Case Report

Percutaneous peripheral nerve stimulation for treatment of shoulder pain after spinal cord injury: A case report

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Context: This describes the first person with spinal cord injury (SCI) treated with percutaneous peripheral nerve stimulation for chronic shoulder pain.

Findings: From baseline to one-week after treatment, the subject's worst pain in the last week, rated on a 0–10 numerical rating scale (BPI-SF3), decreased by 44%. Pain interference decreased and remained below baseline 12 weeks after the end of treatment. There was an associated improvement in the mental component of quality of life.

Conclusion: This case demonstrates the feasibility of treating shoulder pain in patients with SCI with percutaneous PNS. To demonstrate efficacy further studies are required.

Key Words: Spinal cord injury, Shoulder pain, Electrical stimulation

Introduction

For those who have a loss of function in the lower limbs after spinal cord injury (SCI) there is a predisposition to injury due to overuse of the arms for weight bearing, mobility, and due to impaired biomechanics of the shoulder.^{1,2} The prevalence of shoulder pain among manual wheelchair users ranges from 38% to 73% with an increasing incidence over time.^{1–8} Shoulder pain, in particular, can be detrimental to functional independence and quality of life in those with SCI.⁹ Causes of shoulder pain in persons with SCI include subacromial impingement syndrome (SIS), tendonitis, bursitis, rotator cuff tears, glenohumeral instability, spasticity, and possibly central sensitization.^{2,10} Treatments for chronic shoulder pain in SCI include analgesics, exercise therapy, wheelchair modifications, corticosteroid injections, and even surgery.^{11–14} While such programs have been shown to be effective, it is apparent by the 42% prevalence of chronic shoulder pain for those 5

years or more after injury¹⁵ that better treatments are needed to address the needs of those with SCI.

There are many potential causes for shoulder pain in persons with SCI, and the etiology is likely multifactorial. There is increasing evidence that pain that persists longer than would be expected for an acute injury to heal may be due to alterations in central nervous system processing, particularly central sensitization.^{16–20} Percutaneous peripheral nerve stimulation (PNS) of the axillary nerve has been shown to successfully treat chronic hemiplegic shoulder pain (HSP),²¹ and there is evidence that PNS might be effective for chronic shoulder pain due to SIS in those without neurologic injury,²² both of these are thought to be mediated through central sensitization.^{23–30} Although the exact mechanism of action of PNS in the treatment of chronic shoulder pain is unknown, it has been suggested that PNS may alter central sensitization.³¹ If the mechanism is modulation of central sensitization, and chronic shoulder pain is associated with central sensitization, then it is reasonable to explore the use of PNS for chronic shoulder pain in persons with SCI. This case report presents the first

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experience with percutaneous PNS for the treatment of persistent shoulder pain in an individual with SCI.

Case presentation

The subject is a 45-year-old man, with a history of a C4 ASIA D tetraplegia due to a gunshot wound to the neck 20 years before enrollment. Because of the injury, the strength of his right arm was impaired. He had a 2-year history of right shoulder pain that was not responsive to treatment with non-steroidal anti-inflammatory drugs, opioid and non-opioid analgesics, physical therapy, sling and arm support, heat, surface electrical stimulation, or subacromial corticosteroid injection. Imaging with computed tomography did not show evidence of anatomic abnormality. On physical examination the subject had strength of 4 out of 5 on the Medical Research Council (MRC) scale³² throughout all myotomes on the right except for those in C8 and T1 which were 3 out of 5. He had 5 out of 5 strength in all myotomes on the left. He had spasticity graded as Modified Ashworth of 2 at the right triceps, right knee flexors and extensors. His right shoulder was limited in active range of motion in all planes due to pain. At his right shoulder, he had pain on palpitation of the subacromial bursa and coracoid process, positive Hawkins' sign and negative Neer's sign.

At time of enrollment, there was no evidence of infection of the skin overlying the affected shoulder. He was not taking any opioid medications or receiving physical or occupational therapy. His last steroid injection was two years prior to enrollment, and he had not received botulinum toxin injection in the 12 weeks prior to the trial.

Methods

The local institutional review board approved the intervention protocol. Investigators obtained informed consent from the subject prior to enrollment.

Intervention

The single percutaneous electrode stimulation system was implanted as described previously.^{21,33} The skin overlying the subject's affected shoulder was prepared and sterilized prior to the procedure. To stimulate the axillary nerve, investigators inserted monopolar needle electrodes perpendicular to the skin surface at the locations where the axillary nerve innervated the middle and posterior deltoids (i.e. the motor points) and iteratively stimulated and repositioned until a strong contraction occurred at each muscle. A third monopolar needle electrode was placed at the midpoint between the 2 motor points of the middle and posterior

deltoid muscles. Stimulation was applied to the single mid-point electrode and the position was adjusted until strong contraction of both the middle and the posterior deltoid muscles was achieved. The depth of the third needle electrode was recorded. A 20-gauge, insulated introducer loaded with a percutaneous lead was then inserted perpendicular to the skin surface to the depth and location indicated by the third needle electrode. The introducer was withdrawn, leaving the electrode in place. Stimulation was delivered through the lead to the axillary nerve to ensure stimulation produced comfortable contraction of the middle and posterior deltoid, confirming proper placement. A dry sterile dressing was placed over the lead, and an occlusive dressing was applied.

After a 1-week lead stabilization period, the stimulator (SPRINT™ (formerly SMARTPATCH™) PNS SYSTEM, SPR Therapeutics, LLC, Cleveland, OH, USA) was connected to the lead, and parameters were set to stimulate the axillary nerve at a frequency of 12 Hz and an amplitude of 20 mA to activate the middle and posterior deltoids. The pulse duration was set at an intensity to produce the strongest yet still comfortable contraction of both the middle and posterior deltoids, with the final pulse duration being 60 microseconds. The 30-second duty cycle consisted of 5-second ramp up, 10-second maximum stimulation, 5-second ramp down, and 10-second relaxation period. The participant was prescribed six hours of stimulation per day for three weeks for a total of 126 hours of stimulation. A compliance monitor recorded the total time of stimulator use.

Investigators contacted the subject weekly during the 3-week stimulation phase and asked about pain intensity and adverse events. At the end of the 3-week stimulation phase, the subject returned for lead removal and evaluation of primary and secondary end-points. He returned at 1, 4, and 12 weeks after treatment for outcomes assessments.

Outcomes

The primary outcomes were safety and the Brief Pain Inventory Short-form Question 3 (BPI-SF3), which rates the "worst pain" in the previous week on a 0–10 numerical scale, where 0 indicates "no pain" and 10 indicates "pain as bad as you can imagine". A clinically meaningful difference is defined as a reduction in the pain score by 30% or greater.³⁴ Secondary outcomes included the remainder of the Brief Pain Inventory Short-form, Short-Form 36 version 2 (SF-36v2), and the Patient Global Impression of Change (PGIC) scale. The BPI-SF4, SF5, and SF6 rate the least pain

in the last week, average pain in the last week, and current pain, respectively, on the 0–10 numerical pain scale. The BPI-SF9 assesses the degree to which pain interfered with daily activities during the past week, on a numeric scale of 0 to 10, where 0 indicates no interference and 10 indicates complete interference. The BPI-SF9 score is an average of the ratings in general activity, mood, walking ability, normal work, interpersonal relationships, sleep, and enjoyment of life. A clinically meaningful difference is defined as a reduction in the pain interference score by 1 or greater.³⁴

The SF-36v2 is a quality of life (QoL) measure that provides a profile of health and well-being in several domains: physical functioning, social functioning, physical role, emotional role, mental health, bodily pain, general health, and vitality. Results are grouped further into Physical Health Component and Mental Health Component. Results are norm-based with a population mean of 50, and standard deviation (SD) of 10. Higher scores indicate higher quality of life.

The Patient Global Impression of Change scale (PGIC), quantifies the degree of improvement or deterioration since the beginning of the study using a 7-point Likert scale ranging from “very much worse – very much improved.” The PGIC was measured at the end of the treatment.

Results

The subject tolerated the lead placement and stimulation without difficulty. There were two adverse events during the study. One, study related, was a subjective increase in tone in the subject’s affected arm immediately after placement procedure. The increased tone resolved without intervention by the time of his next scheduled visit 48 hours later. The second adverse event, a rash on the subject’s affected arm and back, was not study-related, and resolved without treatment. The subject completed 118 hours (93.6%) of the prescribed 126 hours of stimulation.

Results are summarized in Table 1 and Figure 1. The subject experienced a 22% reduction in worst pain (BPI-SF3) from the start of stimulation to the end of treatment, and a 44% reduction in worst pain 1 week after the end of treatment. BPI-SF3 returned to baseline over the course of the 12-week follow-up period. There was a reduction in least pain in the last week (BPI-SF4), average pain in the last week (BPI-SF5), and current pain (BPI-SF6) from the start of stimulation to the end of treatment, and improvements were sustained through the 12-week follow up. Pain interference (BPI-SF9) decreased 47.1% from the start of stimulation to

the end of treatment, and was 52.9% lower at 12 weeks follow up than at start of stimulation.

Quality of life improved in multiple aspects as measured by the SF-36v2. The Bodily Pain and Physical Role Function subscales improved at the end of treatment, but returned to baseline by 12 weeks after treatment. The Mental Health component improved and remained higher than baseline at 12 weeks after treatment. At the end of the treatment period, the subject rated the pain as ‘Minimally Improved’ in the PGIC.

Discussion

This case presentation is the first to describe the treatment of chronic shoulder pain after SCI with a 3-week therapy of single lead percutaneous PNS. The procedure was safe and there was an associated reduction in the worst pain in the last week, reaching a clinically meaningful difference³⁴ by 1-week after the end of treatment. The reduction in pain interference exceeded the minimally clinically important difference³⁴ by the end of treatment and remained meaningfully improved for the duration of the study. There were also sustained improvements with least pain, average pain, and current pain. These improvements appear to be reflected in the SF36v2 in the domains of Bodily Pain and Physical Role Functioning.

The discordance between BPI-SF3 and the secondary measures may be an artifact of the specific nature of BPI-SF3. BPI-SF3 does not consider the duration or the frequency of the “worst pain” episodes. Thus, if the treatment reduced the frequency and duration of the “worst pain” episodes, but the intensity itself was unchanged, the effect on the overall pain experience would not be detected by BPI-SF3. However, the treatment effect may be reflected in pain interference with daily activities, least pain, average pain, current pain, and QoL.

To our knowledge, there are no other case reports of percutaneous PNS used for treatment of shoulder pain in SCI. Prior studies for those with chronic shoulder pain after stroke²¹ and subacromial impingement syndrome²² have demonstrated sustained improvement in pain interference and quality of life after a 3-week treatment of PNS. While those studies also demonstrated sustained improvement in pain relief, there is evidence in those with shoulder pain after stroke that earlier treatment with PNS is associated with greater likelihood of sustained relief.³⁵ It is possible, though unknown, if time from spinal cord injury might be similar.

The exact mechanism of pain relief of PNS is not known. Studies have shown that SCI can create

Table 1 Outcomes of pain, function, and quality of life.

	Baseline		Treatment					
	Week 0	Implant	Week 1	2	3	4	8	16
Pain (BPI-SF)								
Worst pain in past week (BPI-SF3)	9	10	10	9	8	6	10	9
Least pain in past week (BPI-SF4)	4	6			1	3	2	3
Average pain in past week (BPI-SF5)	7	7			4	4	7	4
Pain right now (BPI-SF6)	6	8			5	5	4	5
Function (BPI-SF)								
Interference from Pain (BPI-SF9)	6.3	7.0			3.7	2.7	4.1	3.3
Quality of Life (SF-36v2)								
Physical Functioning	29.7	31.8			23.4	25.5	27.6	27.6
Physical Role Functioning	37.3	32.4			39.7	42.2	47.1	37.3
Bodily Pain	37.2	33.4			41.4	41.4	33.4	37.2
General Health	62.5	55.3			55.3	57.7	62.5	57.7
Vitality	55.2	52.1			58.3	55.2	61.5	45.8
Social Functioning	45.9	45.9			51.4	51.4	51.4	40.5
Emotional Role Functioning	36.4	32.6			40.3	44.2	52	48.1
Mental Health	38.7	44.4			52.8	55.6	58.5	52.8
Physical Component	41.2	36.8			35.2	36	35.4	33.6
Mental Component	46.1	47			57.7	59.2	65	54.9

BPI-SF, Brief Pain Inventory, Short Form; SF-36v2, Short Form-36, Version 2.

alterations in pain perception that are indicative of central sensitization,^{36,37} even with lack of supraspinal control.³⁸ Prior work in non-SCI populations has shown that chronic shoulder pain attributed to common musculoskeletal pathologies, which are also common in those with SCI, are associated with central sensitization.^{23,26,28–30} An emerging hypothesis is that PNS might reduce chronic pain by altering maladaptive neuroplasticity in the central nervous system that allows central sensitization to persist longer than acute injuries.²²

This case report demonstrates use of PNS to treat chronic shoulder pain in an individual after SCI is safe

Figure 1. Pain-related outcomes from the Brief Pain Inventory: BPI-SF3 - Worst pain in the last week on a 0–10 scale. BPI-SF5 – average pain in the last week on a 0–10 scale. BPI-SF9 - interference from pain in the last week on a 0–10 scale. The shaded area indicates treatment with PNS.

and may be associated with a reduction in pain and improvements in quality of life and pain interference. As a single case study, however, these results cannot be generalized to others with SCI and chronic shoulder pain. The results seen in this case could be due to placebo effect, natural recovery, or other phenomenon. While it is possible that a lead may impede shoulder function and thus interfere with activity of daily living (ADL), this study, and previous studies using the same lead placement, have not shown the lead to be cumbersome or detract from ADLs. The reduction in pain interference with treatment supports that treatment does not present a barrier to function. Further studies are needed to determine efficacy and mechanism of action, define optimal dose, duration, and timing of treatment, demonstrate long-term effect and identify any potential adverse effects in those with SCI.

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