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# Physical Therapy Management of Complex Regional Pain Syndrome I in a 14-Year-Old Patient Using Strain Counterstrain: A Case Report

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## Abstract

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This report describes the examination, intervention, and outcomes for a patient with Complex Regional Pain Syndrome I (CRPS I) treated with Strain Counterstrain (SCS). The patient was diagnosed with CRPS I following a Grade II ankle sprain. Treatment consisted of SCS once per week for six months with one additional session each week in Months 4 through 6 for strengthening, endurance, and gait training. A re-examination was performed monthly. A clinically significant decrease of 2 points in overall pain as measured with a numeric pain rating scale (NPRS) occurred as of Month 2; a 2-point decrease in tenderness on 10 of 13 SCS tender points also measured with an NPRS was documented as early as Month 1. Throughout the treatment period, an increase in function was noted by way of patient report and objective tests and measures. Gait improved with regard to cadence, use of an assistive device, and weight-bearing status. Single limb stance on the involved leg increased from 0 (s) to 40 (s) over the course of treatment and ankle active range of motion as measured with a goniometer and muscle strength as measured with manual muscle tests both returned to normal values. CRPS I remains a poorly understood and difficult-to-treat chronic syndrome. By way of its proposed effects on the neuromuscular system and facilitated segments, SCS may be an additional effective treatment tool in the management of some patients diagnosed with CRPS I.

**Key Words:** Complex Regional Pain Syndrome, Reflex Sympathetic Dystrophy, Strain Counterstrain, Physical Therapy

Complex Regional Pain Syndrome I (CRPS I) is a poorly understood and progressive pain syndrome often leading to impairments, disabilities, and handicaps[1,2]. Developing most often after trauma to a limb or a surgical procedure and sometimes presenting with no precipitating event, CRPS I is a chronic condition with involvement of the sensory, motor, and autonomic nervous systems[2–4]. CRPS I may affect millions of Americans[5]. Hooshmand[6] estimated that 30% of the general population suffers from chronic pain with approximately one-third of those suffering the effects of CRPS I. There is general agreement in the literature that two distinct types of CRPS exist[2]:

- CRPS I (previously known as RSD), which occurs without evidence of nerve damage

- CRPS II (previously referred to as causalgia), which is associated with evidence of significant nerve damage

Table 1 contains the diagnostic criteria proposed by the International Association for the Study of Pain (IASP) for CRPS[7].

TABLE 1

Clinical diagnostic criteria for Complex Regional Pain Syndrome as proposed by the International Association for the Study of Pain

I. Continuing pain that is disproportionate to the inciting event

II. The patient must report at least one symptom in three of the four categories:
1. Sensory: Reports of hyperaesthesia and/or allodynia
2. Vasomotor: Reports of temperature asymmetry and/or skin color changes and/or skin color asymmetry
3. Sudomotor/edema: Reports of edema and/or sweating changes and/or sweating asymmetry
4. Motor/trophic: Reports of decreased range of motion and/or motor dysfunction (weakness, tremor, dystonia) and/or trophic changes (hair, nails, skin)

III. The patient must display at least one sign, at time of evaluation, in two or more of the following categories:
1. Sensory: Evidence of hyperalgesia (to pinprick) and/or allodynia (to light touch and/or deep somatic pressure and/or joint movement)
2. Vasomotor: Evidence of temperature asymmetry and/or skin color changes and/or asymmetry
3. Sudomotor/edema: Evidence of edema and/or sweating asymmetry
4. Motor/trophic: Evidence of decreased range of motion and/or motor dysfunction (weakness, tremor, dystonia) and/or trophic changes (hair, nail, skin)

IV. There is no other diagnosis that better explains the signs or symptoms.

As a result of the extreme pain, edema, motor, and trophic changes, individuals diagnosed with CRPS I tend to develop significant weakness, soft tissue and joint hypomobility, and sometimes motor control dysfunction such as tremor and dystonia[8–10]. If left untreated, these impairments can lead to functional limitations and disability. The lack of understanding of the etiology of this syndrome has led to patient management that tends to be poorly defined and symptomatic in nature. Proposed treatment options for CRPS I have included:

- Pharmacotherapy consisting of corticosteroids, calcitonin, biphosphonates, topical local anesthetics, antiepileptics, opioids, tricyclic antidepressants, adrenergic modulators, and other medications[11–14]
- Sympathetic nerve blocks[13,15–17]
- Physical therapy[8,10,13,17–19]
- Acupuncture[14,20]

- Sympathectomy[13]
- Spinal cord stimulation with electrodes implanted in the epidural space[12,14,21–25]
- Transcutaneous electrical nerve stimulation[14,26,27]

Interdisciplinary pain management, with an emphasis on functional restoration, is thought to be necessary for an optimal outcome in treatment of individuals with this syndrome[28]. There is widespread agreement that physical therapy is of the utmost importance and an essential part of the treatment approach for CRPS I[3,8,10,13,17,26,29]. However, a review of the literature revealed that the term "physical therapy" is often used without a specific description or definition of which procedures were actually employed in treatment. Given the varied interventions within physical therapy[30], this lack of information has left physical therapists with little research-based guidance on how to effectively approach the treatment of this patient population.

Strain Counterstrain (SCS) is a manual therapy intervention developed by the osteopathic physician Lawrence Jones[31–33]. The intent of this intervention is to reduce somatic or musculoskeletal dysfunction and thereby produce improvements in the patient's pain and functional skills. Based on neurophysiologic principles, specifically as they relate to the muscle spindle system, SCS is hypothesized to have a therapeutic effect by causing a decrease in proprioceptive hyperactivity, thereby allowing tissues to regain normal neuromuscular function[31–35]. Discovered by Jones by chance while treating a patient with psoasitis, SCS was developed empirically through years of observation and trial-and-error treatment of patients presenting with symptoms of somatic dysfunction. In the description of SCS, Jones presented an etiologic model of somatic dysfunction amenable to treatment with SCS[32], and explained that the sudden overstretch and increased neural discharge from muscle spindles produced during a mechanical strain injury may leave the involved muscles in a state of hyperactivity, causing persisting dysfunction[31,33,35]. Basic science support for the hypotheses at the basis of SCS was provided by Korr[36,37], who observed that proprioceptors, muscle spindles in particular, are key elements in the neural basis of neuromuscular lesions often leading to hyperfacilitation at the spinal cord level. This central hyperfacilitation may be the reason for persistent peripheral neuromuscular dysfunction. As an indirect and gentle therapeutic approach, SCS has been suggested as an appropriate clinical intervention for both acute and chronic injuries of neuromuscular origin.

When using SCS, the clinician identifies the presence of tender points. These tender points are defined as small zones of tense, tender, and edematous muscle and fascial tissue about 1 (cm) in diameter that are at least four times more tender than normal tissue. Literature on the use of SCS[31–35,38] provides no further quantitative information on the amount of pressure applied for the diagnostic palpation of these tender points. The tender points are considered to be sensory manifestations of neuromusculoskeletal dysfunction[32]. SCS intervention consists of relieving each identified tender point by placing the involved body part in a position of comfort (POC) for 90 sec; Jones identified this as the duration required to cause cessation of the inappropriate proprioceptive hyperactivity thought responsible for the dysfunction[32]. The treatment positions, or POC, are positions that allow for a shortening of the muscle tissue containing the involved hyperactive muscle spindle[32]. Treatment is considered successful when the POC reduces the tenderness elicited by palpation of the tender point by a minimum of 70%[32]. D'Ambrogio and Roth[35] noted that when affected tissues are placed in a POC for the SCS treatment, the reduced tissue tension also allows for the release of hypothesized fascial restrictions; without providing basic science or clinical research evidence for this hypothesis, they noted that the POC may allow for the reduction in tension of the fascial collagenous fibers with a resultant hypothesized disengagement of the electrochemical bonds leading to a normalization in the condition of the fascial matrix[35]. In contrast to the required 90-sec hold proposed by Jones, this fascial release phase may require holding the POC

for several minutes[35,38] as the length of time required for this phase to occur is not pre-determined. D'Ambrogio and Roth[35] and Weiselfish[38] noted that the POC should be held for as long as it takes for any release signs to subside. Suggested signs indicative of a fascial release include the dissipation of heat, vibration, and any other palpable release response such as pulsation[35,38]. The clinician completes the SCS intervention by slowly and passively returning the body part to its resting position, thereby preventing reactivation of the proprioceptive hyperactivity and thus restoring normal neuromuscular function[32].

Only a few studies have researched the efficacy of manual therapy techniques in the treatment of individuals diagnosed with CRPS I. Cleland and McRae[39] provided a case report on the use of a neural mobilization technique referred to as the slump long sitting with sympathetic emphasis in a patient with lower extremity CRPS I. Outcome measures included goniometric measurements of ankle active range of motion (AROM), the numeric pain rating scale (NPRS), the pain rating component of the McGill Pain Questionnaire (MPQ), and the SF-36 measure of quality of life. At discharge and at 1-year follow-up, the patient demonstrated improvement in all outcome measures related to pain, AROM, and function[39]. Muir and Vernon[40] suggested that spinal manipulation might be beneficial for patients with CRPS I. Menck et al[18] provided a case report on physical therapy management including T3-T5 thrust manipulation for a patient with upper extremity CRPS I. Outcome measures included the NPRS, goniometric measures of upper-extremity AROM and passive range of motion (PROM), dynamometer measures of grip and pinch strength, manual muscle tests, upper-extremity girth tape measurements, manually assessed segmental thoracic mobility, and patient-reported function. At discharge, the patient demonstrated improvements in AROM and PROM, pain, and functional skills. The authors also reported immediate improvements in autonomic function following manipulation of the thoracic spine as evidenced by decreased allodynia and normalization of skin temperature and color[18].

SCS is a gentle manual therapy intervention and, therefore, perhaps better suited to patients with CRPS I than other, more forceful manual therapy techniques. Its hypothesized action on the hyperfacilitated central nervous system (CNS) may provide an indication for its use in CRPS I as the diagnostic criteria and presentation of this syndrome seem to indicate CNS involvement. However, a literature review, including the CINAHL EBSCO publishing, EBSCOhost EJS, Expanded Academic ASAP, LexisNexis Academic, Nursing and Allied Health Collection: Comprehensive, and Pub Med electronic databases from 1900 to 2005 using the following search terms: *Reflex Sympathetic Dystrophy, Complex Regional Pain Syndrome, manual therapy, physical therapy, treatment approaches*, and *Strain Counterstrain* failed to locate articles documenting any other cases where patients diagnosed with CRPS I were treated with this approach.

The patient described in this case report was an adolescent male diagnosed with CRPS I following a grade II ankle sprain. The author choose to use SCS for this patient because of the presence of an inciting sprain injury, which upon examination seemed to have led to neuromusculoskeletal dysfunctions, and the appearance of a centrally facilitated neurological system evidenced by the presence of multiple tender points. The author of this case report used SCS intervention to reduce the tenderness of these identified tender points in combination with education and graded exercise. The goal of this case report is to describe the physical therapy management of this patient using SCS in combination with education and graded exercise and the observed clinical and functional improvements.

## Case Description

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### History

The patient was referred to outpatient physical therapy 15 months after a grade II left ankle sprain and after prior failed attempts at pain control and functional rehabilitation through physical therapy and medical management. Prior to this injury, the patient was an active 13-year-old, involved in baseball, soccer, handball, and basketball. The patient suffered an ankle sprain while playing basketball and was treated immediately with ice and elevation. The patient's medical records indicated that radiographs taken at the time of the injury were negative for fractures. The patient was subsequently diagnosed with a grade II ankle sprain and sent home with recommendations for continued icing, elevation, immobilization, and the use of crutches for non-weight-bearing (NWB) ambulation on the left lower extremity. Two months later, due to persistent and progressive pain and edema, an MRI was performed revealing a stress fracture of the calcaneus. The patient was subsequently placed in a hard cast for 3 weeks. Further review of the patient's medical records indicated that upon early removal of the cast due to complaints of increasing and significant pain, the physician noted persistent significant edema, discoloration, sweating, allodynia, and increased temperature. A bone scan was performed revealing a decrease in bone density at which time the patient was diagnosed with CRPS I. While bone density is not a factor in the IASP diagnostic criteria, a change in bone density has been considered indicative of the presence of CRPS I/RSD in earlier studies[3,13,41,42] and was used by this physician as the main diagnostic criterion.

During the initial evaluation of the first course of physical therapy treatments, the patient reported having severe pain, extreme sensitivity to touch, inability to bear weight on the involved lower extremity, and significant difficulty ambulating after the cast was removed. Physical therapy goals included pain management, edema control, desensitization, weight bearing, and functional training. The patient received physical therapy treatments twice a week for 30 minutes during 9 months. The patient's physical therapy discharge notes reported improvements with regard to edema, discoloration, and temperature changes.

At one year post-injury, the patient continued to report an inability to ambulate without the use of an assistive device, with painful hypersensitivity to all touch, decreased motor control of the left foot when attempting to bear weight on it, and average pain over 24 hours rated at 10 on an NPRS. The NPRS is an 11-point self-report measure with anchors of “no pain” (0/10) and “extreme pain” (10/10). Its test-retest reliability varies from substantial to near perfect ($ICC_{2,1}$ =0.67–0.96)[43–45]. As the NPRS is a self-report measure, inter- and intrarater reliability of course is irrelevant. Correlation between the visual analog scale, by many considered the gold standard of clinical pain measurement, and the NPRS is high (r=0.79–0.95)[46,47]. Childs et al[48] reported that a 2-point change on the NPRS represented the minimal clinically important difference (MCID) for this measure in patients with low-back pain. Finch et al[49] reported an MCID of 3 points. For this patient with spinal involvement, in the sense of tender points present upon examination as discussed below, the author interpreted the 2-point difference as the more relevant MCID reported for the NPRS.

At 15 months post-injury, the patient was referred to this author with complaints of persistent difficulty ambulating, frequent school absences due to pain and medical appointments, and depression. At the time of this initial examination, the patient was on 25mg of Elavil for pain management and 30mg of Prozac for depression. Neurontin had been attempted for four months but had been discontinued due to complaints of confusion and memory loss. The patient reported average left ankle and foot pain in the previous 24 hours to be constant at 10 on the NPRS (Table 2). The patient's primary stated goal was pain management and regaining the ability to ambulate without assistive devices.

TABLE 2

Average Pain Intensity in Left Ankle using a Numerical Pain Rating Scale (0-10) measured as average pain in previous 24 hours at Initial Examination and Monthly Re-examinations

| Initial Examination | Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 (D/C) |
|---|---|---|---|---|---|---|
| Left Ankle Pain | 10 | 10 | 8 | 6 | 3 | 1 | 0 |

D/C–discharge

## Examination

The patient presented ambulating with bilateral axillary crutches and toe-touch weight bearing (TTWB) on the left foot. Ambulation was limited to short distances indoors and a wheelchair was used outdoors. Attempts to bear weight on the left lower extremity resulted in a partial withdrawal response with seemingly involuntary left ankle plantarflexion and inversion. Subsequent non-weight-bearing assessment confirmed a flexion withdrawal response whenever a tactile stimulus was applied to the plantar aspect of his foot. This flexor withdrawal response has been described as a component of the possible motor dysfunction present in some cases of CRPS I[2,13].

An observational gait assessment (Table 3) revealed a slow (13 steps/minute), antalgic, step-to approach with the toes of the healthy lower extremity reaching the toes of the involved one, and with fatigue after 15 min. Fatigue was a subjective measure indicated by the patient's report of being unable to ambulate further due to increased physical difficulty. The patient was able to ambulate up and down stairs again using a step-to approach with one crutch and one handrail, all the while maintaining the TTWB status on the left foot. Gait was assessed by observational analysis and the use of a clinical evaluation worksheet to record gait pattern, speed in steps per minute, use of an assistive device, and endurance as measured in distance ambulated prior to fatigue. Although this particular observational gait analysis tool has not been validated, Brunnekreef et al[50] have found average intrarater reliability for inexperienced and experienced raters visually assessing videotaped gait in orthopaedic patients with an analysis form to be moderate (ICC=0.57 and 0.63, respectively). Interrater reliability was poor for both inexperienced and experienced raters (ICC=0.40 and 0.42, respectively).

TABLE 3

Gait at Initial Examination and Monthly Re-examinations

| Examination | Cadence (steps/minute) | Gait Pattern | Assistive Device | Endurance | Stairs | Weight Bearing Status |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Initial | 13 | Step-to | Bilateral axillary crutches | 15 meters | Step-to with handrail and crutch | TTWB |
| Month 1 | 24 | Step-to | 1 SC | 30 meters | Step-to with handrail and SC | PWB |
| Month 2 | 32 | Step-to | 1 SC | 45 meters | Step-to with a SC | PWB |
| Month 3 | 50 | Step-over step | 1 SC | 115 meters | Step-to with a SC | FWB |
| Month 4 | 80 | Step-over step | Outdoors: 1 SC<br>Indoors: none | 160 meters | Step-to with a SC | FWB |
| Month 5 | 90 | Step-over step | None | 20 min TM @2.5mph | Step-over-step | FWB |
| Month 6 (D/C) | 90 | Step-over step | None | 20 min TM @2.5mph | Step-over-step | FWB |

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Note: SC = straight cane, TM = treadmill, TTWB = toe touch weight-bearing, PWB = partial weight-bearing, FWB = full weight-bearing

Single limb stance (Table 4) on the unaffected right lower extremity was 20 sec. The patient was asked to stand on the right lower extremity while holding the left lower extremity at approximately 70° of hip flexion and without any upper extremity support. The patient was unable to bear weight on the left for single limb stance due to severe pain and a withdrawal response. Although the validity and reliability of the single limb stance when measured clinically, as described in this case, have not been determined for this patient population, Sherrington and Lord[51] have demonstrated that this test has good test-retest reliability for measuring balance performance in older individuals after hip fracture in both the affected and unaffected leg (ICC = 0.75 and 0.83, respectively). Balogun et al[52] determined normative values for physically active and sedentary 12-40-year-old men and women and concluded that single leg balance testing was a responsive tool for measuring outcome in rehabilitation of patients after lower extremity injuries.

TABLE 4

Single Limb Stance (in seconds) at Initial Examination and Monthly Re-examinations

| Initial Exam | Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 (D/C) |
|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Right LE | 20 | 30 | 40 | 45 | 60 | 60 | 60 |
| **Left LE** | 0 | 5 | 5 | 10 | 10 | 25 | 40 |

LE–lower extremity; D/C–discharge

Strength of the left hip and knee was measured at 4-/5 using manual muscle tests (MMT) conform Kendall et al's 0–5 grading scale.[53] At the initial evaluation, the left ankle was not assessed for strength due to reported sensitivity and pain to touch. The use of MMT as a diagnostic and outcome measure is a common practice in physical therapy, and MMT has been described as a valid, reliable, and responsive measurement tool, especially when used by experienced clinicians[53,54]. Perry et al[55] determined that MMT of the hip extensor muscles is a reliable and valid method of strength testing. The Great Lakes ALS Study Group[56] has found MMT to be a preferred measure of strength, with strong reproducibility.

Wadsworth et al[57] compared MMT to hand-held dynamometer testing and also concluded that MMT was a valid and reliable measure of strength. In contrast, some studies[58,59] have shown large interrater variability in the forces used to establish manual muscle test (MMT) grades of 3+, 4-, 4+, and 5, thereby casting doubts on the clinical responsiveness of MMT and its utility as an outcome measure for upward changes from 3+/5 or higher.

Visual assessment of the right hip, knee, and ankle revealed AROM that was within expected normal limits. Left hip and knee AROM were measured by goniometry[60,61] and were also within the expected normal range. Table 5 indicates the findings on goniometric ankle AROM. Goniometric measurements have been shown to be a valid and responsive measure of joint ROM[60]. Although interrater reliability has been found to be poor to moderate (ICC=0.5–0.72), the intrarater reliability of goniometric measurements for ankle dorsi- and plantarflexion has been determined to be good to sufficient for clinical measurement (ICC=0.86–0.91)[61,62]. No information on the intrarater reliability of tarsal joint inversion and eversion goniometric AROM tests, as used in this patient, was found. The responsiveness of goniometric measurement of ankle AROM also has yet to be determined.

TABLE 5

Left Ankle Active Range of Motion (AROM)/Strength at Initial Examination and Monthly Re-examinations

| | Initial Examination | Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 (D/C) |
|---|---|---|---|---|---|---|---|
| DF AROM | 0° | 5° | 10° | 10° | 15° | 20° | 20° |
| Strength | NA | NA | 3/5 | 4/5 | 4/5 | 5/5 | 5/5 |
| PF AROM | 25° | 30° | 30° | 35° | 45° | 45° | 45° |
| Strength | NA | NA | 3/5 | 3/5 | 3/5 | 4/5 | 4/5 |
| Inv AROM | 15° | 20° | 20° | 25° | 25° | 35° | 35° |

| | Initial Examination | Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 (D/C) |
|---|---|---|---|---|---|---|---|
| Strength | NA | NA | 4/5 | 4/5 | 4/5 | 4/5 | 5/5 |
| Ev AROM | 5° | 5° | 10° | 10° | 15° | 20° | 20° |
| Strength | NA | NA | 3/5 | 3/5 | 4/5 | 4/5 | 5/5 |

DF–dorsiflexion; PF–plantarflexion; Inv–inversion; Ev–eversion; NA–not applicable; D/C–discharge

Palpatory examination with specific attention to identifying tender points as described in the SCS paradigm revealed a tenderness reported at 10/10 on the NPRS for the left medial ankle (MAN), left lateral ankle (LAN), left flexion ankle (FAN), left talus (TAL), left lateral hamstring (LH), left iliacus (IL), left anterior seventh rib (AT7), left anterior 5$^{th}$ rib (AR5), anterior 2–4 thoracic (AT2-4), posterior 2-4 thoracic (PT2-4), right low ilium-sacroiliac (LISI), right lateral hamstring (LH), and right lateral ankle (LAN) tender points (Tables 6 and 7, Figures 1–3). As described by Jones et al[32], tender points were identified by manual palpation using the amount of pressure necessary to elicit a mild response from normal tissue, which is defined as a response that indicates the awareness of manual pressure, without pain or discomfort, on any tissue that is not a tender point[63]. Wong and Schauer[64] used a 4-point scale for palpatory tenderness and noted poor to fair test-retest reliability for both hip abductor and adductor SCS tender points ($\kappa$=0.327 and 0.228, respectively). Concurrent validity with the VAS varied from near absent to good (Spearman's $\rho$ = 0.233–0.709). For this patient, an 11-point NPRS was used rather than a 4-point rating scale. Although the NPRS has been determined to be a valid and reliable measure for the assessment of pain[43–45], to date no published studies have looked at the validity and reliability of SCS tender-point palpation when using the NPRS. The reliability and validity of an appropriate pain rating scale for SCS tender points has yet to be determined.

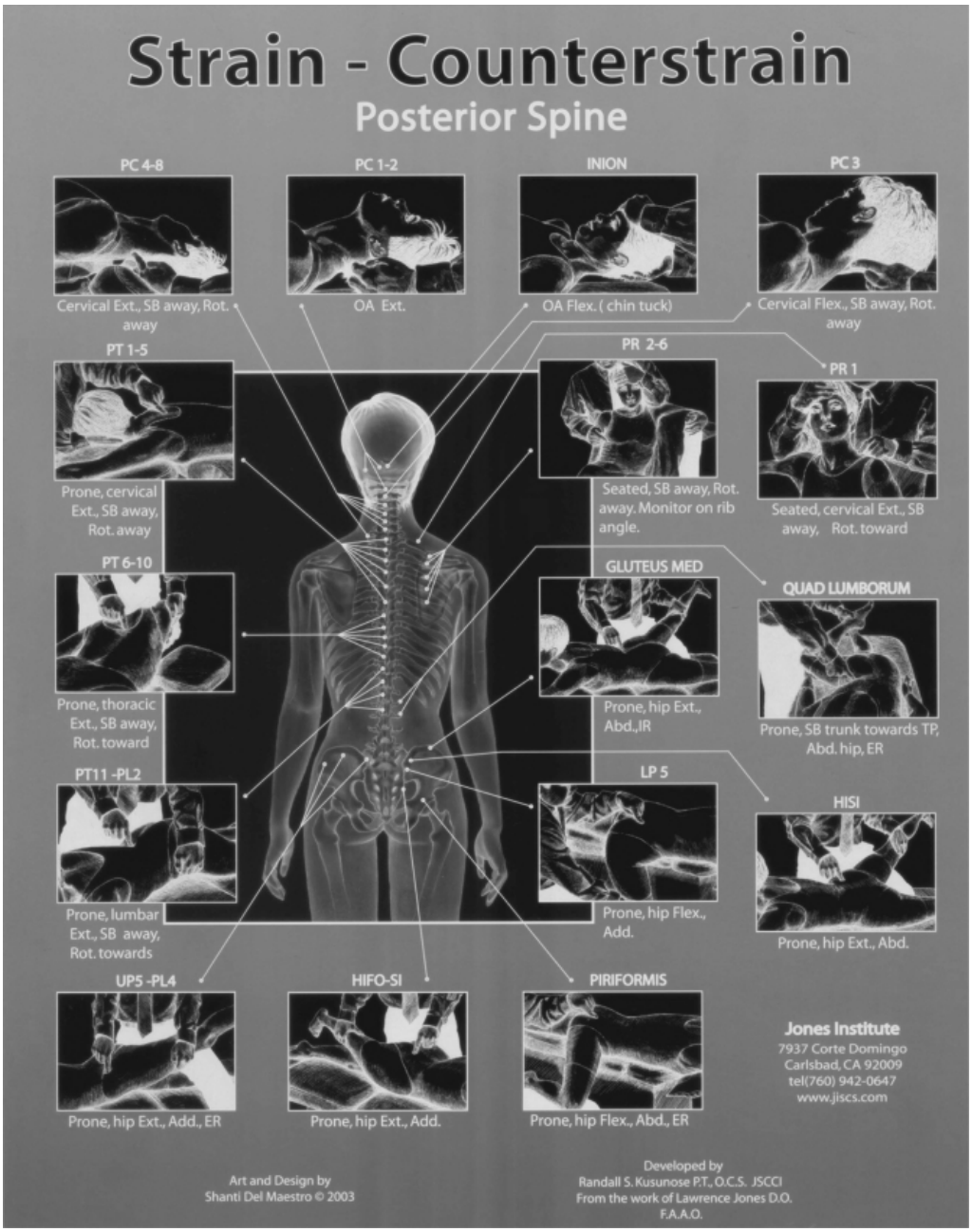


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Fig. 1

Strain-counterstrain posterior spine. (Reproduced with kind permission from the Jones Institute)

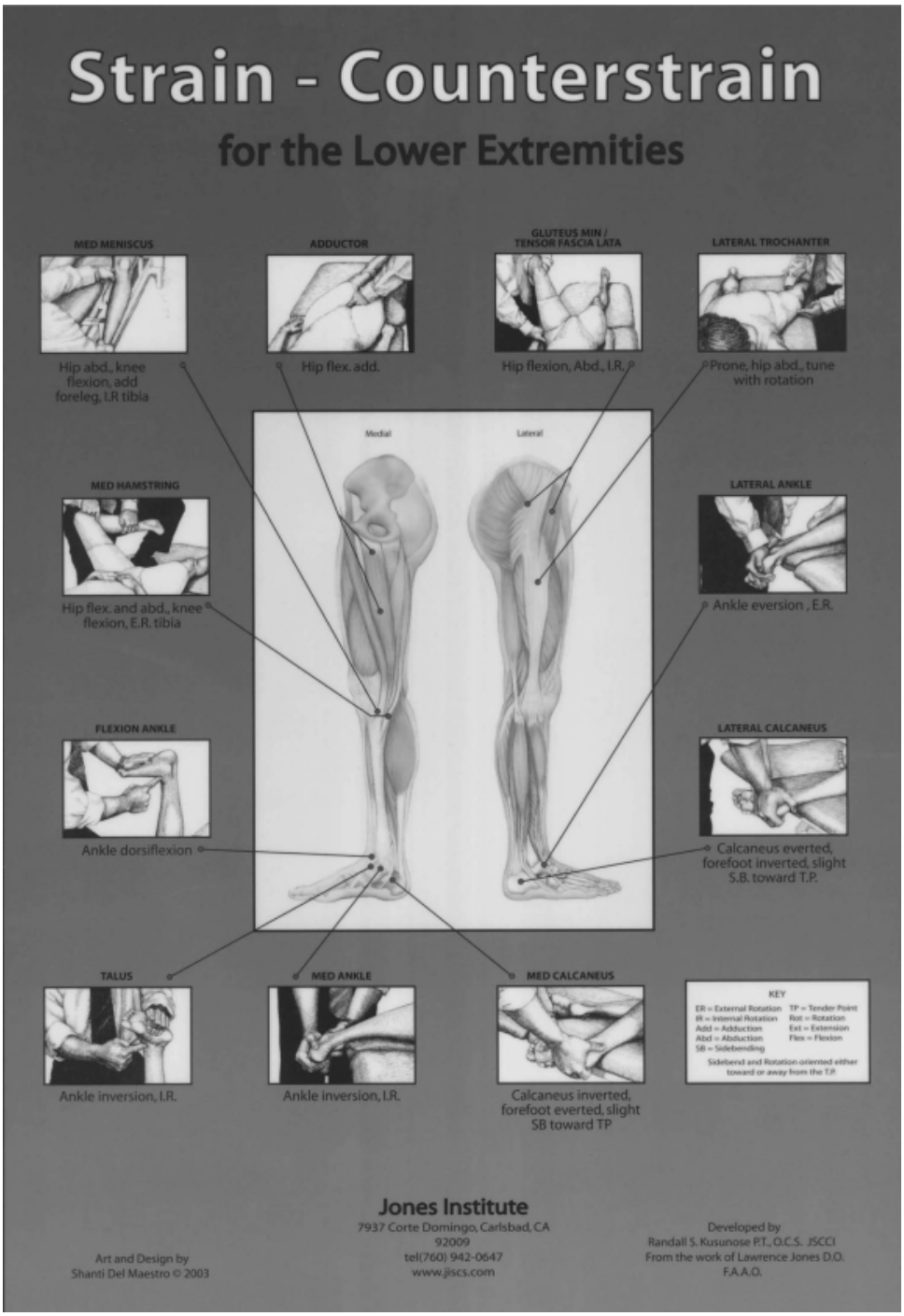


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Fig. 3

Strain-counterstrain for the lower extremities. (Reproduced with kind permission from the Jones Institute)

TABLE 6

SCS Tender Point Intensity Level at Monthly Re-examinations (Numeric Pain Rating Scale 0-10) at Initial Examination and Monthly Re-examinations

| | Initial Examination | Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 (D/C) |
|---|---|---|---|---|---|---|---|
| Left MAN | 10 | 10 | 10 | 8 | 6 | 6 | 2 |
| Left LAN | 10 | 8 | 8 | 8 | 6 | 4 | 1 |
| Left FAN | 10 | 8 | 6 | 6 | 4 | 2 | 0 |
| Left TAL | 10 | 8 | 6 | 4 | 2 | 1 | 1 |
| Left LH | 10 | 6 | 6 | 4 | 2 | 0 | 0 |
| Left IL | 10 | 4 | 2 | 2 | 0 | 0 | 0 |
| Left AT 7 | 10 | 2 | 2 | 2 | 0 | 0 | 0 |
| Left AR 5 | 10 | 2 | 0 | 0 | 0 | 0 | 0 |
| AT 2-4 | 10 | 10 | 10 | 8 | 4 | 4 | 2 |
| PT 2-4 | 10 | 10 | 10 | 8 | 4 | 4 | 2 |
| Right LISI | 10 | 2 | 0 | 0 | 0 | 0 | 0 |
| Right LH | 10 | 2 | 0 | 0 | 0 | 0 | 0 |
| Right LAN | 10 | 2 | 1 | 0 | 0 | 0 | 0 |

MAN–medial ankle; LAN–lateral ankle; FAN–flexion ankle; TAL–talus; LH–lateral hamstring; IL–iliacus; AT7–anterior seventh rib; AR5-anterior 5th rib; AT2-4–anterior 2–4 thoracic; PT2–4- posterior 2–4 thoracic; LISI–low ilium-sacroiliac (LISI); D/C–discharge

TABLE 7

SCS Tender Point Location and Treatment Position.

| | Location | Treatment Position |
|---|---|---|
| Left MAN | Approximately 2 cm caudad to the left medial malleolus in an arc about 2 cm long | Patient is in right sidelying with ankle off the edge of the table. PT takes ankle into marked inversion and slight internal rotation. |
| Left LAN | Approximately 2 cm anterior and caudad to the left lateral malleolus | Patient is in left sidelying with ankle off the edge of the table. PT takes ankle into marked eversion and slight external rotation. |

| | Location | Treatment Position |
|---|---|---|
| Left FAN | Anterior to the left medial malleolus and medial to the tendon of the anterior tibialis muscle | Patient is in prone. PT takes the ankle into marked dorsiflexion. |
| Left TAL | Approximately 2 cm anterior and caudad to the left medial malleolus, in a depression in the anteromedial portion of the ankle | Patient is in right sidelying. PT takes the ankle into marked inversion and internal rotation. |
| Left LH | At the attachment of the left lateral hamstring to the posterolateral surface of the fibular head | Patient is supine with the left leg abducted off the edge of the table. PT takes left knee into approximately 30 degrees of flexion, light varus, and tibial external rotation. |
| Left IL | Approximately 4 cm medial and caudad to the left ASIS in the iliac fossa | Patient is supine. PT takes both lower extremities into extreme hip flexion, abduction, and external rotation. |
| Left AT 7 | Under the costochondral margin of the left $7^{th}$ rib | Patient is side seated to the left. Supporting the patient's right arm, the PT takes patient into flexion, left sidebending (through right translation), and right rotation to the level of the TP. |
| Left AR 5 | On anterior axillary line, inferior to the left $5^{th}$ rib margin | Patient is side seated to the left. Supporting the patient's right arm, the PT takes patient into left sidebending and left rotation to the level of the TP. |
| AT 2 | Middle of manubrium | Patient seated with hands on top of head. PT's hands interlocked and placed at the level of sternal angle. PT brings patient's torso backwards producing thoracic flexion to the level of the TP. |
| AT 3-4 | AT3=on sternum, just below the sternal angle; | |
| | AT4=on the body of the sternum at the level of the $4^{th}$ intercostal space | Patient seated with arms dropped back. PT takes patient's arms posteriorly, producing thoracic flexion and a fulcrum at the level of the TP. Thoracic flexion is augmented by internal rotation of the arms. |
| PT 2 | Lateral to the spinous process of T2 | Patient prone with arms alongside the body. PT takes patient into thoracic extension to the level of the TP (through the head), sidebend away, and rotation away from the tender point. |
| PT 3-4 | Lateral to the spinous processes of T3 and T4 | Patient prone with arms alongside the head. PT takes patient into thoracic extension to the level of the TP (through the head), sidebend away, and rotation away from the tender point. |
| Right LISI | On superior aspect of the lateral ramus of the pubic bone, approximately 2 cm lateral to the pubic symphisis. | Patient is supine. PT takes right hip into marked hip flexion (90-100 degrees). |
| Right LH | Same as left LH on the right | Same as left LH on the right. |

| | Location | Treatment Position |
|---|---|---|
| Right LAN | Same as left LAN on the right | Same as left LAN on the right. |

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Adapted from Strain Counterstrain I for the Spine and Strain Counterstrain II for the Extremities, Jones Institute, CA. PT–physical therapist; TP–tender point; ASIS–anterior superior iliac spine

## Evaluation and Diagnosis

The diagnostic criteria proposed by the IASP for the diagnosis of CRPS were discussed above (Table 1 ). In the absence of a gold standard test for CRPS, data on diagnostic accuracy of these IASP criteria were calculated by determining the discriminative diagnostic utility of the described CRPS signs and symptoms with regard to other defined disorders[7]. After the initial discriminant function analysis and external validation studies, separate clinical and research criteria were proposed in an effort to maximize sensitivity for the clinical diagnosis and specificity for the research diagnosis[7]. The improved clinical diagnostic sensitivity allows the clinician to exclude the diagnosis of CRPS with greater confidence if the diagnostic criteria are not met; the increased specificity of the research diagnostic criteria allow the researcher to diagnose a subject with CRPS with a greater degree of diagnostic confidence if the diagnostic criteria are satisfied. The clinical diagnostic criteria require that the patient demonstrate at least one symptom in three of the four symptom categories (Table 1, diagnostic category II) and at least one sign in two or more of the sign categories described earlier (Table 1, diagnostic category III)[7]. The less stringent research criteria differ from the clinical criteria in that, to be positive, they require only one symptom and one sign in these symptom and sign categories described, allowing for improved specificity for research purposes. Sensitivity and specificity for the research criteria has been reported as 0.70 and 0.96, respectively. The sensitivity for the clinical criteria is 0.85 and their specificity is 0.69[7].

The patient presented with signs and symptoms that did not correlate with the expected presentation for a typical grade II ankle sprain since signs and symptoms had become progressively worse and more widespread instead of resolving in a 2-4 week period, as expected[65]. The patient subsequently received a medical diagnosis of CRPS I. Examination results indicated that this patient satisfied the CRPS I clinical diagnostic criteria, presenting with:

- Continuing pain that was disproportionate with the sprain injury
- Hypersensitivity to touch, discoloration, edema, sweating, increased temperature, decreased ROM, and motor dysfunction in the form of weakness and motor control deficits (i.e., at least one symptom and one sign in each of the four sign and symptom categories)
- No other diagnosis that could better explain the signs or symptoms

The clinical diagnostic criteria have an established specificity of 0.69. High specificity in combination with positive test results allow the clinician to more confidently rule in a diagnosis. In the author's opinion, a specificity of 0.69 was sufficiently high for a confident diagnosis of CRPS for the patient in this case report.

As for a physical therapy diagnosis using the terminology as proposed by the World Health Organization in its International Classification for Functioning, Disability and Health[66] (Table 8), findings at the impairment level included:

- Decreased AROM of ankle dorsiflexion, plantarflexion, eversion, and inversion
- Decreased strength of ankle dorsiflexion, plantarflexion, eversion, and inversion
- Ankle pain severely limiting function
- Tenderness of the SCS tender points noted above

TABLE 8

Definitions of the dimensions of health state (World Health Organization).

| Dimensions of health state | Definitions |
|---|---|
| Impairment | Any loss or abnormality of body structure or of a physiological or psychological function. |
| Activity | The nature and extent of functioning at the level of the person. Activities may be limited in nature, duration, or quality. |
| Participation | The nature and extent of a person's involvement in life situations in relation to impairments, activities, health conditions, and contextual factors. Participation may be restricted in nature, duration, or quality. |

At the level of limitations in activities and restrictions in participation, findings included:

- Inability to ambulate functionally, with the need to use an assistive device or a wheelchair
- Inability to participate fully in school or sports activities

In addition, the patient had stopped participating in any social activities.

Under the current prevailing evidence-based practice paradigm, physical therapists attempt to base evaluation and diagnosis, to the maximum extent possible, on the combination of test findings and research-based data on the diagnostic accuracy of the tests and measures used. The high research-based level of confidence in the medical diagnosis was discussed above. However, as has also been discussed, the data on psychometric properties of the tests and measures used is frequently limited to inconclusive data on reliability or is absent altogether. This implies that physical therapists have to rely to a great extent upon pathophysiologic hypotheses when it comes to the interpretation of test results and the formulation of physical therapy diagnosis. The research-based medical diagnosis in combination with the physical therapy diagnosis, including the presence of tender points beyond the site of the initial injury and extending centrally and across to create a mirror image of the injured ankle, alerted this clinician to the pathophysiologic hypothesis of a facilitated segment. Previous experience with the use of SCS in patients with sprain injuries and an understanding of the principles and applications of SCS with regard to treatment of a suspected facilitated segment led this clinician to the use of SCS in the treatment planning for this patient.

### Prognosis

The large variety in presentation, the absence of unified and definitive diagnostic criteria until recently, and the great variety of treatment approaches have made it difficult to establish an accurate and objective prognosis in CRPS I based on published research evidence. The Guide to Physical Therapist Practice[30] reported that 80% of individuals diagnosed with CRPS I are expected to reach planned goals and outcomes in 3 to 36 visits[30]. However, considering the arguments above, it would seem that these prognostic data are in fact based not on research but rather on expert consensus. The National Institute of Neurological Disorders and Stroke[4] stated that if begun early, or within three months of the onset of symptoms, treatment often results in remission. If treatment is delayed, which occurs often given the seemingly common difficulty with regard to a definitive diagnosis in patients with CRPS I, 50% of patients end up with pain that persists longer than six months, possibly even years[4]. Gellman and Nichols[67] stated that "… prognosis is, at best, guarded…" and agree that early prognosis is of utmost importance. Soucacos and Johnson[42] described three stages of CRPS I/RSD with the late stage possibly lasting as long as several years. Paice[68] stated that if left untreated, this condition could lead to "… devastating longterm disability." Hord and Oaklander[12] described CRPS as a "…disabling and difficult to treat…" condition. In summary, it seems that a consensus exists—albeit not necessarily a research-based consensus—on the potentially debilitating nature and poor prognosis for patients diagnosed with CRPS I, especially in the absence of early diagnosis and appropriate intervention. In light of this information, and the clinical presentation and delayed diagnosis and treatment in this case, it is reasonable to assume that the prognosis for this adolescent patient with CRPS I was poor. On the other hand, this could be interpreted to mean that a positive outcome, despite this seeming consensus with regard to a poor prognosis, might lend additional credence to the therapeutic effect of the intervention described in this case report.

### Intervention

During the initial 3 months, the patient was seen once a week for 1-hour treatment sessions including 5 minutes of re examination, 45-50 minutes of SCS treatment, and 5-10 minutes of gait training as tolerated by the patient for neuromuscular re-education. Gait training was performed with and without assistive device, inside and outside of the parallel bars, using manual assistance and manual and verbal input for improving gait parameters as deemed clinically appropriate at the time. During Months 4 through 6, the patient was seen twice a week, as functional gains allowed for increased focus on strengthening, endurance, and gait training.

At the beginning of each physical therapy session, a re-examination of the SCS tender points was performed, and results with regard to the reported pain level with palpation were documented using the NPRS. Each treatment session involved the release of the identified symptomatic tender points. This treatment followed the general rules of treatment as established by Jones et al[32]. These general rules describe the order in which identified tender points are addressed:

- More severe tender points as identified by tenderness to palpation are treated before less severe tender points
- More proximal or more medial tender points are addressed before more distally and laterally located points
- The area of greatest accumulation of tender points is treated first
- When tender points are located in a row, in any given body area, the one in the middle of the row is treated first.

The treatment positions were held for 90 sec to allow for the hypothesized normalization of gamma gain

to occur and then longer if a fascial release seemed to be occurring, as identified by the clinical signs described above. Figures 1–3 provide information on SCS treatment of most tender points identified in this patient; Figures 4–5 depict the treatment of tender points in the iliacus and lateral hamstrings tender points.

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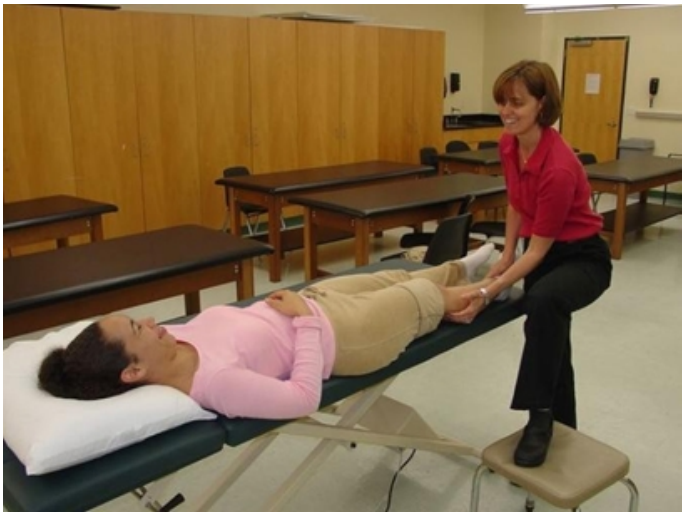

Fig. 4

(From left to right) Fig. 4A. Lateral hamstring-SCS treatment position; Fig. 4B. Lateral hamstring-SCS tender point;

Fig. 5

Fig. 5A. Iliacus-SCS treatment position; Fig. 5B. Iliacus-SCS tender point.

The second weekly physical therapy session, during Months 4 to 6, focused on strength, endurance, and gait training as tolerated. Emphasis was placed on neuromuscular re-education for proper weight-shifting and weight bearing on the left lower extremity, symmetrical step lengths, and increased cadence. Strengthening was performed through progressive resistive exercises for all four extremities and trunk using therapeutic exercises as tolerated. This generalized strengthening program was added to allow for the strengthening needed for functional activities since the patient had been inactive and functionally restricted for a long period of time. The program included cable column and Theraband™ resistive exercises for all upper and lower extremity musculature with resistance increased as tolerated by the patient–resistance was determined and increased based on the patient's ability to complete 12 repetitions with correct form and without pain. Abdominal strengthening was performed through straight and oblique sit-ups, also as tolerated—the patient was instructed to perform up to 12 repetitions as tolerated by strength and fatigue. Each exercise was performed for 2 sets with repetitions as described above. Endurance training was done on an isokinetic Biodex recumbent bicycle for 20 minutes set at 60 rpm. The patient was instructed to attempt to maintain the rpm goal as demonstrated through the digital display on the bicycle and to slow down if he felt pain or fatigue. Gait training was performed with manual and verbal guidance for emphasis on symmetrical weight-shifting and weight-bearing, symmetrical stance time, and cadence. Starting in Month 4, the patient was instructed on a general full body strengthening home exercise program, using light weights and Theraband resistance, to be performed 3-4 times per week. This strengthening program was aimed at overall strengthening for functional purposes and consisted of exercises for upper and lower extremity musculature using submaximal loading for 2 sets of 8-12 repetitions 2-3 times per week, as tolerated; the resistance was

again determined by the patient's ability to complete 12 repetitions with correct form and without pain. Although no formal measure was used to establish the level of compliance with this home program, the patient reported being fairly consistent with this exercise routine.

### Outcomes

The patient received physical therapy for 6 months. Tables 2 through 6 present the results of outcome measures used with regard to gait, single limb stance, goniometric ankle AROM, strength, average pain rating over the previous 24 hours, and palpatory tenderness of SCS tender points.

At the end of each physical therapy session, the patient consistently reported a reduction in overall resting ankle pain and a reduction in tenderness for all tender points down to 0-2/10 on the NPRS. The patient also consistently reported that the overall pain remained reduced for a period of 1-3 days. Even though this immediate post-treatment improvement did not hold completely from session to session, the patient noted a steady overall improvement with regard to pain and functional abilities each week as evidenced by a subjective report of an increased ability to ambulate and participate in daily activities.

Although the improvement in average pain over the preceding 24 hours as measured by the NPRS did not meet the 2-point MCID until re-evaluation in Month 2, the 10-point change at discharge most certainly exceeded this value, clearly indicating clinically relevant improvement (Table 2). Although the reliability and responsiveness have not been established for this particular use of the NPRS, the decrease in reported tenderness from 10 at initial evaluation to 0-2 at discharge on the NPRS on all tender points also seems clinically significant (Table 6). This steady decrease in palpatory tenderness at all tender points and in average 24-hour foot and ankle pain was accompanied by concomitant improvements with regard to ankle AROM, strength, and gait throughout the treatment period. As a result of these improvements in function and pain, the patient was extremely motivated and compliant with physical therapy attendance and participation. At discharge, the patient was starting to increase participation in activities with friends, including attempts at rollerblading and skate boarding.

Additionally, although not a primary outcome measure of physical therapy treatment efficacy–and admittedly perhaps in no way related, frequency of visits to the psychiatrist was decreased from twice per week at onset of the treatment period to once per week at Month 3, and to twice per month at Month 5.

## Discussion

Go to:

Although the neurophysiological mechanisms occurring in CRPS I are not yet fully understood, there is agreement that this is a systemic condition involving the entire neuraxis, with central and peripheral manifestations[2]. The use of SCS, in conjunction with a strengthening, endurance, and gait training program, may have assisted this 14-year-old patient, diagnosed with CRPS I, in returning to a pain-free and active lifestyle. The 10-point change from initial evaluation to discharge in average pain over the preceding 24 hours as measured using the NPRS most certainly exceeded the MCID for this measure, indicating that true and meaningful change had occurred. Despite the discussed absence of research data on the psychometric properties of the NPRS used, as in this case report, for quantification of palpatory tenderness of SCS tender points, the decrease from 10 at initial evaluation to 0-2 at discharge for all tender points in this author's opinion also seems to indicate a clinically significant change. Changes on ankle dorsiflexion, plantarflexion, and eversion strength assessed by way of MMT from 3/5 at Month 2 to 5/5 at discharge seem to constitute clinically relevant changes in contrast to upward changes from an MMT grade of 3+/5 as discussed above[58,59]. Although no quantitative data on responsiveness of goniometric measurements of ankle AROM, single leg stance, and the observational gait analysis used

could be found, there was gradual improvement noted across all measures, including steady gains in balance and gait parameters. Especially given the previous unsuccessful attempts at physical therapy and medical management and the reported poor prognosis for individuals with CRPS I for whom diagnosis and intervention has been delayed, it is possible that SCS had an influence in the clinical and functional outcomes of this case, allowing for effective strengthening, endurance, and gait training.

As discussed earlier, research-based information on the physical therapy management of patients with CRPS I is very limited and often contradictory. A literature review including the CINAHL EBSCO publishing, EBSCOhost EJS, Expanded Academic ASAP, LexisNexis Academic, Nursing and Allied Health Collection: Comprehensive, and Pub Med electronic databases from 1900 to 2005 using the following search terms: *Reflex Sympathetic Dystrophy, Complex Regional Pain Syndrome, physical therapy, treatment approaches, manual therapy, intervention, rehabilitation, medical management*, and *pharmacology* yielded only two studies[9,69] comparing physical therapy intervention to other interventions for this patient group. One study compared 30-minute physical to occupational therapy sessions in patients with upper extremity CRPS I[9]. Outcome measures included AROM measurements and pain measured with a VAS and the MPQ. Treatment protocols were not described and duration of the course of treatment was not noted but described as dependent on the severity of each case[9]. The second study compared 6 weeks of physical therapy treatment combined with cognitive-behavioral therapy for children aged 8-17 diagnosed with CRPS[69]; one group received physical therapy once a week and the other group three times per week. Outcome measures included assessments of pain and function. Again, no further descriptions of the physical therapy protocol were provided. Both studies[9,69] found physical therapy (or more frequent physical therapy) to provide more beneficial effects than the comparison treatments. However, as discussed earlier, the lack of information on the specific protocols used provided little research-based information to guide physical therapy management of patients with CRPS I. Illustrating the contradictory research-based information on physical therapy management of patients with CPRS I, a study of 54 patients with chronic RSD aged 21-65 intended to establish clinical predictors for success with an again unspecified physical therapy protocol showed no influence on patient satisfaction or functional outcome measures[19].

Despite this lack of research evidence, several guidelines for the provision of physical therapy for patients with CRPS I have been established[8,10,13,17]. These guidelines have been generally designed with a main emphasis on symptomatic treatment and functional training. Proposed physical therapy interventions have included[8,10,13,17]:

- Desensitization techniques (techniques where a variety of sensory inputs used to pain tolerance are used in an attempt to increase the systems threshold and decrease sensitivity)
- Transcutaneous electrical nerve stimulation
- Joint mobilization
- Passive, active assistive and active range of motion
- Progressive weight-bearing
- Strengthening
- Cardiovascular activities
- Functional training
- Vocational training

Stanton-Hicks et al[10] have proposed a treatment algorithm for patients with CRPS I that is recommended by the IASP[28,70]. This functional restoration algorithm includes desensitization, flexibility, edema management, strengthening, pain management, range of motion exercises, aerobic conditioning, posture training, balance training, ergonomics training, movement therapy, and functional

or vocational rehabilitation. Reviewing the proposed guidelines, it becomes clear that these approaches are all aimed at treating the impairments and functional limitations resulting from CRPS I. Given the poor understanding of the etiology of CRPS I, clinicians have been unable to fully address the underlying cause of the impairments occurring in this syndrome. A continued research effort aimed at a better understanding of all factors involved in this syndrome will hopefully lead to an improved treatment approach.

The decision to use SCS in the management of the patient described in this case report was based on the hypothesized action of SCS on a hyperfacilitated central nervous system (CNS) and the fact that both the established diagnostic criteria and presentation of CRPS I seem to indicate such CNS involvement. The author hypothesized that the tender points found locally on the left foot were the result of the initial ankle sprain injury and that the additional tender points identified may have resulted from a subsequent facilitated segment with resultant multi-level involvement of both the sympathetic and somatic nervous system, allowing and promoting the maintenance and spread of neural hyperactivity. A facilitated segment is described as resulting from any excessive neuronal discharge spilling over into collateral pathways and leading to hyperfacilitation contralaterally, ipsilaterally, and/or vertically along the central nervous system[31,32,35]. This hyperfacilitation may explain the tenderness pattern found in this patient, i.e., significant tenderness at the site of the original injury, contralateral to the injury, as a mirror image, and centrally along the spine. If CRPS I in this patient resulted from a peripheral injury leading to central hyperfacilitation, it is possible that SCS is an appropriate treatment technique as it aims to reduce this central hyperactivity and restore normal neuromuscular and musculoskeletal function. If SCS is able to affect the facilitated segment, as theorized by Korr[36,37] and Jones and colleagues[31–34], it may also be effective in reducing the sympathetic hyperactivity noted to be present in CRPS I.

Research evidence on SCS is very limited. Lewis and Flynn[71] reported in a case series on four patients with low back pain. Two to three treatment sessions over 1 week consisted of SCS for up to six identified tender points. The authors reported an overall reduction in pain and disability as measured with the MPQ and the Oswestry Low Back Pain Disability Questionnaire. Wong and Schauer-Alvarez[72] examined and compared the effects of SCS and SCS plus exercise on pain and strength of the hip musculature in a convenience sample of 49 subjects. Following intervention twice per week for 2 weeks and using a VAS for pain and a digital dynamometer for strength, the researchers concluded that SCS was effective in reducing tender point pain and increasing strength[72]. It is clear that to date no research evidence supporting the clinical use of SCS in patients with CRPS I and its proposed mechanism of action in this patient population is available.

As indicated earlier, this case report has obvious limitations. The clinical evaluation used in this case was based on an evaluation form used for clinical purposes and included AROM measured by goniometry, strength measured by MMT, subjective pain measured by NPRS, single limb stance measured by ability to maintain balance on one limb, and gait assessed by visual gait analysis. Most of these measures do not have the documented psychometric properties needed to establish a confident physical therapy diagnosis. Nonetheless, these are measures commonly used in physical therapy practice[30]. Not assessed in this case was the status of capsular and ligamentous structures and their effect on signs and symptoms. Also part of the physical therapist scope of practice and of great clinical value for examination, diagnosis, and intervention, such measures might have provided the author with valuable clinical measures and treatment options. Of course, a case report also lacks the ability to establish a cause-and-effect relationship between the intervention described, including SCS, and the outcomes reported. Nor was SCS the only intervention used in this patient allowing only limited assumptions about the efficacy of the comprehensive program described. Despite these weaknesses, in the author's opinion the noted clinical and functional changes warrant a further look into the

effectiveness and mechanisms underlying the use of SCS on patients suffering from this chronic and debilitating pain syndrome.

## Conclusion

Go to:

This report describes the case of an adolescent patient with chronic pain and disability due to CPRS I after a grade II ankle sprain who was treated with SCS, strengthening, and gait training for a period of 6 months. Clinically significant impairment-level and functional improvements, as measured by ROM, strength, pain, and gait function, were documented over the course of treatment despite earlier failure with medical and physical therapy management. CRPS I is a debilitating syndrome leading to impairments commonly treated by physical therapists. The progressive and extreme nature of symptoms associated with CRPS I and the lack of research based guidance for the development of a physical therapy treatment plan have often left clinicians unable to confidently assist these patients in their rehabilitation process. Further research in this area is of utmost importance.

Although MMT and AROM measurements are commonly used by physical therapists and are recognized as standard clinical measurements of impairments[30], the lack of research-based information on the reliability, validity, and responsiveness of these measures leads to a great weakness in the physical therapy literature, especially in case reports such as this one, where these commonly used measures were primary components of the evaluation process.

SCS offers additional treatment possibilities for physical therapists working with individuals with somatic dysfunction. The lack of research-based information on this technique, including the reliability, validity, and responsiveness of tender point measurement and tender point palpation parameters, present a significant weakness for its clinical application. Further research in the basic and clinical sciences as it applies to SCS is imperative in the development of evidence-based information for its clinical rationale and application. Although it cannot be said that SCS alone was responsible for the changes noted in this case, it can be hypothesized that SCS was an integral part of the successful treatment of this adolescent patient diagnosed with CRPS I. The SCS technique, through its proposed effects on the hyperactive proprioceptive spindle system and the resultant facilitated segment, may prove to be one additional treatment tool in the management of CRPS I, reducing the extreme pain reported by individuals suffering with this syndrome and leading to improved function. Further case studies and prospective randomized clinical studies using validated and reliable clinical and research measures are not only indicated but imperative in the understanding of this treatment technique and its potential effect on CRPS I.

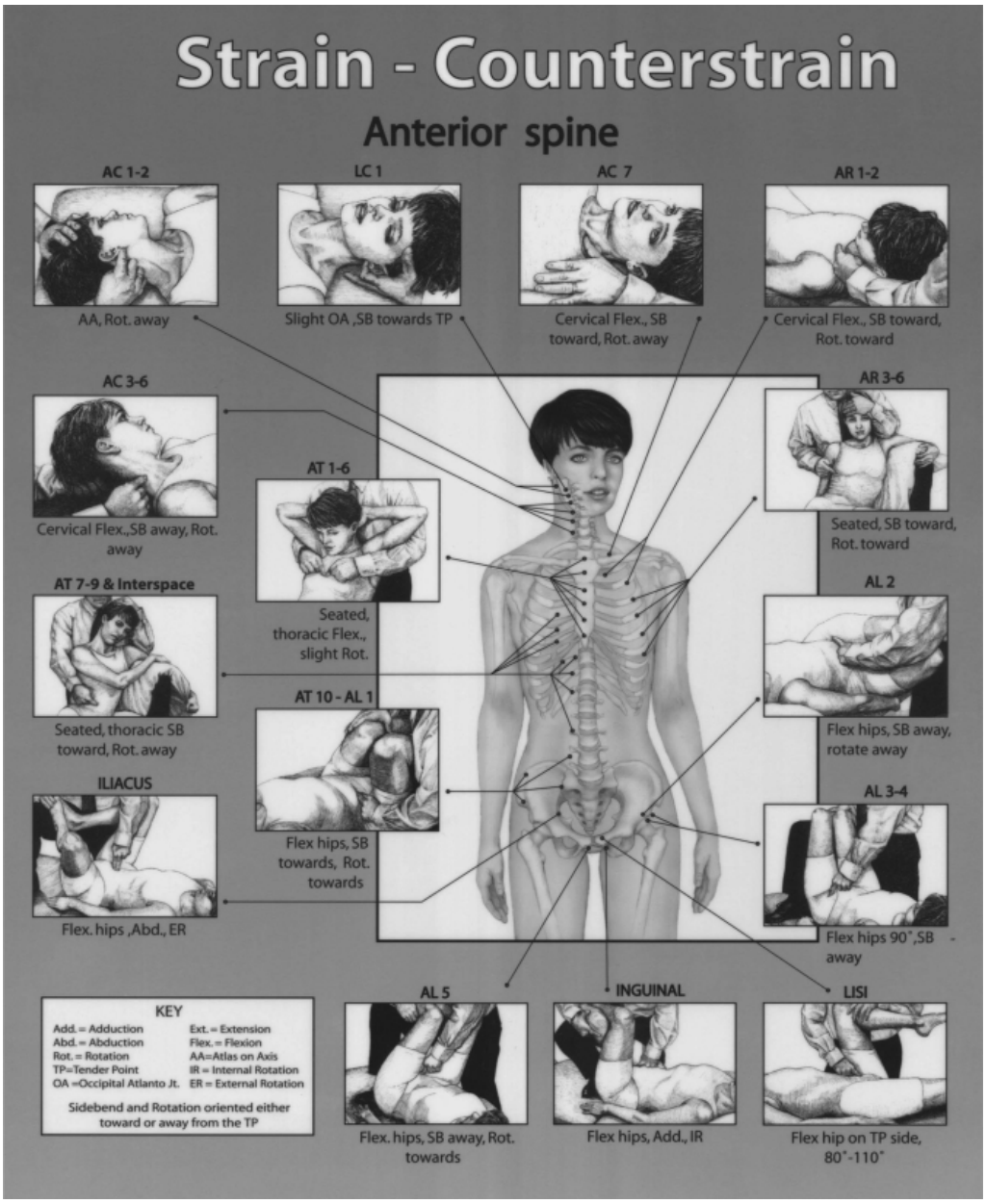


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Fig. 2

Strain-counterstrain anterior spine. (Reproduced with kind permission from the Jones Institute)

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