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Altering Physical Therapy Interventions to Address Evolving Symptoms in a Patient Appearing to Develop CRPS after Foot Crush Injury: A Case Report

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Abstract

Background: Complex Regional Pain Syndrome (CRPS) is a rare, complicated condition that can develop after trauma and is primarily characterized by high pain intensity that is disproportionate to injury expectations. Persistent CRPS symptoms can lead to permanent impairment and disability due to activity avoidance and limb disuse. While interventions such as Pain Neuroscience Education (PNE) and Graded Motor Imagery (GMI) are generally supported for use in patients diagnosed with CRPS, there is a gap in the literature regarding the use of these interventions as a means of preventing full CRPS onset in individuals developing signs of the condition. **Case Description:** The following report describes the case of a patient referred to physical therapy after sustaining a foot crush injury. During the episode of care, the patient began to develop CRPS-like symptoms. **Interventions:** The purpose of this case report is to highlight the multimodal therapeutic interventions utilized when early symptoms were suggestive of CRPS, with the intention of preventing full CRPS onset. **Outcome Measures:** The CareConnections Functional Index, Tampa Scale of Kinesiophobia, and Pain Catastrophizing Scale were used to measure the patient's pain intensity, function, global rating of change, pain-related fear of movement, and negative feelings regarding pain. **Discussion:** While early treatment of CRPS is crucial in reducing the likelihood of permanent impairment and disability, this case suggests that utilization of CRPS interventions with CRPS-like symptoms prior to an official diagnosis may be too early and therefore not effective at preventing the disease course.

Keywords: Physical Therapy; Rehabilitation; Crush injury; Complex Regional Pain Syndrome; Pain Neuroscience Education; Graded Motor Imagery

Background

Complex Regional Pain Syndrome (CRPS) is a complicated condition that can develop after an injurious event to a limb, such as trauma or surgery (Elsharydah et al., 2017; Rand et al., 2019). CRPS is primarily characterized by pain that is unusually high in severity or prolonged in time compared to the usual course of a known injury (Elsharydah et al., 2017; Rand et al., 2019). CRPS also includes abnormal sensory, motor, vasomotor, sudomotor, and/or trophic findings (Elsharydah et al., 2017; Rand et al., 2019). The International Association for the Study of Pain (IASP) established the term Complex Regional Pain Syndrome in the 1990s to replace terms like Reflex Sympathetic Dystrophy and Causalgia that had been previously used to describe such signs and symptoms (Harden et al., 2013; Rand et al., 2019). Creating one comprehensive term with specific diagnostic criteria was necessary to create consistency within nomenclature and diagnosis, more easily facilitate research, and to emphasize the complicated nature of the condition (Rand et al., 2019; Shepherd et al., 2018).

The specific pathological mechanisms of CRPS are unclear, but research has shown that it usually occurs after injury to a limb and includes classic and neurogenic inflammation, autonomic nervous system dysfunction, peripheral and central sensitization, and cortical changes especially in primary motor and somatosensory cortices (Bruehl, 2015; Bussa et al., 2015; Elsharydah et al., 2017; Goebel et al., 2019; Urits et al., 2018). The prevalence of CRPS is rare with epidemiological studies reporting an incidence rate of 5.46-26.2 per 100,000 person years (de Mos et al., 2007; Sandroni et al., 2003). Persistent CRPS symptoms may lead to permanent impairment and disability due to activity avoidance and limb disuse, and complete recovery is less likely if symptoms last longer than one year (Lee et al., 2018; Rand et al., 2019). Preservation of function and shorter overall disease timeline are more likely the earlier treatment is started (Goebel et al., 2019).

There is no consensus on optimal treatment for CRPS, but the United Kingdom and the United States have developed treatment guidelines that emphasize multidisciplinary care and include physical therapy as first line treatment (Goebel et al., 2019; Harden et al., 2013). While there is limited high-quality evidence regarding physical therapy interventions for CRPS, there is some evidence in the literature to support use of therapeutic interventions such as Pain Neuroscience Education (PNE) and Graded Motor Imagery (GMI) to decrease pain and disability in individuals with CRPS (Smart et al., 2016). While PNE and GMI are generally supported for use with CRPS patients, a gap is present in the literature regarding the use of these interventions as a means to prevent full CRPS onset in individuals with demographic characteristics typical of those who later go on to develop CRPS and have started demonstrating signs of the condition.

Considering CRPS most commonly develops after a traumatic injury or surgery, it is likely that a physical therapist will encounter a patient developing CRPS during rehabilitation. Therefore, recognition of demographic indicators, signs, and symptoms are important in order to make an appropriate referral and initiate treatment. The following case report describes recognition of the demographic characteristics common in those who develop CRPS as well as the CRPS-like symptoms that developed during a physical therapy episode of care for a patient after a foot crush injury. The purpose of this case report is to highlight the multimodal therapeutic interventions utilized when early symptoms were suggestive of CRPS, with the intention of preventing full CRPS onset.

Case Description

History of Present Illness

The patient was a 51-year-old female referred to outpatient physical therapy by a podiatrist with a medical diagnosis of right foot bone contusion. The patient's foot injury occurred 6 weeks prior to physical therapy evaluation. The patient worked as a custodian for the maintenance and custodial services department at a local university. She reported the injurious incident occurred at work when a 50 to 60-pound object fell off a waist-high cart onto her foot. Radiographs were taken two weeks after the incident and were negative for fracture. The patient was placed in a controlled ankle motion (CAM) walking boot and instructed to ambulate with it on at all times. The patient reported inconsistent CAM boot usage during the 6 weeks prior to physical therapy evaluation as compression from the boot on

the top of her foot was painful. The patient reported wearing loose fitting tennis shoes when not wearing the CAM boot to reduce the pressure that she thought was increasing the pain at the top of her foot. Regardless of wearing the CAM boot or loose fitting shoes, the patient reported pain and feelings like electrical shocks in her right forefoot when bearing weight.

At the initial physical therapy evaluation, the patient reported right foot pain as 5.5/10 on a visual analog scale (VAS). The patient indicated pain was located at the dorsal and plantar forefoot from the second through fourth metatarsophalangeal joints and extended proximally about two inches on the dorsal surface. Aggravating activities included standing, walking, and ascending and descending stairs which would increase her pain to 7/10 on verbal numeric rating scale (NRS). The patient reported that sitting down and getting pressure off of her right foot reduced the intensity of her pain to 3/10 on NRS at best, but that the pain never completely went away. The patient reported significant activity limitations due to pain including only being able to stand for about 10 minutes, walk approximately 150 feet, and ascend/descend one small flight of stairs before needing to sit down and get weight off her foot. While the patient was continuing to work, she reported the pain and activity limitations were restricting her ability to perform her work duties fully. The patient also reported difficulty sleeping through the night due to pain.

Medical History

The patient reported a history of left rotator cuff injury that occurred at work for which she completed physical therapy with a successful outcome. The patient also reported seeing a physical therapist with successful outcome for bilateral radicular leg pain. The patient reported no other history of musculoskeletal injuries. The patient reported the inability to take non-steroidal anti-inflammatory drugs (NSAIDs) due to history of gastric bypass surgery. The patient reported a history of bilateral restless leg syndrome for which she had been taking gabapentin for almost 20 years. In addition to gabapentin, the patient was taking Extra Strength Tylenol and nortriptyline as prescribed for pain relief by the referring provider.

Social and Environmental Factors

The patient reported a long history of smoking; however, did not state specific quantity or frequency as it varied day by day. Due to the nature of the incident occurring at work, the patient's episode of care was a workers' compensation case. At the time of evaluation, the patient was still working full time, however was not functioning at her usual level at work due to pain and decreased weight-bearing activity tolerance.

Patient Reported Measures

The CareConnections Functional Index (CCFI) was assessed as a means of collecting patient reported outcome measure data. CCFI is a body-region specific questionnaire and consists of a ten-category functional index, a VAS for rating pain, and a global rating of change scale. A study conducted by Hoekstra and colleagues (2014) found the CCFI to have good to excellent test-retest reliability and valid correlations (>0.7) with other standard measures. Each of the ten categories in the functional index has a six-item list of statements that range from unable to do an activity (scored as 0) to able to complete an activity with no difficulty (scored as 5) where a patient marks the statement that best fits their current level of function. A total score is determined by summing the score of the individual categories and dividing by the total possible score (number of categories completed x 5) to yield a functional index score where 100 indicates no difficulty in function. The visual analog scale component is a line 10 centimeters in length that is free of numbers and has "No pain" as the left margin and "Worst pain imaginable" as the right margin. A ruler is used to measure where the patient rated their pain in centimeters and is recorded as being out of 10. The global rating of change scale has 0 at the center representing "unchanged", -7 as the left margin representing very much worse, and +7 as the right margin representing completely recovered. The global rating of change component was only completed at certain follow up visits and discharge.

The patient completed a lower extremity specific CCFI questionnaire at initial evaluation, the fifth visit, the fifteenth visit, and the twentieth visit. The patient's initial score on the lower extremity functional index that included categories such as standing, walking, stairs, and squatting was 56/100 and she rated her pain at 5.5/10, as previously mentioned. A minimum clinically important difference in functional score for lower extremity CCFI is 11 points (Hoekstra et al., 2014).

Examination

Details of the initial physical examination and findings can be found in Table 1. The patient's symptoms were highly irritable and therefore minimal formal testing was performed.

Table 1. Description of initial examination findings.

Objective Assessment	Initial Findings
Visual Assessment	• Moderate swelling noted dorsally and plantarly around 2nd-3rd metatarsophalangeal joints • Mild swelling noted dorsally and plantarly around 3rd-4th metatarsophalangeal joints
Right Foot Active Range of Motion (AROM)	• Ankle DF: WNL • Ankle PF: WNL • Ankle Eversion: 8° • Ankle Inversion: 40° • Minimal movement of 2nd-5th toes with attempts at active toe flexion, extension, or spreading. • Intermittently painful with attempts at toe AROM
Right Foot Manual Muscle Testing (MMT)	• Ankle DF: 5/5 • Ankle PF: *Unable to assess due to pain • Ankle Eversion: 5/5 • Ankle Inversion: 5/5 *pain into 2-3 metatarsals
Palpation	• Hypomobility between metatarsal heads that was difficult to assess due to pain • Allodynia: pain with light palpation of dorsal and plantar forefoot
Sensation	• Dysesthesia at area of pain: Light touch intact but feels different between sides • Unable to assess deep pressure, sharp/dull due to pain
Functional Activities	• Ambulatory with CAM boot • Slow, antalgic gait with and without CAM boot • Without CAM boot: patient avoids weight bearing through the forefoot and metatarsophalangeal joint extension at terminal stance/toe off by ambulating on lateral border of right foot • Ascends and descends stairs laterally with bilateral upper extremity support on hand rail • Unable to perform double or right single limb heel raise

Clinical Impression #1

The patient's presenting signs and symptoms including the localized nature of pain and swelling, decreased range of motion, and decreased functional mobility were consistent with expectations following a crush injury and subsequent immobilization; however, the high pain intensity rating with activity six-weeks post-injury, dysesthesia and allodynia with light palpation at the injured area were concerning for other soft tissue involvement, especially neural. The referring provider had ordered a magnetic resonance image (MRI) to be done to assess soft tissue involvement which was scheduled for the week following physical therapy evaluation. The MRI would later confirm bone marrow edema of the second metatarsal, no evidence of fracture, and soft tissue swelling dorsally overlying the extensor tendons of the 2nd-4th rays. Factors complicating the case at this time were the patient's smoking status as smoking is widely known to delay healing, the patient's inability to take NSAIDs to aid in decreasing the inflammatory response to the injury, and continually aggravating symptoms throughout the day due to work requirements.

Interventions

The patient was seen twice per week for treatment sessions following the initial evaluation with the goal of decreasing pain and increasing function by increasing foot and ankle active range of motion (AROM) and strength, normalizing gait mechanics, and increasing activity tolerance in order to achieve the long-term goal of completing activities of daily living (ADLs) and a full work day without increasing symptoms. Initial interventions included those typical of any post-immobilization plan of care which included edema management, addressing tissue extensibility and range of motion (ROM), gradual increase in weight-bearing activity, and gait training.

From evaluation through the fifth visit, treatment included non-weight-bearing intrinsic foot and ankle AROM activities such as toe curls, toe spreading, and ankle alphabet; low-load weight-bearing AROM activities such as NuStep, seated heel and toe raises, and level 1 biomechanical ankle platform system (BAPS) board in sitting; weight-shifting; and gentle manual joint and edema mobilizations. Manual therapy was approached with caution at this time, as the patient was only able to tolerate very little outside pressure on the dorsal or plantar surface of the toes or forefoot. This required therapist hand placement to be on the medial or lateral surfaces of the toes for joint mobilization or passive range of motion (PROM) and very gentle with attempts at edema management.

From the sixth through tenth visits, emphasis was placed on progressing AROM and weight-bearing activities such as recumbent bike, level 2 BAPS board in sitting, gait training such as heel-toe gait and side stepping. At this time, the patient was no longer tolerating manual therapy well and was educated on means of self PROM and desensitization techniques using a cotton ball or cotton swab. At each session up to this point, the patient was informally educated on tissue healing times, use of elevation and ice to manage swelling, and desensitization.

Evolving Characteristics

Leading up to this point, the patient had made little progress with regard to transitioning to normal gait. While she had improved in the ability to tolerate wearing tennis shoes with laces tied and achieving forefoot extension during gait rather than keeping the weight on the lateral border of the foot, she continued to have significant pain with gait.

Visits eleven through thirteen continued to emphasize AROM, gait training, desensitization, and tissue extensibility; however, during this time her symptoms and status began to change. The “pinching” and mild pain she complained of with toe and forefoot extension was now an extreme sharp and shooting pain on the whole dorsal surface of the right foot. Additionally, the patient reported pain at the lateral border of the foot where it extended up the lateral leg to the level of the knee. The swelling had migrated from the right forefoot around the base of the 2^{nd}-4^{th} toes to include the lateral border of the foot as well. She continued to complain of dysesthesia in the 2nd-3rd toes. She also continued to be intolerant to other people touching her foot due to pain and was barely able to tolerate the light compression of a sock. At this time, a consistent skin color difference was noted between the dorsum of the feet and toes with a red and ashy purple appearance on the right compared to the left. The patient began to report temperature fluctuations of the right foot and general temperature differences between right and left feet. The patient also reported abnormal sensations at this time such as “like someone is spraying back of my leg and heel with a squirt gun”. The patient’s fourteenth visit consisted of patient education only due to the patient being in severe pain and unable to tolerate any other forms of treatment. Education during the fourteenth visit covered topics such as her symptoms in relation to nerve healing, desensitization, edema management strategies, and the effects of psychosocial factors on pain. At this time, the referring provider was contacted and updated on the patient’s status.

Nineteen days elapsed between the patient’s fourteenth and fifteenth visits. During that time, the patient reported being hospitalized for a few days for pneumonia and going to the emergency room once due to foot pain. The referring provider also started the referral process for the patient to work with a pain management specialist during that time. The pain specialist evaluated the patient for CRPS and performed a right lumbar sympathetic nerve block as interventional treatment to alleviate the patient’s pain. At the fifteenth visit, the patient indicated to us that she had begun seeing a pain specialist who

gave her an injection to help with her pain. However, she did not mention the pre-procedure suspected diagnosis of CRPS or the specific procedure completed until weeks later. The patient reported slight pain relief in her foot and leg after the procedure with the relief only lasting approximately one day before returning to previous levels. The patient also reported being off of work for an unknown length of time per the pain specialist's restriction of seated work only, which was not possible due to the nature her custodial job.

The fifteenth visit primarily consisted of a reassessment of the patient's status due to the time elapsed between physical therapy sessions. At that time, the patient continued to complain of severe sharp, burning pain in her foot that extended up the posterior lateral leg with weight-bearing activities and forefoot extension. The patient previously had progressed to achieving forefoot extension with gait, but had now returned to avoiding forefoot extension by maintaining weight through the lateral border of her foot. Forefoot swelling at the base of the 2nd-3rd toes had decreased but forefoot swelling at the base of the 4th and 5th toes and lateral border of the foot had increased. The patient continued to demonstrate skin color differences between feet with the dorsum of the right foot and toes appearing an ashy purple-red color compared to the left. The patient also continued to complain of temperature differences between feet as well as allodynia and abnormal sensations at the dorsum of the right foot. The patient was able to fully perform non-weight-bearing active toe extension and spreading but continued to demonstrate minimal toe flexion and decreased metatarsal head mobility.

Physical therapy interventions at visits fifteen through eighteen continued to focus on non-weight bearing AROM, weight-bearing/low-load AROM, weight shifting, lower extremity tissue extensibility, lower extremity strengthening, and pain management via transcutaneous electrical nerve stimulation (TENS). At the end of the eighteenth visit, the patient confided in us the pain specialist's evaluation for CRPS, reported she had been diagnosed with CRPS, and asked many questions about the condition. At this time, a progress note and an updated diagnosis were requested from the pain specialist; however, only the procedure note for the right lumbar sympathetic nerve block was received.

Clinical Impression #2

The patient-reported CCFI data captured at the fifth and fifteenth visits compared to initial evaluation indicated that the patient's rating of function had slightly decreased, pain rating had increased, and global rating of change was minimally improved (Table 3). The evolution of the patient's symptoms indicated pathology beyond what was expected of a typical crush injury and subsequent immobilization. The patient's reported diagnosis and discussion of CRPS with her pain specialist as well as lack of communication from the referring provider and pain specialist prompted further investigation into CRPS diagnostic criteria and physical therapists' role in managing the condition.

The most current CRPS diagnostic criteria was established by the IASP at a conference held in Budapest and have thus become commonly known as the "Budapest Criteria" (Goebel et al., 2019; Harden et al., 2013; Rand et al., 2019). The Budapest Clinical Diagnostic Criteria for CRPS was validated in 2010 and demonstrates excellent diagnostic sensitivity (0.99) and specificity (0.68) that is much improved from previous versions (Bruehl, 2015; Goebel et al., 2019; Harden et al., 2013; Lee et al., 2018). The Budapest Clinical Diagnostic Criteria (Figure 1) describe pain, symptoms, signs, and differential diagnosis exclusions that must be met in order to be diagnosed with CRPS (Lee et al., 2018; Rand et al., 2019; Shepherd et al., 2018). CRPS is a diagnosis of exclusion, meaning that all other explanations for a patient's signs and symptoms must be ruled out in order to be considered for a CRPS diagnosis. Imaging or other testing procedures might be done such as radiographs, computed tomography (CT), MRI, bone scans, nerve conduction studies, or sympathetic nerve block in order to meet this criterion, but it is important to note that these procedures are being done to rule out other diagnoses, not to test for CRPS specifically as there are no diagnostic tests for CRPS (Goebel et al., 2019; Lee et al., 2018; Rand et al., 2019).

While making a medical diagnosis is not within the scope of practice of a physical therapist, the patient's high intensity disabling pain and the presence of sensory, vasomotor, sudomotor, and motor signs and symptoms appeared to be consistent with the specifications of the Budapest Criteria for

CRPS. Objective measures of symptoms other than pain were not conducted. The intermittent nature of temperature and skin color asymmetry, edema of localized areas rather than the entire foot, decreased AROM but not PROM, and motor dysfunction of only toe flexors indicated that if CRPS was developing, it was in the preliminary stages or at a lower severity compared to cases where symptoms are more constant in nature, asymmetries are more dramatic, and dysfunction is more pronounced (Dimova & Birklein, 2019; Galve Villa et al., 2016).

Budapest Criteria
1. Continuing pain which is disproportionate to any inciting event
2. Must report at least 1 symptom in 3 of the 4 following categories: [ ] Sensory: Hyperalgesia and/or allodynia [ ] Vasomotor: Temperature asymmetry and/or skin color changes and/or skin color asymmetry [ ] Sudomotor: Edema and/or sweating changes and/or sweating asymmetry [ ] Motor/Trophic: Decreased ROM and/or motor dysfunction (weakness, tremor dystonia) and/or trophic changes (hair, skin, nails)
3. Must display at least 1 sign at the time of evaluation in 2 or more of the following categories: [ ] Sensory: Hyperalgesia (to pinprick) and/or allodynia (to light touch or deep somatic pressure) [ ] Vasomotor: Temperature asymmetry (>1 degree C) and/or skin color changes and/or skin color asymmetry [ ] Sudomotor: Edema and/or sweating changes and/or sweating asymmetry [ ] Motor/Trophic: Decreased ROM and/or motor dysfunction (weakness, tremor dystonia) and/or trophic changes (hair, skin, nails)
4. There is no other diagnosis that better explains the signs and symptoms

Figure 1. The Budapest Clinical Diagnostic Criteria adapted from figures depicted in the publications by Goebel et al. (2019) and Lee et al. (2018).

Outcome Measure Modifications

A systematic review by Grieve and colleagues (2015) analyzed the many different patient-reported outcome measures that have been used by providers in the past to collect objective data from CRPS patients. From this data, they determined that multiple domains must be included in order to comprehensively capture the multidimensional nature of CRPS, with key domains including pain intensity, disease severity, participation, physical function, emotional and psychological function, self-efficacy, catastrophizing, and global impression of change (Grieve et al., 2015; Grieve et al., 2017). Of these domains, pain intensity, physical function, and global impression of change are captured within the CCFI that was already being used with this patient. In order to capture patient-reported data within the key domains of emotional and psychological function and catastrophizing, it was decided to add the Tampa Scale of Kinesiophobia (TSK) and the Pain Catastrophizing Scale (PCS).

The TSK is a 17-item questionnaire that serves as a patient-reported measure of pain-related fear of movement. The TSK was originally developed in the 1990s for use in individuals with chronic low back pain but has since been found to be valid and reliable for use in other chronic pain conditions (Hapidou et al., 2012). When completing the questionnaire, the patient indicates the degree to which they agree with the statement made in each item by marking a 4-point Likert scale from 1 (strongly disagree) to 4 (strongly agree). The questionnaire is scored by inversing the score for items 4, 8, 12, and 16 before summing the score of all items. Scores can range from 17 to 68, where a cut off score of 37 or higher indicates high pain-related fear of movement (Hapidou et al., 2012).

The PCS is a 13-item questionnaire that serves as a patient-reported measure of irrational negative thoughts and feelings about pain (Sullivan & Pivik, 1995). When completing the questionnaire, the patient indicates the degree to which they experience the thought or feeling listed in the item from 0 (not at all) to 4 (all the time). The score of each item is summed to result in a total score which can range from 0 to 52 where a score of 30 or greater indicates a clinically relevant level of pain catastrophizing (Sullivan & Pivik, 1995). In addition to assessing catastrophizing via the total score, the PCS assesses rumination, magnification, and helplessness by yielding subscores. Subscores are determined as a result of summing 4 items for rumination, 3 items for magnification, and 6 items for

helplessness. The mark indicating clinical significance for the subscales is a score greater than or equal to 11 for rumination, 5 for magnification, and 13 for helplessness (Sullivan & Pivik, 1995).

Intervention Modifications

Pain Neuroscience Education (PNE) is a tool used by physical therapists to teach those with chronic pain about the biophysiology behind pain and pain processing (Watson et al., 2019). The approach uses metaphors and analogies to explain complicated topics such as allodynia and central sensitization in a way that is more easily understood by a patient with the goal of changing their perception of pain to be less threatening (Shepherd, 2018; Watson, 2019). PNE facilitated reconceptualization of pain has been shown to positively impact a person's ability to cope with their condition (Watson et al., 2019). Use of PNE as a therapeutic intervention for individuals with chronic pain has been shown to lead to reduced pain, improved function, and reduced psychosocial factors such as fear-avoidance and catastrophizing (Louw et al., 2011; Louw et al., 2016; Watson et al., 2019).

One study compared the common metaphors and analogies used in PNE and found that no single metaphor or analogy was more helpful than the others at changing patients' perception of pain (Louw et al., 2019). For this particular patient, the nervous system was compared to an alarm system to explain allodynia and central sensitization at the nineteenth visit (Louw et al., 2019) (Table 2). Before an injury, the electrical activity generated by normal daily activities is well below the level that would be detected by the alarm system. After an injury, the alarm system becomes more sensitive to what it reacts to because of pain and other psychosocial factors. This means the electrical activity that is generated by normal daily activities now activates the alarm system even though it didn't before. At visit twenty, the analogy of police responding to a house call in the middle of the night and waking up the neighbors with the lights and sirens was also used to explain how parts of the body surrounding the original location of the injury can be more sensitive, irritated, or even painful after an injury (Louw et al., 2019) (Table 2).

Graded motor imagery (GMI) is a therapeutic intervention that has been shown to decrease pain an increase function in those with chronic pain, including CRPS (Harden et al., 2013; Lee et al., 2018; Mendez-Rebolledo et al., 2017; Pollard, 2013; Rand et al., 2019; Smart et al., 2016). GMI is a three-part series of exercises that aim to address the cortical reorganization that occurs as a result of maladaptive neuroplastic activity in individuals with chronic pain (Harden et al., 2013). The three parts are sequential beginning with laterality, then motor imagery, and ending with mirror therapy (Harden et al., 2013; Shepherd et al., 2018).

Laterality is also referred to as left/right discrimination and requires a person to identify as quickly as possible whether the body part shown is the left or right side (Pollard, 2013; Shepherd et al., 2018). The body part displayed is the affected body part of the patient, so for this particular patient a foot was displayed. The RecogniseFoot App (www.noigroup.com) was used to show multiple pictures of feet and objectively measured how quickly the patient selected left or right side and the accuracy of the patient's selection. The patient was started on a level that showed pictures of bare human feet in different positions against a plain background and progressed to a more difficult level if a response time of less than 1.6 seconds was achieved with greater than 80% accuracy bilaterally (Moseley et al., 2019). More difficult levels increase the complexity of the images by making them abstract like including drawings or statues and by adding distractions such as shoes or a textured background. Left/right discrimination was initiated at visit nineteen and continued through visit twenty-two (Table 2). Five rounds of twenty images were completed at each visit with the average speed and accuracy used to determine progression. The patient had the resources to obtain the RecogniseFoot App on her smart phone and was asked to perform left/right discrimination training on her own. Based loosely on previous publications, the patient was asked perform 5 rounds of 20 images at least every other waking hour each day (Pollard, 2013).

Motor imagery involves imagined movements of the affected limb with the intention of eliminating the mismatch between efferent signaling for motor intention and afferent sensory feedback that occurs in individuals with chronic pain (Lee et al., 2018). Visualization or imagining movement activates the neural networks associated with the motor task without the afferent pain signaling that actually moving

the limb would cause (Diers et al., 2010; Pollard, 2013). For this particular case, the patient was initially asked to visualize the foot and ankle moving in non-weight bearing positions such as seated toe flexion and extension, ankle plantarflexion and dorsiflexion, and ankle inversion and eversion with progression to weight-bearing activities such as walking and ascending stairs. Motor imagery was initiated at visit nineteen and continued through visit twenty-two (Table 2). The patient was asked to perform motor imagery on her own for at least five minutes after completing left/right discrimination training.

Mirror therapy, the third stage of GMI, was originally developed by Ramachandran for treatment of phantom limb pain but its use has been expanded to other chronic pain conditions such as CRPS (Selles et al., 2008). Mirror therapy is executed by concealing the affected limb behind a mirror while the unaffected limb is positioned so that its reflection appears where the affected limb should be, creating an illusion of normality in the affected limb (Pollard, 2013). Mirror therapy is based on the idea that the brain prioritizes visual feedback over proprioceptive feedback, allowing the visual feedback of the reflection to provide alternative feedback that might be prioritized compared to other afferent signals being received from the affected limb, activating mirror neurons and facilitating cortical reorganization (Diers et al., 2010; Pollard, 2013). For this particular patient, mirror therapy was conducted with the patient seated with her right foot and ankle concealed behind a 12-inch by 12-inch mirror positioned such that a reflection of her left foot was in place of her right foot. Initially, the patient was asked to focus only on the image without moving either foot and was progressed to imagining movement of the reflection, moving the unaffected foot only, and then moving both feet and ankles symmetrically. Mirror therapy was initiated at visit twenty-one and continued to visit twenty-two (Table 2). The patient possessed a mirror that was adequate to perform mirror therapy at home. In accord with the dosing of previous publications, the patient was asked to practice mirror therapy three to five times daily for bouts of at least fifteen minutes each (Selles et al., 2008).

Table 2. Physical therapy interventions added after emergence of CRPS-like symptoms.

		Physical Therapy Visit Number					
		17	18	19	20	21	22
Pain / CRPS Specific Interventions	• TENS	X	X				
	• Pain Neuroscience Education			X	X		
	• Left/Right Discrimination			X	X	X	X
	• Imagined movements			X	X	X	X
	• Mirror Therapy					X	X

Outcomes

The patient was seen for a total of twenty-two visits over the course of fifteen weeks. At visit twenty-two, the patient continued to demonstrate similar signs and symptoms as when reassessment was done at visit fifteen. The patient continued to complain of severe sharp, burning pain in her foot that extended up the posterior lateral leg with weight-bearing activities and forefoot extension. The patient continued to demonstrate antalgic gait and avoided forefoot extension during gait by maintaining weight through the lateral border of the foot. Forefoot swelling overall had decreased, while swelling at the lateral border of the foot remained unchanged. While the patient continued to demonstrate skin color differences between feet, it was noted that skin color of the dorsum of the right foot normalized for about 30 minutes after each bout of mirror therapy. At this time, the patient experienced less frequent noticeable temperature differences between feet, but continued to experience allodynia and abnormal sensations at the dorsum of the right foot at the same rate. The patient continued to be able to fully perform non-weight-bearing active toe extension and spreading with improved but still limited toe flexion and metatarsal head mobility.

CCFI outcomes can be found in Table 3. While the patient marked global rating of change for the time period between initial evaluation and just prior to the initiation of PNE and GMI (visit fifteen) as slightly improved, she had rated an overall decrease in the functional index score and an increased

pain intensity rating. After PNE, left/right discrimination, and motor imagery were introduced, the patient's functional index score and global rating of change both decreased while pain rating improved. CCFI data was not collected after mirror therapy was initiated.

TSK and PCS outcomes can be found in Table 4. Prior to the initiation of PNE and GMI, the patient scored at a moderate level of pain-related fear of movement and high pain catastrophizing, rumination and helplessness. After PNE and GMI had been introduced, the patient's scores increased across areas to a high level of pain-related fear of movement; even higher levels of pain catastrophizing, rumination, and helplessness; and a high level of magnification.

Table 3. CCFI outcome data for initial evaluation, visit five, visit fifteen, and visit twenty.

	Initial Evaluation	Visit 5	Visit 15	Visit 20
Functional Index	56	50	50	48
VAS	5.5	3.7	9	7
Global Rating of Change	-	0	+1	-1.5

Table 4. TSK and PCS outcome data for visit nineteen and visit twenty-two.

	Visit 19	Visit 22
TSK	32	39*
PCS – Total	30*	37*
PCS – Rumination	13*	16*
PCS – Magnification	3	5*
PCS – Helplessness	14*	16*

(*) indicates a score equal to or higher than respective cut-off score indicating a clinically high value.

Discussion

CRPS-like signs and symptoms can be difficult to distinguish from normal healing after trauma, as evidenced by visits one through eighteen of this case, but acknowledging and identifying signs, symptoms, and any demographic indicators early can be helpful in making an appropriate referral and modifying interventions. A study by Dietz and colleagues (2019) identified pain and psychological factors such as depression and anxiety as clinically measurable means of differentiating CRPS patients from patients experiencing normal trauma healing. The study found that CRPS patients, on average, scored at the cut off for mild depression, above the cut off for anxiety, and reported a pain rating of >4/10 on a NRS (Dietz et al., 2019). Whereas, normal trauma healing patients scored low on depression and anxiety measures and rated pain as < 4/10 on a NRS (Dietz et al., 2019). For this particular case, the patient did not have a history of depression or anxiety and these two psychological factors were not measured; however, screening for these factors could have provided useful information in forming this patient's prognosis. The patient did report a pain rating of greater than 4 at the time of initial evaluation, and throughout the episode of care, which immediately raised concern for pathology beyond what was expected at 6 weeks after crush injury occurrence and subsequent immobilization.

Pain rating of intensity on a NRS is a commonly used measure to describe pain, as previously mentioned, but identification of pain mechanisms can also be useful in guiding a physical therapist's treatment approach. Pain is generally separated into three mechanisms: nociceptive, nociplastic, and neuropathic as described by Chimenti and colleagues (2018). Pain after an acute injury is largely nociceptive in nature and occurs due to activation of peripheral nociceptors, while nociplastic pain occurs as a result of altered nociceptive processing in the central nervous system with persistent pain conditions, and neuropathic pain occurs with dysfunction of the nerves of the somatosensory system (Chimenti et al., 2018). Each of the three pain mechanisms are influenced by biopsychosocial factors and may respond differently to various treatment modalities (Chimenti et al., 2018). All three pain mechanisms can be contributing to a patient's pain at a given time in varying proportions (Chimenti et

al., 2018). For this specific patient, evaluating pain beyond intensity rating on a NRS and determining the point at which the active pain mechanisms transitioned from nociceptive-neuropathic to largely nociplastic-neuropathic would have been useful to guide treatment. As previously mentioned, it is difficult to determine when acute to subacute pain with a primarily nociceptive mechanism transitions to chronic pain with a primarily nociplastic mechanism. Earlier identification of the patient's pain mechanism transition may have allowed earlier implementation of treatments that nociplastic-neuropathic pain is more receptive to, such as transcutaneous electrical nerve stimulation (TENS).

While it was not a majorly highlighted intervention within this report, the use of TENS was trialed at visits seventeen and eighteen (Table 2). TENS consists of using gel-adhesive electrodes attached to the skin to apply an electrical current with the goal of decreasing pain. TENS is proposed to activate a multimodal endogenous pain-relieving cascade that primarily involves action in afferent nociceptive and efferent analgesic pathways at the neurotransmitter and receptor levels (Chimenti et al., 2018). TENS has been shown to significantly decrease pain in individuals with chronic neuropathic pain conditions, including CRPS (Bilgili et al., 2016). Conventional TENS was first trialed at visit seventeen with one electrode placed at midline of the plantar forefoot and the second electrode at midline of the anterior surface of the ankle in order to surround the patient's most symptomatic area, the dorsum of the foot. With TENS applied, the patient noted little to no effect on resting pain or pain with activities performed throughout the session. Conventional TENS was again trialed at visit eighteen but electrode placement was changed to being directly over the symptomatic area due to lack of analgesic results with bracketing. At visit eighteen, one electrode was placed directly over midline of the dorsal forefoot while the second electrode was placed just inferior and anterior to the lateral malleolus. Similarly to the previous trial, the patient noted little to no effect on resting pain or pain with activities performed throughout the session. Removal of the gel-adhesive electrodes from these sites significantly increased the patient's pain to the point of tears. While TENS is a commonly used tool by physical therapists for assisting with pain management, after two unsuccessful trials it was decided to discontinue the use of TENS with this patient.

Population-based studies have identified several demographic characteristics that are commonly seen in CRPS patients. Knowledge of such indicators can be useful in identifying individuals who might be more prone to developing CRPS. The population-based studies found that females are 3-4 times more likely to develop CRPS than males, the age at which CRPS most commonly occurs is between 45 and 70 years old, and Caucasians are more commonly affected than any other race (de Mos et al., 2007; Elsharydah et al., 2017; Sandroni et al., 2003). These studies also found that CRPS occurs in the upper extremity almost two times more frequently than in the lower extremity, and the most common precipitating injury, seen in nearly 50% of cases, was a fracture (de Mos et al., 2007; Sandroni et al., 2003). Factors related to mechanisms of injury, other than fracture, that have been shown to precipitate CRPS development are high impact injuries, falls from a height, and immobilization lasting longer than 8 weeks (Rand et al., 2019). Psychosocial characteristics have also been studied in relation to CRPS development with depression (Elsharydah et al., 2017), history of any psychiatric disease (Sandroni et al., 2003), and the presence of secondary gain such as disability or lawsuit (Rand et al., 2019) all as contributing factors that might indicate future development of CRPS. While a diagnosis of CRPS was only claimed by the patient but never actually received from the referring provider or pain specialist, the patient in this case had several demographic characteristics in common with what population-based studies have identified as commonly seen in CRPS patients. This particular scenario was a workers' compensation case where the patient was a 51-year-old Caucasian female who experienced a traumatic injury to a limb and subsequent immobilization. While the affected limb in this case was a lower extremity which is less common, the patient's age, sex, race, mechanism of injury, and opportunity for secondary gain with the involvement of lawyers in the workers' compensation case were all later identified as flags and potential indicators for CRPS development. Early identification of such indicators could have allowed CRPS to continue to be on a differential diagnosis list for this patient and facilitate earlier recognition of CRPS-like signs and symptoms. Earlier recognition would have allowed a

referral to the pain specialist to be made earlier than it was in this case, potentially saving the patient from suffering from such severe pain levels and saving time.

Prior knowledge of different classifications of CRPS would have been useful when documenting this patient's evolving signs and symptoms in an organized manner and is a limitation of this case study. CRPS signs and symptoms have varying presentations and thus have been divided into multiple classifications. The first classification divides CRPS into Type I and Type II based on presence or absence of nerve injury. CRPS is deemed Type I if no identifiable nerve damage is present and Type II if a nerve lesion is present (Bruehl, 2015; Lee et al., 2018; Rand et al., 2019). While differentiating between CRPS Type I and Type II is possible and might provide a more comprehensive view of a patient's case, it is not necessary for treatment as the approach to treatment for CRPS Type I and CRPS Type II is the same (Goebel et al., 2019; Rand et al., 2019). A second classification that is commonly seen divides CRPS based on signs and symptoms into "warm CRPS" and "cold CRPS". "Warm CRPS" is associated with increased temperature, rubor, and edema in the affected extremity whereas "cold CRPS" is associated with decreased temperature, dusky color, and excessive sweating of the affected extremity (Bruehl, 2015; Galve Villa et al., 2016). While acute CPRS usually presents as "warm CRPS" and chronic CRPS usually presents as "cold CRPS" a patient's symptoms might fluctuate between these two presentations over the course of their disorder (Bruehl, 2015; Galve Villa et al., 2016). As with Type I and Type II, differentiating between "warm" and "cold" CRPS provides a means of documenting changes in a patient's presentation but does not have any implications for treatment (Bruehl, 2015; Galve Villa et al., 2016). For this particular patient, symptoms were a mix of "warm" and "cold" CRPS characteristics and fluctuated between the increased temperature, rubor, and edema that is characteristic of "warm" CRPS and the decreased temperature and ashy purple color that is characteristic of "cold" CRPS.

Another limitation of this case was that it was a worker's compensation case with a limited number of authorized visits, 22 total. Late identification of demographic characteristics typical of those who are likely to later develop CRPS and CRPS-like signs and symptoms left a window of only four remaining authorized visits over the course of two weeks in which therapeutic interventions could be altered. The timeline of GMI studies typically have participants complete two weeks of laterality training only before progressing to motor imagery for an additional two weeks and then progressing to mirror therapy for two more weeks (Moseley, 2006). Due to the condensed nature of the available timeline and with the uncertainty of additional visits, laterality training and motor imagery were initiated at the same time and mirror therapy was started one week later. Progressing the patient through GMI faster and in a similar but different order than what is established in the literature for the implementation of GMI could have contributed to the lack of improvements in pain and function that is different than might be expected when using the GMI intervention. Additional visits were eventually authorized after the end of this writer's clinical education experience at this site. While pain and function scores were not significantly changed in the 2 weeks that PNE and GMI interventions were initially implemented, continued implementation of PNE and GMI at future authorized visits leaves the potential for long-term decreased pain and increased function to possibly still be achieved.

An additional limitation of this case is the intervention dosing with regard to implementation of GMI. While the exact dosing for GMI is unknown, the parameters supported in the literature are intense, requiring a patient to practice laterality training at least three times every waking hour and mirror therapy three to five times per day for at least ten to fifteen minutes per bout (Moseley, 2006; Pollard, 2013; Selles et al., 2008). For this particular case, laterality training was done twice per week for two weeks at clinic visits where the patient performed five rounds of twenty images followed by at least five minutes of motor imagery. While the patient was asked to perform laterality and motor imagery training consisting of five rounds of twenty images followed by five minutes of motor imagery at least every other waking hour each day as part of a home exercise program, the patient reported only performing laterality and motor imagery training three to four times per day which is much less than the frequency of every waking hour that is supported by the literature (Moseley, 2006; Pollard, 2013). Similarly, while the patient was asked to perform mirror therapy three to five times per day for ten to fifteen minutes at a

time as part of her home exercise program, the patient reported performing mirror therapy on her own at most one-time per day which is well below the frequency supported by the literature (Pollard, 2013; Selles et al., 2008). Under-dosing of GMI could also have contributed to the lack of improvements in pain and function that is different than might be expected when using the GMI intervention.

Conclusion

This case highlights that CRPS demographic indicators and symptoms are recognizable by physical therapists and warrants appropriate referral to a pain specialist for further differential diagnosis. While early treatment of CRPS is crucial in reducing the likelihood of permanent impairment and disability, this case suggests that implementation of CRPS interventions such as PNE and GMI when symptoms are emerging but an official diagnosis has not been made may be too early and may not be effective at preventing the disease course (Lee et al., 2018; Rand et al., 2019). Future studies could focus on the dosing and timing of GMI interventions, which were major limitations in this case, when used as a means of potentially preventing full CRPS onset in individuals with demographic characteristics typical of those who later go on to develop CRPS and have started showing signs of the condition.

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