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PERIPHERAL NERVE STIMULATION FOR ROTATOR CUFF-INDUCED CHRONIC SHOULDER PAIN: A LITERATURE REVIEW

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Background: Chronic shoulder pain is one of the most common musculoskeletal complaints in a primary care setting, with a worldwide prevalence ranging from 10.8% to 55.2%. Peripheral nerve stimulation (PNS) was discovered in the 1960s; however, it is a newly emerging treatment for chronic shoulder pain secondary to rotator cuff pathology.

Methods: Patients in these studies had chronic shoulder pain, lasting 12 months or more, attributable to rotator cuff etiology. The search was limited to studies published between 2010 and 2023.

Results: All 4 studies reported a substantial reduction in pain ranging from 40% to 100%, observed between 42 and 407 days post-PNS placement. Three patients also noted a 29% to 75% reduction in opioid use.

Conclusions: Preliminary studies suggest that PNS may be an effective treatment option for chronic shoulder pain due to rotator cuff etiology. To accurately assess the effect of PNS on chronic shoulder pain due to rotator cuff pathology significantly more data, including prospective trials, are required and warrant pursuit.

Key words: Peripheral nerve stimulator; PNS; chronic shoulder pain; shoulder pain; rotator cuff; rotator cuff tear

BACKGROUND

Chronic shoulder pain is known to be one of the most common presenting chief musculoskeletal complaints in a primary care setting, with a worldwide prevalence ranging from 10.8% to 55.2% over a reference period of 12 months or more (1). Chronic shoulder pain can arise from a multitude of etiologies, including subacromial bursitis, glenohumeral joint arthritis, hemiplegia, adhesive capsulitis, labral tears, cervical myelopathy, and rotator cuff pathologies (2). Among these conditions, rotator cuff pathologies (i.e., tears, tendonitis, sprains, arthropathy, subacromial impingement syndrome, and bursitis) are recognized as the leading cause of disability related to the shoulder (3). The origin of rotator cuff syndromes is believed to be multimodal. However, the most common risk factors and sources of these injuries stem from acute trauma, repetitive eccentric tension, age, osteoarthritis, sports, occupation, history of smoking, and medical comorbidities (i.e., metabolic syndrome, thyroid disorders, diabetes, and inflammatory arthritis) (3-5).

Rotator cuff pathologies are initially treated with conservative therapies that may include nonsteroidal anti-inflammatories, physical therapy, and intraarticular shoulder and/or subacromial bursa steroid injections (6). Surgical interventions may be considered depending on the severity of the rotator cuff tear or its progression; emerging research on peripheral nerve stimulation (PNS) suggests that it may serve as an effective treatment modality for rotator cuff pathologies (4-9).

PNS has been employed since the 1960s for chronic pain management through percutaneous electrical stimulation (10). The use of PNS has evolved to target specific peripheral nerves through percutaneous implantation of leads, which alter nerve firing rates and

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modulate pain (10). Poststroke shoulder pain is the most common shoulder pathology treated with PNS (10). A systematic review, published in 2020, examined the use of PNS for hemiplegic shoulder pain, osteoarthritis of the shoulder, adhesive capsulitis, shoulder impingement, and postoperative analgesia following rotator cuff repair; however, it did not assess the effect of PNS on chronic shoulder pain secondary to rotator cuff pathologies (10).

This literature review aims to summarize the current literature on the use of PNS for chronic shoulder pain secondary to rotator cuff pathology.

Literature Search

We conducted searches in various databases, including Google Scholar, Pain Medicine and Case Reports, JSTOR, ScienceDirect, PubMed, ClinicalKey, Cochrane Library, and Medline. Our keywords were: "peripheral nerve stimulator," "PNS," "chronic shoulder pain," "shoulder pain," "rotator cuff," and "rotator cuff tear." Patients in these studies had chronic shoulder pain, lasting 12 months or more, attributable to rotator cuff etiology. The search was limited to studies published between 2010 and 2023. No studies were excluded due to the limited amount of studies available in this large time frame. The studies included were Chitneni et al's (6) case series, Ycaza et al's (7) case report, Shah et al's (8) case report, and Alvarez et al's (9) case report. Additionally, we reviewed the reference lists of all selected studies for additional sources not initially identified.

RESULTS

Based on these criteria, we identified 4 studies with low-level evidence. These studies included 3 case reports and one case series, which are summarized in Table 1. A variety of brands, implantable pulse generators (rechargeable/primary cell), and frequencies were used in these studies. The common measured outcome in all 4 studies was percent pain reduction. Chitneni et al's (6) case series and Ycaza et al's (7) case report examined morphine milligram equivalents (MME) reduction; Shah et al's (8) and Ycaza et al's (7) case reports also assessed the range of motion post-PNS placement. All 4 studies reported a significant reduction in pain between 42 and 407 days post-PNS placement.

Chitneni et al's (6) case series described the use of a SPRINT PNS device (SPR Therapeutics, Inc., Cleveland, OH) implanted via ultrasound guidance targeting the suprascapular and axillary nerves. Leads were placed at the suprascapular notch and at the acromion process at the axillary nerve motor points. The frequency, pulse width, and amplitude of the device were not reported. They noted that one of their patients had 100% pain reduction during their 60-day treatment phase and 90% relief 3 months after PNS removal. Their second patient had an 80% pain reduction during their 60-day treatment phase and 80% relief 3 months after PNS removal. In addition, these 2 patients had a significant reduction in MME ranging from 50% to 75% (6).

Ycaza et al's (7) case report described the use of a Stimwave Technologies (Pompano Beach, FL) Freedom PNS System. The settings described included a frequency of 1.5 Hz, pulse width of 30 μs, and amplitude of 3.5 mA. A 4-contact electrode array was used targeting the proximal anatomical (osseous) location where the suprascapular nerve was identified by fluoroscopy. The PNS device was a permanent implant targeting the left suprascapular nerve. The patient had 95% to 100% pain reduction one year after PNS placement. Ycaza et al's (7) case report also noted a 29% reduction in MME one year after PNS placement. A further MME reduction was not attempted because the patient had other underlying medical conditions contributing to his pain. Ycaza et al's (7) patient also noted excellent mobility after the PNS placement that was near his baseline prior to his injury.

Shah et al (8) did not report the device brand, length of treatment, or settings, including the frequency, pulse width, and amplitude. The initial trial targeted the suprascapular nerve (with an unknown surgical approach or lead placement) and the patient noted limited relief. Ultimately, the PNS leads were repositioned under ultrasound guidance to target the axillary nerve, which was identified over the shaft of the humerus beneath the deltoid approximately to the teres muscle. The patient noted 80% pain reduction 6 months post-PNS placement. Their patient was also able to discontinue opioid use, although the initial MME or opioid dosage was not provided. Shah et al (8) noted that their patient achieved 100° of shoulder abduction without pain and regained 5/5 shoulder strength post-PNS placement, significantly improving from the preintervention state.

Alvarez et al (9) did not report the device brand, lead placement, frequency, pulse width, and amplitude. The patient underwent an ultrasound-guided PNS implantation using a 60-day temporary device targeting the right suprascapular and axillary nerves. The patient had 25% pain reduction at one week, 60% at 2 weeks, and 40% at 7 weeks post-PNS placement (9).

Table 1. Summary of the studies reviewedon PN for the treatment of chronic shoulder pain.

Author, Year	Design	Patient(s)	Device	Target(s)	Outcomes	Adverse Outcomes
Chitneni et al, (2022) (6)	Case Series	#1: 75 year old male with a full thickness rotator cuff tear with chronic shoulder pain for 2 years #2: 53 year old male with a partial thickness rotator cuff tear with chronic shoulder pain for 1 year	Device: SPRINT PNS – Unreported Frequency, Pulse Width, and Amplitude	60 day PNS treatment phase targeting suprascapular and axillary nerve	#1: 100% pain reduction during 60 day treatment phase; 90% relief after 3 months after PNS removal; 75% opioid MME reduction; 100% relief with physical therapy during treatment phase #2: 80% pain reduction during 60 day treatment phase; 80% relief 3 months after PNS removal; 50^ opioid MME reduction; 75% relief with physical therapy during treatment phase	No serious device related adverse events
Ycaza, R & Vanquathm, N (2022) (7)	Case Report	#1: 65 year old male with chronic shoulder left shoulder pain for 4 years. Patient had full-thickness tear of the supraspinatus muscle, degenerative tearing of the inferior and superior labrum, degenerative hypertrophy of the acromioclavicular (AC) joint, and mild-to-moderate glenohumeral (GH) joint degenerative arthritis. Patient had a right sided rotator cuff repair in 2015.	Device: Stimwave Technologies Freedom PNS System Frequency: 1.5 Hz Pulse Width: 30 µs Amplitude: 3.5 mA	Permanent PNS placement targeting left suprascapular nerve	– 1 year post operation pt was able to reduce MME from 315 to 225 (29% reduction) – 95-100% pain reduction – Oswestry Disability Index (ODI) 6 weeks post operation was 4% (0% = no disability, 100% = bed ridden).	No serious device related adverse events
Shah et al, (2023) (8)	Case Report	#1: 51 year old female with a full thickness tear of her right supraspinatus and infraspinatus; this patient had a paracentral disc extrusion at C5-C6 mildly compressing on the cervical cord. The patient also had severe mobility impairment	– Unreported Device, Frequency, Pulse Width, and Amplitude	Trialed suprascapular nerve without success Trialed axillary nerve with success	– 80% pain reduction at 6 month follow up and patient stopped using opioids; – She was able to abduct the right shoulder 100 degrees with no pain, good range of motion, and 5/5 strength throughout.	No serious device related adverse events
Alvarez et al, (2023) (9)	Case Report	#1; 60 year old female who underwent a right rotator cuff repair 3 years after her chronic pain started. This was complicated by arthofibrosis and persistent pain, leading to surgical lysis of adhesion and reverse total shoulder arthroplasty. The patient's shoulder pain is non-radiating, anterolateral and posterior right shoulder pain. Her pain was ongoing for 5 years.	– Unreported Device, Frequency, Pulse Width, and Amplitude	60 day PNS treatment phase targeting suprascapular and axillary nerve	– 25% pain reduction at one week, 60% at two weeks, and 40% at seven weeks post PNS placement.	No serious device related adverse events

No surgical complications or adverse reactions were reported in any of the studies reviewed (6-9).

DISCUSSION

This review analyzed 3 case reports and one case series involving 2 patients. All 4 studies reported a substantial reduction in pain ranging from 40% to 100%, observed between 42 and 407 days post-PNS placement. Furthermore, 3 patients exhibited a noteworthy 29% to 75% reduction in opioid usage (6,7). One case report (8) highlighted a patient's complete discontinuation of opioid use following PNS placement. Additionally, 2 patients experienced a significant improvement in shoulder mobility after PNS placement (7).

An essential observation from these studies is the significance of the placement of PNS leads. Alvarez et al (9) and Chitneni et al (6) placed leads targeting the suprascapular and axillary nerves, which resulted in significant pain reduction. Shah et al (8) initially attempted suprascapular nerve PNS stimulation, which did not yield significant pain relief. Instead, they placed a PNS lead targeting the axillary nerve, resulting in an 80% reduction in pain at 6 months. A recent case series examining axillary nerve stimulation via PNS for subacromial impingement syndrome, rotator cuff pathology, glenohumeral joint arthritis, acromioclavicular joint arthritis, adhesive capsulitis, and biceps tendinopathy revealed that 88% (7 out of 8 patients) experienced > 50% pain relief (11,12). While not causal evidence, the nature and anatomic origin of the rotator cuff pathology may respond variably to different PNS targets of the shoulder joint (6,8,9).

As we delve into the intricate sensory innervation of the shoulder joint, a fundamental grasp of its anatomy is imperative. The primary sensory innervation of the shoulder joint is primarily supplied by the suprascapular and axillary nerves, with minor sensory input from the subscapularis and lateral pectoral nerves (13,14). The suprascapular nerve is responsible for 70% of the sensory innervation of the shoulder (15). The nerve arises from the superior trunk of the brachial plexus and has a C5-C6 nerve root (15). It runs distally to the superior scapular notch and inferior to the transverse scapular ligament (15). The suprascapular nerve has a multitude of branches that provide sensory innervation to coracoclavicular ligaments, the coracohumeral ligament, the subacromial bursa, infraspinatus tendon, and posterior parts of the glenohumeral joint capsule (15). Similarly, the axillary nerve originates from the posterior cord of the brachial plexus with a C5-C6 nerve root and provides sensory innervation to various regions, including the inferior-anterior joint capsule, axillary recess, posterior glenohumeral joint capsule, humeral head, and humeral neck (12-14). Although the lateral pectoral nerve is primarily known to provide motor innervation to the pectoralis major, it also has a sensory component (16). The lateral pectoral nerve is a branch of the lateral cord of the brachial plexus with a C5-C7 nerve root (16). The lateral pectoral nerve's nociceptive fibers innervate the anterior portion of the glenohumeral joint, subcoracoid region, and inferior portion of the acromioclavicular joint (11,16). The subscapular nerves, originating from the posterior cord of the brachial plexus with C5-C6 nerve roots, provide sensory innervation to the subscapularis and the glenohumeral joint capsule (17). Given the complex innervation of the shoulder joint by various nerves, it is crucial to explore the optimal number and location of PNS leads needed to deliver effective pain relief. In addition, many other variables likely exist for the success of PNS in the treatment of shoulder pain. There are both mechanical and electrical variations to the different brands of PNS systems currently on the market. Ideal waveforms and other treatment settings are also not yet identified. This remains a topic that warrants further exploration in future PNS studies.

CONCLUSIONS

Based on the available literature, PNS may have beneficial therapeutic value in the treatment of shoulder pain secondary to rotator cuff pathology. These ultrasound-guided procedures were minimally invasive, safe, and demonstrated no notable adverse effects (6-9).

This literature review is significantly limited as the currently available evidence consists of low-level evidence studies, including only case reports and one case series. Another limitation stems from protocol inconsistencies amongst the studies. The only common outcome measured in all the studies was percent pain reduction. Ideally, more common outcomes and variables would be reported, including, but not limited to, pre- and post-PNS pain scores, same PNS device manufacturer, frequencies, amplitude, pulse width, MME, treatment phase length, and range of motion changes. To accurately assess the effect of PNS on chronic shoulder pain due to rotator cuff pathology, significantly more data, including prospective trials, are required and warrant pursuit.

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