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Total Knee Arthroplasty Prehabilitation: Clinical Decisions related to Bony Malalignment, Neurologic Complexities, and Getting to Know a Patient

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Abstract

Background: The benefits of pre-operative habilitation or “prehabilitation” for total knee arthroplasty outcomes have been documented and researched over the last twenty years. However, the majority of these studies do not describe prehabilitation programs for patients with complex neurologic comorbidities. **Purpose:** The purpose of this case report is to describe clinical decisions made during the course of a prehabilitation program for a patient with a cerebellar disorder and bony malformation at her knee. **Case Description:** The patient was diagnosed with excessive tibial torsion when she was 60 years old and a year later diagnosed with uterine cancer and paraneoplastic cerebellar degeneration. The patient currently shows significant genu valgum at her right lower extremity and ambulates using a four wheeled walker, bilateral knee braces donned, and has an ataxic gait. Her goals for therapy are to improve her strength as she anticipates having a total knee arthroplasty, improve her balance, and stay active. **Outcome Measures:** Timed Up and Go (TUG), Berg Balance Scale, Dynamometer, as well as mass of weights lifted were used as outcome measures. **Discussion:** Low-load, high repetition and open kinetic chain movements were optimal means of strengthening for this particular patient, addressing both bony malformation and neurologic deficits. Additionally, the patient’s Timed Up and Go and Berg Balance Scale showed meaningful changes, possibly in part because the patient had good afferent signaling, but also because of the large amounts of time the patient dedicated to rehabilitation.

Keywords
Prehabilitation; total knee arthroplasty (TKA); paraneoplastic cerebellar degeneration; tibial torsion; genu valgum; ataxia; physical therapy.

Introduction

Outcomes of rehabilitation following total knee arthroplasty (TKA) have been a focus of research for over thirty years. Preoperative rehabilitation (also known as, “Prehabilitation”) as preparation for a TKA has been a topic of research for the last twenty. While outcome results have been mixed, there is sufficient evidence to suggest that patients who “prehab” have significantly better functional outcomes than patients who do not.[1,2] Most prerehabilitation programs share these general features: strengthening of quadriceps, hamstrings, gastrocnemius, and gluteal muscles, including abductors; as well as stretching of hamstrings and quadriceps. Some studies provide only home exercises and lack detail on whether or not those exercises were progressed in any way.[3,4] Additionally, some studies show small to moderate effects; however, those studies also do not describe dose-response relationships and may have prehab programs that are too short in duration, not allowing for enough adaptation prior to surgery.[5]

In the year 2014, over 650,000 total knee arthroplasty surgeries were performed in the U.S.[6] In 10 years (by the year 2030), it is expected that TKAs will grow by 189%.[6] Additionally, previous knee injuries, such as tearing of knee ligaments like the ACL, are leading correlative precursors to knee OA requiring TKA as an intervention. Additional risk factors are age, female sex, overweight or obese status, repetitive use of joints, bone density, muscle weakness and joint laxity.[7] Patients who have malalignment at the knee are at a significantly greater risk for knee OA and the need for joint replacement.[7]

According to a 2009 query of the Nationwide Inpatient Sample dataset, only 12.7% of the patients who underwent a TKA had zero comorbidities.[8] This means that the vast majority of people who undergo this surgery, then, have some other health issue. In the same query, 37% of patients who underwent TKAs had 3 or more comorbidities.[8] Many of these include hypertension, uncomplicated diabetes, and obesity (in order of decreasing prevalence). The 9th most prevalent comorbidity, at 3.82% of TKA patients, was a neurologic disorder.[8] These medical comorbidities not only lead to a more complex medical and surgical scenario, but they also make both prehabilitation and rehabilitation more complex as well.

This case report reviews clinical decisions related to one patient’s TKA prehabilitation in the context of both neurologic as well as orthopedic considerations. The patient has significant bony malalignment (tibial torsion and genu valgum) at her right knee in addition to a neurologic condition, paraneoplastic cerebellar degeneration. This case reviews her initial phase of prehabilitation, which focused primarily on strengthening interventions across 7 weeks of therapy. This case closes just prior to the start of her second phase of prehabilitation, which prioritized interventions specific to ataxia and balance.

Subjective Findings

A 62-year-old former college athlete presented to an outpatient orthopedic physical therapy clinic seeking services to assist with prehabilitation for her anticipated total knee replacement. She stated she had three main goals. First, she wanted to improve strength, as she experienced significant muscle atrophy following neurologic decline about 1.5 years prior. Secondly, she sought to improve her balance. She reported she was highly conscious of her risk for falling. Thirdly, the patient wanted to increase independence with her very active lifestyle. Although pain was not her primary concern, the patient reported that it could be functionally limiting and included sensations of popping and giving way.

During her neurologic decline she had to cease her job as a pharmacist and stopped most activities altogether. This included participation in recreational basketball. At the time of her initial evaluation, she reported her activity included tricycling outside independently most days of the week, participation in a weekly yoga class, and a weekly water aerobics class.

Past Medical History

The patient reported that she consulted with an orthopedic surgeon in 2017 after having increasing genu valgus and knee pain. The surgeon advised her that she had excessive tibial torsion (with a torsion angle of approximately 20 degrees), and she would need a TKA. However, because she was so young and active, she was advised to delay surgery until the pain at her knee was too painful to tolerate. He wanted to try to prevent or delay her from having to undergo a revision surgery 15 years after her TKA. The patient took the surgeon's advice but reported she wished she had gone forward with the TKA then. Months later, in 2018, her health started to decline. She was diagnosed first with Stage 1 uterine cancer and then months later with Paraneoplastic Cerebellar Degeneration (PCD), a very uncommon condition that in very rare instances coincides with cancer. She reported that during this time of decline she stopped her activities, quit her job and because of her significant decrease in movement, experienced severe muscle atrophy.

The patient reported she had sought diagnosis and treatment from multiple clinicians during her neurologic decline. She was diagnosed at the Mayo Clinic in 2018 with Paraneoplastic Cerebellar Degeneration and had since consulted with multiple orthopedic surgeons in order to pick one whom she would like to perform her arthroplasty.

Paraneoplastic Cerebellar Degeneration is a rare autoimmune pathology associated with cancer of any kind, but more often carcinoma.[9] It is most commonly associated with lung, gynecologic, breast, and Hodgkins Lymphoma.[10] The neurologic symptoms often predate or coincide with a patient's cancer diagnosis.[9] Again, in this patient's case, she was diagnosed with uterine cancer.

Paraneoplastic Cerebellar Degeneration affects the cerebellum, and its general course includes neurologic decline. There are several forms of PCD that correlate to the type of antineural antibody, with some antibodies having more profound effects on the brain and body.[10] Stabilization can occur by way of cancer treatment. When neurologic stabilization occurs, a "plateau phase" is reached and symptoms stabilize. One study showed that upon diagnosis, 63% of the patients were still ambulatory and by the time patients had reached the plateau phase, only 34% were ambulatory.[10] Symptoms of PCD have marked cerebellar features related to the interruption of smooth and coordinated movements, as well as motor learning. They include ataxia (impaired muscle coordination and control), dysmetria (dyscoordination characterized by under- or over-shooting degrees of movements), dysdiadochokinesis (impaired ability to perform rapid and alternating movements), dysarthria (slurred speech resulting from an inability to coordinate oral and facial movements necessary for speaking), and dysphagia (the impaired ability to coordinate muscles of swallowing). In this patient's instance, ataxia, dysmetria, as well impairment to her vestibular system affect her balance and decrease both her dynamic and static stability.

To address her neurologic symptoms, the patient had gone through multiple forms of care which included craniosacral therapy, chiropractic care, relaxation training, and aquatherapy. She reported that chiropractic interventions had resulted in improved use of her left lower extremity, particularly with improved sensation to her anterior thigh (she pointed to areas in L3-5 dermatomes). She had put craniosacral therapy on hold when she began therapy at our clinic and thought that it was no longer helping improve symptoms. Chiropractic care remained concurrent with physical therapy and included stem cell therapy into her left knee joint (10/17/19), vibration therapy, laser therapy, and electric stimulation. Her medication list was completely under the "Alternative Medications" classification of "Complementary and Alternative Medications" (CAMs). The patient's list of CAMs was extensive, and she reported she experienced considerable benefit from these medications.

Objective Findings

The patient presented to physical therapy with bilateral braces donned at knees, ambulated with a four-wheeled walker, had an ataxic gait pattern that included irregular foot trajectories and placement, spoke with mild dysarthria, and was accompanied by her partner. The patient presented with excessive genu valgum of the right knee. During heel strike, in addition to ataxia, the patient demonstrated right-sided calcaneal eversion as a compensatory pattern for knee angle. Patient gait speed was slow, unstable and appeared to dominate the patient's attention.

Initial Tests and Measures

Range of motion deficits of the lower extremities were insignificant and included minimal hip internal rotation limitations on the left.

Manual muscle testing revealed deficits in force production but were symmetrical. All muscles tested were 4/5 and included hip flexion, extension and abduction, as well as shoulder external rotation. Manual muscle testing was used in order to see any gross deficits to single planar movements. While MMT was retested at reevaluation, changes in functional movements and tasks would be better captured in functional tests described below like the SARA, Berg Balance Scale, TUG, and Five Times Sit-to-Stand test, for example.

Upon initial testing, the patient's unaffected left leg performed a 10 repetition maximum (10RM) at a seated leg press of 37.5 pounds, whereas the affected leg performed a 10RM of 15 pounds. Only 2 sets of 15 were able to be performed on the right. Cogwheel muscle tremor and severe crepitus with pain limited the patient from performing higher load or additional repetitions or sets.

The patient's initial trial at the cable and pulley weight machine doing long arc quads, the patient began with 4.0 lbs for a set of 20 repetitions and progressed to 12.5 lbs, completing a total of 140 repetitions, increasing by 1.5 lbs every 20 repetitions. For hamstring curls, the patient began at 5.5 lbs for a set of 20 repetitions and increased to 10.5 lbs, completing a total of 80 reps, having increased by 1.5 lbs every set. This began at week 7. While the patient was already showing improvements in leg strength, we note her initial weights here to demonstrate later progress she made at the close of this case report. At this machine, the maximum weight the patient moved was reduced; however, the lever arm increased. The patient was much less limited by sensations of popping and grinding with these exercises.

The initial score on the Scale for Assessment and Rating of Ataxia (SARA) was 16.5. The SARA was utilized to quantify severity of ataxia at baseline and to serve as a reassessment tool that can demonstrate effectiveness or ineffectiveness of neurologic-targeted interventions.

The patient used a four wheeled walker during the Timed Up and Go (TUG) test, completing the test in 27.15 seconds. This was selected in order to demonstrate baseline gait speed. Additionally, it was used for re-evaluations to assess the level of progress. Improvements in dynamic balance and ataxia should also be caught by this test.

The patient scored a 33/56 on the Berg Balance Scale. This 14-item test served as a baseline assessment related to balance required for functional tasks and also grades fall risk. This test should capture changes to patient's balance and serve as an assessment of effectiveness of balance interventions.

Testing of proprioception, kinesthesia and light touch was administered on lower extremities. This was performed in order to determine if the Dorsal Column Lateral Lemniscus (DCML) system was sending reliable afferent information for conscious proprioception, kinesthesia and pressure sensation related to movement and ambulation.

Proprioception scores of bilateral ankles, knees and hips were 5/5 except for the R knee (2/5). As the right knee was further tested, the score improved to 100% accuracy. Testing of kinesthesia occurred next, and the patient tested with 100% accuracy. Light touch was tested last using a tissue to bilateral shanks and feet (due to patient attire). Abnormal findings included small areas in the L5 and S1 dermatomes of the left great toe and medial heel. When retested during the same session, the patient reported sensation of those areas.

Initial Assessment

Based on the patient's report, she had already seen improvement in function and general capabilities since diagnosis with PCD. This was a good sign for overall prognosis with the disease course and for her goals.[10] Greater progress can be made when degeneration slows or ceases. Additionally, the antineuronal antibody associated with PCD is highly correlative with a patient's functional outcome of being able to walk.[10,11]

The patient's initial goal of improving her strength in order to prepare for her right TKA was deemed appropriate and the prognosis for meeting that goal was good. The patient was highly motivated. She designated much of her time to improving her outcomes and quality of life. It was predicted that the patient would make significant improvements to force production and strength after 6 weeks of dedicated work in this area. Limitations from dysfunctional bone/joint alignment along with associated symptoms were assessed as being significant and could negatively impact the amount of progress that could be made. It was questioned initially if more meaningful improvements would occur post-operatively.

The patient showed significant in-session improvements with balance even during the brief moments of balance testing as well as during initial treatment. Static balance was predicted to have a fair to good likelihood of making clinically detectable changes, including with eyes closed. Again, the patient showed in-session improvements where she was initially able to perform tandem stance with one hand holding at waist-height bar to no hand support for 60 seconds. The patient also was able to advance from standing on foam with knees together (because feet cannot touch due to genu valgum) with intermittent use of both hands for righting to no support of hands for righting for 20 seconds. The patient initiated the conversation about performing static balance exercises at home as part of her home exercise program (HEP), demonstrating high levels of motivation. The limiting factors would be any progression of PCD that negatively affects truncal posture or increasing knee pain that would limit tolerance for standing.

The patient's dynamic balance and gait stability initially were assessed to have a fair prognosis, dependent on multiple factors. First, the ataxia possibly more than strength deficits increased the instability of the patient's gait and other dynamic movements. Again, prognosis would be dependent on neurologic status of the progression of PCD, as well as the ability for the patient to maintain her highly motivated attitude and compliance with her HEP. That said, it was evident during testing (and after watching the patient over the course of several weeks) that the patient showed quick in-session motor planning improvements when given feedback. Even though the cerebellum plays a critical role in motor learning, the patient demonstrated that she could adapt quickly. That said, she still shows high amplitude ataxia with movements of lower and upper extremities.

Interventions

As with other TKA prehabilitation programs, interventions used for this patient focused on strengthening quadriceps, hip abductors and hamstrings. Secondarily, treatment also focused on static and dynamic balance and coordination of movement. The following outlines the clinical decisions related to our interventions.

<u>Patient-Specific Clinical Decisions</u>

Clinical decisions were made in order to cater treatments specific to the needs of the patient. First, the patient stated her goals for physical therapy. Her first was to increase her strength and she discussed that she thought our clinic would be a good fit because of our sports medicine, orthopedic focus. Secondly, when the patient gave her history, she emphasized how active she was – she was a former college basketball player who decades after that career, continued to play basketball in her free time. Once her balance was impaired, and after her knee became a limitation, she started tricycling outdoors to remain active. Because of these two things, clinical decisions were made to as quickly as possible, move the patient from performing table exercises to more upright activities that would mentally stimulate and motivate a life-long athlete. Namely, we decided to get our patient out into the weight room to lift weights as part of her rehabilitation. Additionally, it was a deliberate decision to ensure that the patient was given a sense of challenge with each exercise.

Each exercise had to present the level of challenge that would motivate the mind of an athlete and create commitment to each intervention. Clamshells with a band were quickly progressed to sidelying hip abduction with resistive bands and given as part of the patient's home exercise program (HEP). In sessions, sidelying hip abduction with manual rhythmic resistance was used and progressed to upright

Storks. To perform a “stork”, a patient stands in a mini squat on one leg and abducts the other leg with a flexed knee, pushing the distal thigh into a Swiss Ball that the patient holds in place at a wall with the abducting leg. These were motivating, not only because of the balance challenge that they provided, but because it did not take many repetitions before the patient felt muscle tremor and fatigue. This was a very challenging exercise for the patient’s hip abductors and was upright, which appeared to motivate the patient.

Quadriceps strengthening began initially with supine straight leg raises without resistance, quickly moved to manual resistance with rhythmic stabilization and then to a leg press. The leg press was later phased-out for seated long arc quads at a cable and pulley weight system, because it was more tolerable for the patient. Additionally, the patient was motivated to increase her weight or increase total repetitions. There was an easy, quantifiable way for the patient to monitor her own progress.

Hamstring strengthening was added at week 5, once we found a position and method that worked for the patient. Two hamstring curl machines were attempted during prior weeks – one seated and one prone – but the patient had to cease each due to complaints of knee pain. Supine hamstring curls using a swiss ball were used initially in-session to trial, to assess movement and safety related to getting down to and up from the floor for the exercise. They were then given as part of the patient’s home exercise program and provided a sufficient challenge to the patient’s motor control, balance as well as hamstring strength. These were advanced to seated hamstring curls using a cable and pulley weight system for in-session strength training but remained as a great exercise for her home environment.

Additionally, as the clinicians got to know the patient and her history more, it became clear that the patient had exercise equipment that could be utilized at home. The patient had an exercise bicycle and swiss ball at home, and these were encouraged to be used as part of the HEP. An understanding of the patient’s home set-up and safety with exercises also allowed us to better tailor a HEP program. For example, as we got to know the patient, we came to understand that she could be safe at home getting up and down from the floor to perform exercises, which allowed us to add challenging swiss ball hamstring curls.

Lastly, conversation was used intentionally with this patient. First, the reason behind why each exercise was selected and the dosage of each exercise was communicated to the patient. Having had a long career in pharmacy, and being highly educated in the health sciences, the therapists understood that she wanted to know the research behind our interventions. Additionally, it was important for the patient to know that we understood the cerebellum’s function in the human body and with movement. Lastly, as the clinicians gained rapport with the patient and continued to get to know her, we learned just how competitive and driven she was. We found ways to motivate her into better in-session performance. We would say things like, “It looks like this is harder for you today”, or “It looks like you’re having a more difficult time doing this with your left leg today”. She would use that feedback to improve her performance. We would also let her know how long she was able to perform a balance task and she was always motivated to improve the time. Positive feedback was also administered when the patient performed a task correctly. These methods of verbal feedback motivated her to improve each task and she would make noticeable in-session improvements.

Working Around Bony-Malformations

The bony malformation of the right knee proved to be an area that required adaptations to standard exercises. Significant discomfort occurred when the patient’s knee moved through her available range of motion, particularly as we loaded the joint. We had to decide how best to load the quadriceps, hamstrings, and gluteal muscles without creating too much discomfort, pain, or buckling at the knee.

When we transitioned the patient from resisted straight leg raises to the leg press, the load at the joint created significant crepitus at the knee, increase in pain and apprehension, and, when the exercise was done, buckling of the knee. We quickly found that high load was not going to be an option to improve strength, but rather, we would have to attempt low load and high repetition. Low-load high-repetition has been found to be effective at significantly increasing strength.[12-15] The patient started at low load and low repetitions (2 sets of 15 reps at 15 lbs.) and progressed to low load high repetitions.

We primed the patient for the leg press with manual tibiofemoral traction to improve mobility and arthrokinematics. Once this was added, the patient experienced less crepitus at the start of her leg press activities, and also allowed her to transition more quickly to higher loads. Additionally, the patient would start at the leg press with lower weight, which likely helped lubricate the joint surfaces. Beginning this way, the patient was able to perform 140 repetitions (7 sets of 20 repetitions each, with increments of 2.5 lbs. increases each set).

We also found that the knee could accept more load in its more open-pack position, where there was least tibia on femur contact. Because the leg-press we used was a relatively closed-kinetic chain exercise, it was more likely producing compressive loading through the knee joint.[16] Additionally, because the patient performed so much better at the leg press directly after traction, and because she performed the exercise using a very limited range of motion, this gave us the idea to change the way we targeted the quadriceps. We decided to change the vector of the load and use the weights and their line of pull to promote a traction-like force. The patient was trialed in a seated position at a cable and pulley weight system, facing away to work on quadriceps and facing toward it to target hamstrings. The patient reported and the clinician palpated no cogwheel crepitus. The patient also was able to complete 7 sets of 20 repetitions of pain-free exercises through a much greater range of motion. The patient reported muscle fatigue but no buckling after exercises with the cables.

The biggest success of this intervention was that it presented as the way to best facilitate strengthening for knee extension and flexion in a non-painful manner. The way we set-up the pulley system promoted a traction force on the lower leg, likely facilitating a mild tibial on femoral distraction while the patient performed these exercises.

Working at and around ataxia and balance

Another series of clinical decisions related to both working around the patient's ataxia and addressing the patient's ataxia. The decision was made to focus on closed kinetic chain movements for strengthening purposes. We decided this would allow the patient to focus on lifting/moving a load as opposed to controlling the fluidity of the movement. Additionally, closed kinetic chain movements are typically thought to be more functional activities and have been demonstrated to, particularly at the knee, facilitate better co-contraction of the hamstrings along with quadriceps.[16,17] For our patient, activities that facilitate better co-contraction should assist in targeting her ataxic symptoms, particularly at mid-range.

The instability of the patient's gait had to be kept in mind during treatment sessions. For example, after the leg press exercise, it was typical for the patient to have buckling of the knee (due to pain) during balance activities. We would make clinical decisions to end treatment for the day because the pain, buckling and our need to catch the patient during balance exercises was limiting what the patient could accomplish in-session. It also put the patient at risk for falls after leaving the clinic. We decided to simply have the patient perform balance activities first during a session, and perform strengthening afterward, to continue to address balance needs, but reduce fall risk.

Initially, static and dynamic balance activities were more heavily incorporated into the treatment sessions and were then given largely as part of her home exercise program. In session, a gait belt was used to ensure baseline level of assist was at contact guard assist (CGA), and the patient moved from standing without an assistive device with a wide base of support, to narrower bases of support on firm ground and with eyes open and closed. The patient also utilized a foam cushion to stand on for balance activities. Narrow base of support activities were advanced such that the upper extremities had to reach to targets that were called out to the patient while the patient's feet were together.

The patient was also given stepping drills in single leg stance with the contralateral leg stepping to targets (various levels of support were provided during this activity, from CGA to the patient using light touch through hands at the bar to minimum assistance of one when loss of balance occurred). Stepping drills were progressed to stepping drills on a taped floor "ladder". Backwards walking, marching, and walking to various tempos were also used. The ladder's lines served as targets for the various stepping patterns.

The patient scored at a high risk for falls according to the Timed Up and Go and Berg Balance Scale. Qualitatively, the patient's gait appeared unstable due to a decreased gait speed, decreased stride length, amplitude of leg movement during swing phase prior to heel strike, and overall conscious effort to walk using her four-wheeled walker. A clinical decision relevant to the patient's safety and instability with gait was to discuss with the patient that changing the assistive device to something like a U-Walker may better stabilize the patient's gait, and it might be worth trialing a different device. The patient was open to the idea, particularly in light of her anticipated surgery and post-operative rehabilitation. By the end of the first phase of treatment, the clinician and patient were working with local providers to set-up a trial of different assistive devices.

Additionally, we worked to address ataxic movement patterns. First, we decided to utilize rhythmic stabilization to help promote control of mid-range movements.[18] A Class IV study validates the use of this neuromuscular facilitation technique in a patient with PCD.[19] We also used targets to assist with movement coordination. Localized vibration was also used (via a Hypervolt at 58 MHz) to the various muscle groups just prior to performing an associated exercise to facilitate motor control.[18] Localized and whole body vibration have shown promising, positive results with muscle fiber recruitment and control in both normative and ataxic populations.[20-23]

Clinical Decisions to Prioritize Certain Interventions Over Others

Clinical decisions were made to prioritize interventions that were aligned with the patient's primary goal - to improve strength and prepare for her anticipated TKA. Because of this valuation by the patient, we made the majority of our sessions focused on strengthening, as opposed to balance, because we had tools in clinic that the patient did not have access to elsewhere (namely the cable weight system and leg press). Some sessions had no additional balance activities outside of what storks or supine swiss ball hamstring curls would facilitate. If the patient had more frequent sessions each week and were not also working on balance during her home and outside activities, we would have further prioritized it. We also thought that more could be done for her balance in treatment sessions after she had her knee surgery.

The ordering of interventions also mattered a lot. It became apparent that balance work had to be performed prior to strengthening activities because the patient could not maintain a narrow or reduced base of support after loading the knee repeatedly. The knee became increasingly painful and would buckle, causing the patient to have losses of balance during session that required external righting to prevent falls. Balance was re-ordered to be the first portion of treatment sessions. Additionally, we would target balance activities in-clinic to assess patient's safety with them so she could work on them at home in order to continue to treat imbalance, but also maximize treatment sessions.

Clinical Decisions Regarding Outcomes Assessment

Initially in this case we used SARA, TUG, Berg, manual muscle testing and a dynamometer to assess progress. We opted not to reassess SARA scoring at the close of the first phase of rehabilitation due to the fact that we prioritized strengthening over interventions specific to ataxia. We also decided that improvements to balance, strength and gait would be observed during the TUG and Berg tests and would directly relate to our patient's activities of daily living and participation. Manual muscle testing was used for historical purposes and dynamometry was used in order to have a more precise measurement that can better track progress. Additionally, we chose to track starting and ending weights lifted at the leg press and cable system, along with sets and repetitions in order to assess progress.

Outcomes

Quadriceps activities from onset to end of initial phase of treatment progressed significantly. Initially, the patient could perform a 10RM of 15 lbs on the right side. Four weeks later, the last time she used the leg press, the patient was able to perform 7 sets of 20 repetitions for a total of 140 repetitions. She began at 15 pounds and increased by increments of 2.5 lbs each set to 30 lbs on the affected leg.

On the left, the patient was unable to perform this exercise on the unaffected (left) side, due to post-stem cell implant protocol restrictions. Popping and grinding at the affected knee joint limited high loads and low repetitions for strengthening, but muscular fatigue was still obtained.

At the final session of the patient's first phase of therapy, the patient was able to comfortably start long arc quads and hamstring curl strengthening at the cables at 9.0 lbs and 7.5 lbs respectively. Initially, the patient began these at 4.0 lbs for long arc quads and 5.5 lbs for hamstring curls. During the final session, the patient only performed 3 sets of 20 repetitions due to time constraints.

Not only did the cable provide a comfortable means for strengthening, but also helped produce increase in the patient's force production for knee extension and flexion. A dynamometer was obtained and used at week 6 to provide a precise measure of strength gains. The patient's right knee extension improved from producing an average maximum force of 50.0 lbs. at week 6 to 83.3 lbs at week 8. Right knee flexion improved only slightly to an average maximum force of 61.4 lbs at week 8, up from 59.0 lbs at week 6.

Manual muscle testing at the end of the first phase of therapy also improved. The patient's right knee extension and flexion as well as left knee flexion improved from a grade of 4/5 to a 5/5. Left knee extension remained at 4/5 with popping sensations that limited the grading. Hip abduction bilaterally remained at 4/5, as did shoulder external rotation.

The patient's TUG improved by 6.31 seconds. The patient's initial time was 27.15 seconds, and upon retesting improved to 20.84 seconds. This improvement surpasses the minimal detectable change (MDC) for comparable populations. MDCs ranged from 2.9 seconds in chronic stroke patients[24] and 3.5 - 4.85 seconds in Parkinson's patients.[25,26] The patient additionally commented that she is having an easier time getting up from and sitting down into a chair.

The Berg Balance Scale by the end of the first phase of therapy increased by 5 points at 38/56. The MDC for chronic stroke patients has been demonstrated to be 4.13 points.[27]

The SARA was not retested at the final session of the patient's first phase of rehabilitation because the focus of therapy sessions had been so heavily focused on strengthening. This would be more relevant to retest during or at the close of the patient's second phase of therapy.

Discussion

This patient's case highlights the clinical decisions required to meet the patient's goals in a small outpatient orthopedic setting. Despite the patient-led, collaborative approach to patient care in this setting, clinical decisions were made in order to 1.) make treatments patient-specific as the clinician learned more about the patient; 2.) work around limitations driven by the bony malformation at the knee; 3.) work around limitations specific to the patient's ataxia and balance; 4.) prioritize interventions that would maximize treatment sessions; and, 5.) best assess outcomes.

The case also highlights how a low-load, high repetition method can be an appropriate means for increasing strength in someone with bony malformation at the knee.[12-15] High load and low repetition has been demonstrated to also be an effective means for improving strength. However, in patient populations with significant pain, high load may not be tolerable. In this patient's instance, pain levels became too high and crepitus intolerable, high load was not appropriate.

Similarly, closed kinetic chain exercises have been argued to be more functional and could be argued to be more task-specific for translation to functional movements for our patient.[16,17] However, it could be argued that the patient showed greater difficulty during open kinetic chain movements, such as during the swing phase of gait, and open kinetic chain movements would actually be more task-specific to the patient's needs. In this manner, the long arc quads at the cable and pulley system could be argued to be part training for gait, as the patient extends the knee and dorsiflexes, she mimics part of her swing phase movement.

An additional advantage of performing high repetitions of her exercises for our patient relates to her neurologic condition. The high quantity of repetitions may have enabled her to better motor-learn. The patient reported that her overall balance and coordination was worse in the morning than in the afternoon. This is most likely due to the continued practice the patient gets at coordinating her movements from the time of waking until about mid-day when it improves. The high repetitions, then, also are playing a similar role of allowing her to have a lot of practice at coordinating both quadriceps and hamstring co-contraction during the leg press and cable exercises. It has been demonstrated that patients with cerebellar damage improve movements with repetitive, small and gradual perturbations to the movement.[28,29] It is possible, that the 80-120 repetitions the patient performed may have improved motor coordination during those movements.

Our interventions for balance and movement coordination during this phase are based off of studies specific to patients with cerebellar damage or cerebellar ataxia. Most studies related to rehabilitation and Paraneoplastic Cerebellar Degeneration are class IV level of evidence, and most simply reference that patients went through either inpatient rehabilitation or completed several weeks of outpatient therapy, they do not comment on the types of interventions, but do provide evidence of improvement in patients with PCD, even when levels of anti-neural antibodies remain unchanged,[19,30,31] as our patient's did. There is one Class III study that also supports physical rehabilitation as an effective treatment for PCD symptoms, but it does not describe interventions.[32] However, PCD shares features with other cerebellar degenerative disorders and spinocerebellar ataxia. There are several studies that detail interventions. One such Class III study details home balance exercises found to result in gait improvements for patients with cerebellar ataxia.[33] These other cerebellar studies (of which the majority are level IV evidence) use exercise interventions for static and dynamic balance, perturbation training, ambulating on varied surfaces, using targets for movement training, vestibular habituation exercises, weighting of limbs and trunk, Frenkel exercises, proprioceptive neuromuscular facilitation (PNF) exercises, split treadmill training and gait training.[34-39]

These studies, among others, demonstrate that people with cerebellar damage and continued degeneration can still motor learn, and that adaptation is taking place possibly in both the cerebellum and elsewhere in the brain.[28,29] Amy Bastian commented[40] on Ilg *et. al.*'s study[29], pointing out that between group differences were apparent for those with and without afferent sensory deficits, with the latter showing greater improvements. The question can be asked, then, is there a way to target movements based off of DCML tract afferent information? Could conscious kinesthesia, proprioception, light touch and pressure be used to assist with movement coordination? It is important to point out that because this patient's DCML tract appeared to function well, sensory inputs may have been utilized to assist with substitution-based motor learning, in addition to cerebellar adaptation, leading to improvements seen in her Berg Balance Score.

Limitations

One limitation to this case report is that we had only 2 sessions per week to work with the patient. Had we had a third day, that session could have been used specifically to target the cerebellar-specific symptoms the patient had and make more progress there during the initial phase of the patient's rehabilitation program.

Another limitation of the interventions used here was that it took 6 weeks prior to starting a strength training program that was pain free. Had we started with the cable system method instead of the leg press, the patient may have been able to make greater gains in strengthening during the first 7 weeks.

In addition to the strengthening exercises, if we had access to a harness system to work on dynamic balance and gait in a supported manner, that may have produced additional gains in balance. For example, a harness used in conjunction with a traditional or split treadmill may have been useful adjuncts to her interventions.

Conclusion

The patient's progress across her first 7 weeks of therapy is significant and attributable, mainly, to the patient's dedication to her rehabilitation. She spent most days of her week practicing yoga, working on balance, performing aquatic therapy, weight-training and performing physical therapy interventions, as well as being treated by her chiropractor. She also was vigilant about taking alternative medicines and remained committed to a highly nutritional diet. All of these things, and all the work she did on a daily basis have resulted in the improvements to her strength and balance. It will be important for this patient, as she begins the second phase of her prehabilitation, to continue with strength gains and also focus more on balance and movement coordination so that once she has undergone her TKA procedure, she is better able to ambulate despite the high levels of pain and stiffness that result in the first several weeks following surgery.

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