROM	Post-casting ROM
Day 144	48 hours	-24 degrees	-15 degrees
Day 151	24-48 hours	-13 degrees	-8 degrees
Day 156	48 hours	-10 degrees	-5 degrees

*Note: "-" indicates "lacking" from neutral (0 degrees knee extension)

Table 4. Lower Extremity Range of Motion at Discharge

	Right Lower Extremity	Left Lower Extremity	Normal Reference Values
Knee Flexion	60 degrees	60 degrees	130 degrees
Knee Extension	-10 degrees	-12 degrees	0 degrees
Hip Extension	-10 degrees	-10 degrees	+15 degrees
Hip Flexion	65 degrees (hip precautions)	85 degrees	125 degrees
Hip Abduction	10 degrees	7 degrees	45 degrees

*Note: "-" indicates "lacking" from neutral; "+" indicates hyperextension

There were three additional outcome measurements that were evaluated later in the patient's recovery that were not assessed at the initial evaluation. The 6MWT measures walking endurance and aerobic capacity. This test has excellent test re-test reliability for patients with traumatic brain injury (ICC = 0.96).[11] Patient A ambulated 212 feet with a front-wheeled walker (FWW) and contact-guard assist for safety during his first 6MWT, which was approximately 4.5 months after his initial evaluation. Serial casting was initiated 6 days after the initial 6MWT. The final 6MWT was conducted 56 days after his initial test (approximately 6.5 months after initial evaluation) and after three rounds of casting. The patient ambulated 408 feet with a FWW and supervision for safety. He did not require any seated rest breaks during his final 6MWT.

The second measure used in this study was a timed up and go (TUG). The TUG is a standardized test that measures of mobility, walking ability, balance, and fall risk. For children with traumatic brain injury, there is excellent test-retest reliability (ICC = 0.86).[12] The patient completed his first TUG in an average time of 48 seconds with a FWW, 4.5 months after his initial evaluation. Again, serial casting was initiated 6 days after the initial test. The final TUG was completed 56 days after the initial test (6.5 months after his initial evaluation) and he scored an average of 35 seconds.

The third additional outcome measure used in this study was the Modified Ashworth Scale, which is a measurement of spasticity in patients with Central Nervous System lesions. For individuals with traumatic brain injury, there is adequate test-retest reliability for the hip and knee (kappa = 0.47-0.62), and an excellent test-retest reliability for the ankle (r = 0.82; k = 0.422).[13,14] During discharge testing, the patient scored a 2-3 on the Modified Ashworth Scale for all lower extremity joints, indicating an increase-to-considerable increase in muscle tone through most of the ROM of each joint.

Discussion

The purpose of this case report was to highlight the use of serial casting as part of a comprehensive rehabilitation process to treat a medically-complex adult. The patient in this study showed improvements in bilateral knee extension range of motion, even though serial casting was only used on one limb. The prolonged stretch that was created by the cast was sustained for 24-48 hours, and then the patient maintained this range of motion by wearing the bivalve splint at night. Therefore, our study suggests that serial casting, along with specific positioning techniques and traditional physical therapy interventions, was beneficial in treating chronic bilateral knee joint contractures.

Research suggests that serial casting following Botox is essential in order to correct chronic joint contractures in patients who have acquired brain injury.[15] Unlike generalized antispasticity drugs, including baclofen, which works at a systemic level and can be detrimental to a brain that is recovering from injury, Botox works to reduce focal spasticity.[7] This is critical for individuals with brain injury and stroke as they are in a state of brain healing and it would be counterproductive, and potentially harmful, to introduce a drug to the system that could cause additional brain damage. Another study suggests that serial casting, with or without Botox, is more effective than passive stretching to maintain range of motion in patients with acute severe brain injuries.[7] While stretching may have short-term effects on muscle length and range of motion, in order to have a long-term effect, passive stretching needs to be performed for at least 3.5 hours each day.[7] Thus, stretching alone may not be an efficient or effective intervention to address significant range of motion impairments.

Furthermore, serial casting after Botox injections may help patients with spasticity in their lower extremities develop a more normalized gait pattern.[9] Studies on unilateral knee flexion contractures demonstrated biomechanical changes in subject's gait secondary to the contracture. Specifically, individuals in knee flexion contractures ambulated with decreased peak ankle plantarflexion, increased knee flexion moments, increased ipsilateral hip flexion and decreased hip extension.[16] Another implication of constant knee flexion is a loss in gastrocnemius muscle tension. As the length-tension relationship of the gastrocnemius muscle changes, the Achilles tendon loses the elastic recoil, which is crucial during the pre-swing phase of gait.[16] Patient A demonstrated similar gait compensatory strategies as mentioned in the study by Sotelo, et al. When he first began ambulating, the patient had significant knee flexion contractures. He demonstrated no ankle plantarflexion during pre-swing (i.e. no

push-off), no hip extension (he could not even extend to neutral), and significant knee flexion in all phases of gait. He also demonstrated more of a flatfoot walking strategy as he had difficulty with heel strike bilaterally. Following serial casting of the left knee, the patient demonstrated improved bilateral knee extension range of motion. Consequently, he demonstrated improvements in his gait pattern, too (see **Figure 3**). Most noticeably, he had decreased knee flexion during all phases of gait, he demonstrated slight improvement in ankle dorsiflexion at initial contact on the right, and he improved ankle plantarflexion bilaterally. However, he continued to demonstrate limited hip extension.

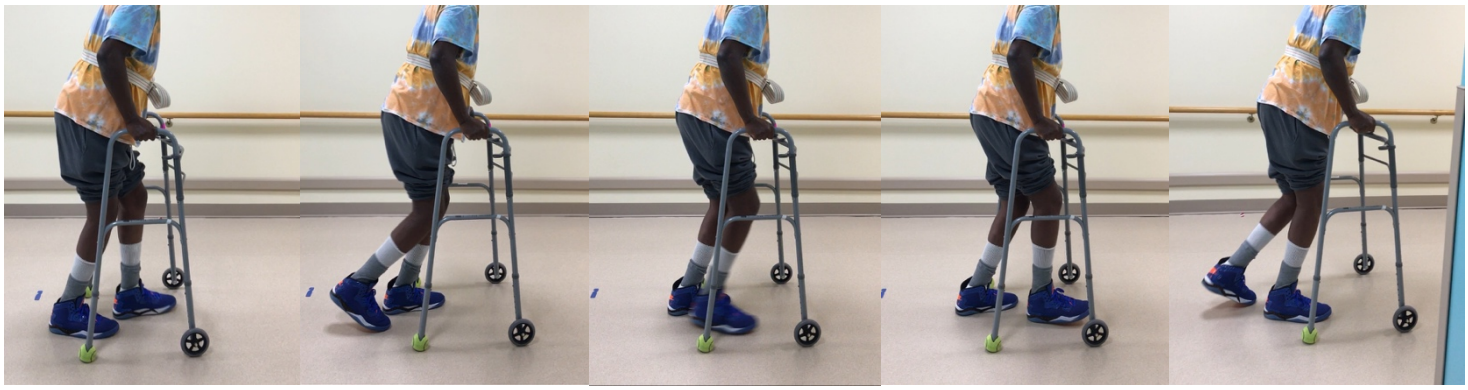

Figure 3. This series of images shows the patient's gait sequence the day before he was discharged home.

Serial casting decreases muscle spasticity through its effects on muscle tone and soft tissue properties. Research suggests that spasticity occurs secondary to hyperactivity of the monosynaptic stretch reflex, which is likely due to diminished presynaptic inhibition of spinal afferent neurons.[17] (In research studies, spasticity is often measured by H-reflex inhibition as an indication of presynaptic inhibition and motor neuron excitability.[18]) Casting holds the affected limb in a position that inhibits the stretch reflex. The low-load, long-duration force of the cast decreases input to tactile, proprioceptive, and temperature receptors by providing total contact and pressure to the casted area, as well as maintaining a constant warm temperature. Consequently, the decreased input to the receptors leads to a reduction in the alpha or gamma motor neuron excitability in the spinal cord.[17,18] Childers, et al. reported that this reduction in motor neuron excitability, and thus a reduction in spasticity, can occur after wearing an inhibitory cast for three days.[18]

The low-load, long-duration force of the cast stretches the surrounding tissue at end-range, leading to permanent physiological changes at the level of the connective and muscle tissue.[17,19] When an individual has a spastic limb, the hyperactive muscles maintain the limb in a shortened position and the muscle tissue rapidly loses sarcomeres in series.[17] This can lead to changes in the length-tension relationship of the muscle and may ultimately lead to the development of a contracture.[17] Serial casting may positively alter the length-tension relationship to correct for these rapid changes caused by spasticity. Studies suggest that the low-load, long-duration force that the cast places on the muscle tissue in its lengthened state leads to an increase in the number and length of sarcomeres in series.[17] Furthermore, the connective tissue becomes lengthened as the fibrous matrix loses its organization and allows the tissue to stretch.[17,20]

In addition to the positive changes at the level of the tissue, there are additional benefits to serial casting as an adjunct intervention for addressing joint contractures. Serial casting is non-invasive, it only affects the specific area of the body that is casted, and it can be performed by a physical therapist in the clinic. In addition, the cast is specific to the individual's limb and it can be made into a bivalve splint following removal. In this case study, each of the patient's casts were made into a bivalve splint that he wore each night to maintain his new ROM. Furthermore, casting can be helpful if the patient has severe tone that may overpower an off-to-shelf splint or a therapist who is manually stretching the joint. Fiberglass casts are light-weight, easy to apply, and can be easily removed by other

staff, if necessary. Finally, serial casting can be used as an adjunct to Botox injections to improve the success of the intervention.[17]

While the benefits of serial casting often outweigh the risks, there are some disadvantages to using this intervention. When a patient has a serial cast on a lower extremity, the patient's independence may be more limited. The patient will likely not be able to walk, or his gait will be significantly altered, and the therapist likely will not want to encourage a gait with compensatory movements. Furthermore, there is a risk of skin breakdown, so the staff needs to be extra diligent about checking the integrity of the skin before and after the patient wears the cast. The cast material cannot get wet, so patients will need to find alternative ways to bathe besides a traditional shower. Finally, the casts can be uncomfortable for the patient, as it is creating a long-duration, low-load stretch on a hyperactive muscle.

While the exact role that serial casting had on the patient's improved knee extension range of motion is unclear, this case demonstrates that the serial casting likely assisted in decreasing the bilateral knee flexion contractures. In addition, the casts were reasonably well-tolerated (the patient did complain about the second cast and it was removed early), and it is possible that the benefits of serial casting positively impacted the patient's ability to ambulate with an assistive device with modified independence, ultimately allowing him to achieve his main rehabilitation goal. More research is needed to determine the effects of serial casting on joint contractures in adults with complex medical cases.

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