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Spinal Cord Stimulator (SCS) therapy: A novel treatment for chronic compartmental syndrome pain

***Corresponding Author:** Kwasi Ampomah*

Email: Kwasi.ampomah@ahn.org

Abstract

Introduction: Compartment syndrome, defined by escalated pressure within a muscle compartment, can result in ischemia, potential tissue necrosis, and nerve damage, predominantly impacting the lower extremities. While surgical fasciotomy remains the gold standard for management, a substantial subset of patients either do not respond adequately or develop chronic symptoms. The Spinal Cord Stimulator (SCS), traditionally utilized for chronic pain syndromes such as post-laminectomy syndrome, neuropathic pain and complex regional pain syndrome, presents an innovative alternative.

Case presentation: Herein, we discuss a case of a 31-year-old female with severe chronic compartment syndrome, who was unresponsive to traditional interventions and underwent a SCS trial and subsequent permanent SCS implantation.

Discussion: Our patient continued to experience significant pain relief reporting >90% relief following her permanent SCS implant at 90 days. This was evidenced by the patient's increased mobility, resumption of normal physical activity, and self-reported pain levels. The successful use of SCS in this instance illustrates the potential for neuromodulatory techniques to offer a non-pharmacological, reversible alternative for managing complex pain syndromes, marking a shift in the therapeutic approach to chronic compartment syndrome.

Kwasi Ampomah[1]*; Jillian Dean[2]; Michael Patterson[1]; Nestor D Tomycz[3]

[1]Department of Anesthesiology, Pain Medicine, Allegheny Health Network, Pittsburgh PA 15201, USA.

[2]School of Medicine, University of Pittsburgh, Pittsburgh PA 15213.

[3]Department of Neurosurgery, Allegheny Health Network, Pittsburgh PA 15201, USA.

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Background

Neuromodulation, which involves modifying nerve activity by directly applying electrical or pharmacological agents to specific regions, has been at the forefront of medical therapeutic research and innovation for many years [1]. Within the spectrum of neuromodulatory instruments, Spinal Cord Stimulators (SCS) distinguish themselves, showcasing significant strides in therapeutic progress and proven efficacy in clinical settings [2-10]. The concept of SCS emerged in the 1960s to address intractable pain. The publication of the Gate Control Theory in 1965, which revealed pain as a complex interplay within the nervous system, shifted the medical approach from irreversible nerve-damaging surgeries to reversible treatments like neuromodulation [10].

Fundamentally, these devices are designed to modulate neural activities within the spinal cord [1]. Through the precise delivery of electrical impulses, they not only mitigate symptoms of chronic pain but also possess the potential to modify neuroplastic changes associated with chronic pain states [3]. Strategically positioned electrodes near the spinal cord intercept nociceptive

signals, modulating their transmission and consequently attenuating the perception of pain at the cortical level [3].

While the primary indication for SCS has been chronic pain syndromes, including post-laminectomy syndrome, complex regional pain syndrome, and neuropathic pain, the versatility of this device has led to its exploration in various other conditions [4]. From ischemic conditions like angina to functional disorders like urinary incontinence and even certain types of migraines, the expanding scope of SCS applications is a testament to its therapeutic potential and adaptability [5]. The paradigm shift in the understanding of chronic pain, coupled with technological advancements, has placed the SCS at the forefront of neuromodulatory interventions. Further, modern SCS systems offer advanced features such as wireless connectivity, customizable pulse outputs, and rechargeable power sources, making SCS systems more efficient, effective, and user-friendly [2].

Unlike the chronic pain conditions usually treated with SCS, compartment syndrome poses a distinct clinical challenge due to its nature of acute or chronic increase in pressure within muscle compartments, leading to severe clinical difficulties [6]. This heightened pressure can impede blood flow, potentially leading to tissue damage, necrosis, and nerve injury. Contributing factors include severe injuries, bone fractures, sustained immobility, or vigorous physical activities [6]. While acute cases often demand emergent interventions, chronic forms of the syndrome, though less immediately life-threatening, present a unique set of challenges in terms of management and long-term prognosis [7]. Traditionally, surgical fasciotomy has served as the primary treatment for compartment syndrome, designed to relieve elevated pressure within compartments and reinstate blood flow. Yet, not every patient experiences enduring relief from this invasive method. Considering the possible complications and the increased risk of morbidity from multiple surgeries, the need for alternative treatment approaches is clear [8].

Connecting the realms of SCS and compartment syndrome is the pioneering promise of neuromodulation. The 31-year-old female patient underwent a percutaneous stimulation trial using a sophisticated neuromodulatory approach for treating compartment syndrome. The device utilized was the Abbott Medical Penta 3 mm Lead, 60 cm; SCS Paddle Lead (Plano, TX, USA), known for its small electrodes arranged in a five-column array. The configuration enhances the ability to manage complex pain by providing advanced control over the affected areas. This innovative fusion of technology and clinical practice suggests a more comprehensive approach to care, enhancing traditional treatments with advanced techniques.

Case

A 31-year-old female with a primary medical history that includes generalized anxiety, chronic depression, mild intermittent asthma, IBS, dyslipidemia, and bipolar disorder consulted her Primary Care Physician (PCP) due to pain in her left lower extremity. She maintained a healthy lifestyle as a non-smoker and non-drinker but had a BMI of 41.

Her symptoms began when she increased her training intensity, running longer distances than she was used to. Initially diagnosed with a sprain in her left foot, subsequent imaging showed a stress fracture, which was managed conservatively. Despite this, she continued her training and began experiencing cramps in both calves while running, more pronounced on the left. Though physical therapy and medications offered momentary relief, the problem persisted.

Throughout this period, her laboratory results and vitals stayed largely within the normal range. Detailed imaging studies, including a doppler of her lower extremities and an evaluation of her popliteal arteries, showed no abnormalities. However, compartment pressure testing revealed elevated pressures in her left anterior (72) and lateral (36) compartments following exercise, with resting values of 14 and 13 respectively. The right side also showed slightly raised pressures. These findings confirmed a diagnosis of chronic exertional compartment syndrome in both lower extremities. After discussing her options, she chose to undergo a bilateral anterior and lateral fasciotomy of the lower extremities, which brought about a significant reduction in her pain, with no major post-operative complications.

Approximately eighteen-months post-procedure, she began experiencing a recurrence of pain in her left lower extremity, reminiscent of her prior exercise-induced discomfort. Subsequent discussions with her orthopedic surgeon culminated in a revision surgery for the left leg's anterior and lateral compartments. The patients pain intensified post-surgery and persisted for about a year, however, her right leg responded well to the initial surgery and remained asymptomatic.

Persisting pain in her left leg was described as sharp, piercing, occasionally accompanied by numbness and weakness. An MRI of her lumbar spine showed no anomalies, while an MRI of her femur/tibia identified nonspecific muscle edema in her left mid-leg, distinct from previous MRIs. Potential causes included exercise-induced trauma, delayed-onset muscle soreness, denervation edema, inflammatory myopathies, or possibly an infectious/viral myopathy. An EMG ruled out neuropathy or myopathy. While there was some consideration for a CRPS diagnosis due to observed allodynia and temperature changes, she didn't meet the complete Budapest criteria. She underwent Botox injections under the guidance of a sports medicine physician to manage her chronic compartment syndrome, but their efficacy diminished over time.

Five years post her initial injury, the patient underwent a SCS trial which yielded promising results. She experienced a notable 70% decline in pain during the trial, which further improved to over 90%. Given the significant relief, she elected to have a permanent spinal cord stimulator implanted (Figures 1a, 1b). At her six-week surgery follow up, the patient continued to fare exceptionally well, still reporting a relief of >80% from her pre-surgical pain levels. Approximately three-months following the revision surgery, the patient reports a significant improvement in pain and quality of life following the implantation of a permanent spinal cord stimulator. Objective measures indicated that her daily movement and step count, as monitored by a wearable device, increased twofold, suggesting enhanced mobility. The patient's self-reported pain levels decreased from a baseline of 7-8 (on a 10-point visual analog scale) to not exceeding a level of 3 post-surgery, denoting >90% reduction in pain perception.

Subjectively, the patient described a substantial uplift in cognitive clarity and energy levels, contrasting her pre-implant state characterized by fatigue and 'brain fog'. She articulated a perceived improvement in her overall quality of life, citing increased physical activity, which included a resumption of gym visits. The patient's testimony corroborates the quantifiable data, encapsulating a recovery trajectory that restored her functional capabilities to a level not experienced in the three years preceding the intervention.

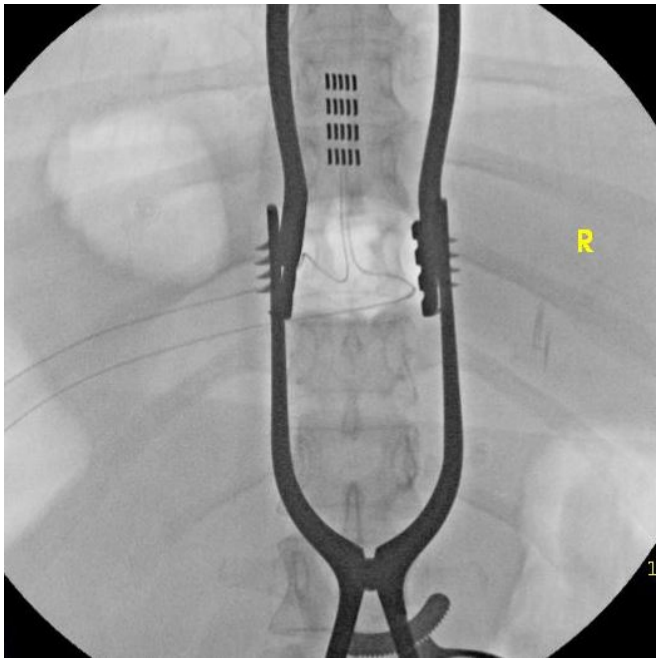

Figure 1A: AP view fluoroscopic X-ray showing an implanted Abbott Medical Penta 3 mm Lead, 60 cm; SCS Paddle Lead. The image shows the paddle leads placed near the spinal cord. The "R" in the image indicates the right side of the patient.

Figure 1B: Initial spinal cord stimulator parameters at recorded at date of SCS implantation. Unchanged at day 3-month interval.

Discussion

Compartment Syndrome is a complex pathological state where increased intracompartmental pressure, primarily in the lower extremities, can precipitate a cascade of detrimental events ranging from ischemic injury to irreversible tissue and nerve damage. This syndrome, influenced by a spectrum of etiologies from traumatic injuries to repetitive exertional activities, presents unique clinical dilemmas, especially in its chronic form which often resists standard treatment modalities [7]. While the acute version of this syndrome requires surgical action, the chronic type, can be subtle and frequently resistant to conventional treatments, as highlighted in our case.

The transition from acute to chronic stages of compartment syndrome particularly complicates management strategies, as the long-term sequelae of sustained intra-compartmental pressure may not be as immediately apparent or responsive to conventional surgical interventions like fasciotomy. In the chronic variant, known as Chronic Exertional Compartment Syndrome (CECS), patients may experience a recurring or persistent symptomatology that subtly undermines their quality of life and physical functionality [15].

The presented case of a 31-year-old female illustrates the typical progression of compartment syndrome, exacerbated by increased physical activity, and unresponsive to conventional therapies including conservative management and fasciotomy. The patient's protracted journey, marked by recurrent pain and functional limitation, underscores the intricate nature of compartment syndrome and the challenges it poses in terms of accurate diagnosis, effective management, and the pursuit of lasting relief. In this case, the initial conservative approach, including physical therapy and conservative management of stress fractures, failed to provide lasting relief. Bilateral fasciotomies with revisions yielded only temporary symptom abatement, with the patient experiencing a symptomatic resurgence in her left lower extremity.

In this context, SCS, traditionally reserved for neuropathic pain syndromes, emerges as a novel and promising alternative for compartment syndrome. Our patient's significant and persistent pain relief following SCS implantation exemplifies the device's capacity to modulate aberrant neural pathways and alter pain perception. This neuromodulatory technique offers a non-pharmacological, reversible approach to pain management, distinct from the irreversible nature of surgical fasciotomy, which may entail complications and a risk of morbidity from repeated interventions [18].

The implementation of SCS in compartment represents a groundbreaking application of this technology, broadening its use to encompass refractory musculoskeletal conditions. The favorable outcome in our patient's case, with a sustained reduction in pain of >90%, suggests that SCS may be a viable component in a multidisciplinary treatment strategy for compartment syndrome, offering an alternative for patients who have not benefited from traditional treatments. The reduction in pain and improvement in functional outcomes associated with SCS may decrease the reliance on surgical procedures and pharmacologic intervention, which, while sometimes necessary, do not always offer a sustainable solution and have high abuse potential. While this case highlights the therapeutic potential of SCS in chronic exertional compartment syndrome, marking a paradigm shift in treatment approaches, it's important to acknowledge that there is a paucity of research and case reports on this topic and that the field would benefit from more case reports and Randomized Control Trials (RTC). The interdisciplinary nature of this intervention, integrating medical, surgical, and technological expertise, represents a new phase in patient-centric care that prioritizes individualized treatment plans and aims for superior clinical outcomes.

The application of SCS in the treatment of compartment syndrome illustrates the expanding capabilities of neuromodulation in managing complex pain syndromes. It reinforces the importance of considering innovative, interdisciplinary approaches when conventional treatments fail, paving the way for patient-specific strategies that hold the promise of improved life quality and functional recovery. The advancement of SCS has expanded their clinical applications, as evident from our case study underscores the potential of interdisciplinary collaborations in enhancing treatment outcomes. While surgical fasciotomy is a mainstay for compartment syndrome, neuromodulatory techniques like the SCS present promising alternative strategies. As the trajectory of medical therapeutics continues to evolve, such interdisciplinary collaborations offer a new era of patient care, characterized by individualized treatments and enhanced patient outcomes.

Declarations

Data availability statement: Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Author contributions: JD and KA responsible for manuscript preparation, writing, and editing MP and NT were responsible for overseeing case and manuscript.

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Competing interests: The authors declare no competing interests.

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