BREAKING THE PAIN-OPIOID CYCLE: THE PROMISE OF SPINAL CORD STIMULATORS

By

Allisyn Rosga

A Thesis Submitted to the W.A. Franke Honors College

In Partial Fulfillment of the Bachelor's Degree

With Honors in

Physiology

THE UNIVERSITY OF ARIZONA

M A Y 2 0 2 5

Approved by:

Dr. Mohab Ibrahim

Department of Anesthesiology

Acknowledgements

I would like to express my greatest thanks to everyone who helped me along the journey of completing this thesis.

First and foremost, I extend my sincere thanks to Dr. Ibrahim for allowing me to shadow him for the past two years. The invaluable experiences that I was provided with will last a lifetime. His guidance throughout this writing process, along with his insight and knowledge has been instrumental.

I would also like to thank Dr. Rankin and Dr. Weinstein for their encouragement, constructive feedback, and the extensive resources they provided, all of which have been essential to my research. Additionally, I appreciate Dr. Martin for supplying the template that enabled me to transition this paper into a poster format.

Thank you to my peers for providing support and thoughtful criticism to successfully complete our theses together.

Lastly, I would like to thank my friends and family. I could not have gotten through this without them. The emotional support and encouragement throughout this entire process meant more to me than words can express.

Without the support and guidance of all of these individuals, this thesis would not have been possible. I am truly grateful for their contributions.

Table of Contents

Abstract

Introduction: Chronic pain affects approximately 20% of U.S. adults, imposing an economic burden of billions of dollars annually. The use of opioids for pain management has contributed to a public health crisis, with over two million Americans diagnosed with opioid use disorder. Non-pharmacological options, like spinal cord stimulators (SCS), offer a promising management option.

Methods: A comprehensive literature review was conducted using a variety of databases. Keywords included “chronic pain”, “opioid use disorder”, “pain management”, and “spinal cord stimulation”. Inclusion criteria focused on studies published in peer-reviewed journals discussing SCS efficacy in adults with non-cancer-related chronic pain.

Results: Evidence implies SCS significantly reduces pain and opioid consumption in patients with chronic pain. It is most effective in those with neuropathic pain. Improvement in quality of life, functionality, and patient satisfaction were mentioned. Long-term outcomes require further research.

Discussion: SCS is a promising solution to chronic pain and opioid dependency through the disruption of pain signaling and modulation of neural pathways. Challenges like high costs, invasive procedures, and variability of outcomes in patients need to be addressed.

Conclusion: SCS is a favorable alternative to opioids for managing chronic pain. Further research is needed to optimize patient selection, refine techniques, and address accessibility to maximize the impact on the population.

Introduction

Chronic pain management is an important area of research due to the size of the population affected and the current opioid epidemic. In the United States, approximately one in five adults experience

chronic pain.[1] This disease puts a significant economic burden on the U.S., costing between $560-635 billion each year in healthcare expenses and lost productivity.[2] Given these costs it is important to recognize the broader impact on patients' well-being.

As chronic pain persists, many patients begin to use pharmacological treatments, specifically opioids, to manage their pain. However, this reliance has contributed to the opioid epidemic, a current public health crisis. In 2020, 1.4 million people in the United States were diagnosed with a prescription opioid use disorder (OUD).[3] Individuals are using both prescription and illicit opioids to treat chronic pain. On average opioids provide 50-70% pain relief which is what makes the treatment option so appealing.[3] The appeal for opioids and their associated risks has caused health professionals to research and shift toward non-opioid management methods. Given the risks, there is an urgent need for alternative pain management strategies that can provide relief without developing dependence.

Spinal cord stimulators (SCS) are a promising chronic pain management option. Studies suggest SCS can provide significant pain relief for patients, in turn decreasing the need for opioid use.[4] This review will begin by examining the prevalence and impact of chronic pain and its association with the opioid epidemic. Next, it will explore the scientific basis of SCS and analyze recent studies evaluating its effectiveness in pain management and opioid reduction. Disparities in access to SCS will be addressed, and policy recommendations and strategies to improve this will be discussed. Synthesizing current and relevant evidence, while identifying gaps in the research, will help increase the understanding of SCS and the vital role the treatment has in chronic pain management.

Background

The International Association for the Study of Pain defines chronic pain as pain that lasts for three months or longer.[2] Chronic pain is an unpleasant experience that involves sensory and emotional

aspects making treatment plans complex. There are specific alterations in the peripheral and central nervous systems that contribute to the overall decline in quality of life seen in those with this disease.[2] Viewing this condition as a disease is key to shift providers' focus from trying to eliminate the pain to trying to effectively manage it.

Chronic pain is classified on multiple levels. Nociceptive pain is caused by actual or potential tissue damage which activates neural pathways causing the sensation of pain.[2] This is the most common type of pain. Neuropathic pain originates from damage or disease affecting the somatosensory nervous system.[2] Symptoms can be numbness, discomfort from a non-painful source, and sudden severe episodes of pain.[2] Nociplastic pain is caused by maladaptive changes affecting pain processing and modulation without evidence of any tissue or nerve damage.[2] In addition to these classifications, pain can be classified as acute, subacute, or chronic based on the duration. Acute lasts less than one month, subacute between one and three months, and chronic more than three months. Physicians may add the anatomical location the chronic pain originates from. Lastly, chronic pain is often split between cancer pain and chronic noncancer pain.

Those with chronic pain experience many disparities that affect their quality of life. There are severe limitations when it comes to daily activities. Simple tasks like exercise, self-care, household chores, and recreational activities become increasingly difficult. Chronic pain is seen to cause increased rates of anxiety and depression, especially in women.[5] The battle between mental health and chronic pain is often a never-ending cycle. Pain worsens mental health, and in turn, mental health struggles can intensify the perception of pain.

The toll chronic pain takes on individuals' lives shows the necessity of effective treatment strategies. There are multiple treatment options for this disease (refer to Table 1), but the goal is to

improve quality of life while minimizing risks. Many current approaches incorporate a combination of pharmacological and non-pharmacological therapies, all with their pros and cons.

Table 1: Pharmacological and Nonpharmacological Treatment Options

Treatment Type	Examples	Mechanism of Action	Considerations
Pharmacological Treatment Options			
NSAIDs	Oral and topical formulas	First-line treatment for non-neuropathic pain[2]	Long-term use: gastrointestinal, renal, and cardiovascular complications[6]
Antidepressants	TCAs, SNRIs	Alters neurotransmitter levels, effective for neuropathic and non-neuropathic pain[7]	Side effects limit widespread use
Anticonvulsants	Gabapentin, Pregabalin	Reduces excitatory neurotransmitter release, effective for neuropathic pain[2]	Side effects include sedation and dizziness
Other Pharmacological Options	Muscle Relaxants, Nerve Growth Factor Inhibitors, Tramadol, Capsaicin & Lidocaine Patches, Ketamine Infusions	Varies by drug (muscle relaxation, nerve inhibition, opioid effects, localized relief)[2]	Potential benefits but also risks such as sedation, addiction (opioids), and need for further research (ketamine)
Opioids	Morphine, Oxycodone, etc.	Reserved for severe pain, acts on opioid receptors	High risk of tolerance, dependence, addiction; limited long-term effectiveness [3]
Non-Pharmacological Treatment Options			
Physical Therapy	Strength training, mobility exercises	Improves mobility, strength, and reduces pain	Consistency for long-term benefits
Massage Therapy	Soft tissue manipulation[2]	Provides short-term pain relief	Effectiveness varies by individual
Cognitive Behavioral Therapy (CBT)	Psychological techniques	Alters perception and reaction to pain[8]	Helps improve quality of life
Biofeedback	Electronic monitoring	Helps control autonomic bodily functions, reduce muscle tension and regulating responses to pain[2]	Requires training and patient engagement
Acupuncture	Traditional Chinese medicine technique	Improves pain perception and stress levels[3]	Efficacy varies by individual and type of pain
Spinal Manipulation	Chiropractic adjustments	Applies controlled force to joints for mobility and pain reduction[3]	Must be performed by trained professionals
Other Complementary Therapies	Yoga, Tai Chi, Qigong	Integrates movement and mindfulness for pain management	Can be used alongside conventional medical treatments
Spinal Cord Stimulation	Spinal Cord Stimulator	Electrical pulses alter the chemical environment in the spinal cord, blocking pain signals to the brain	Post surgical complications

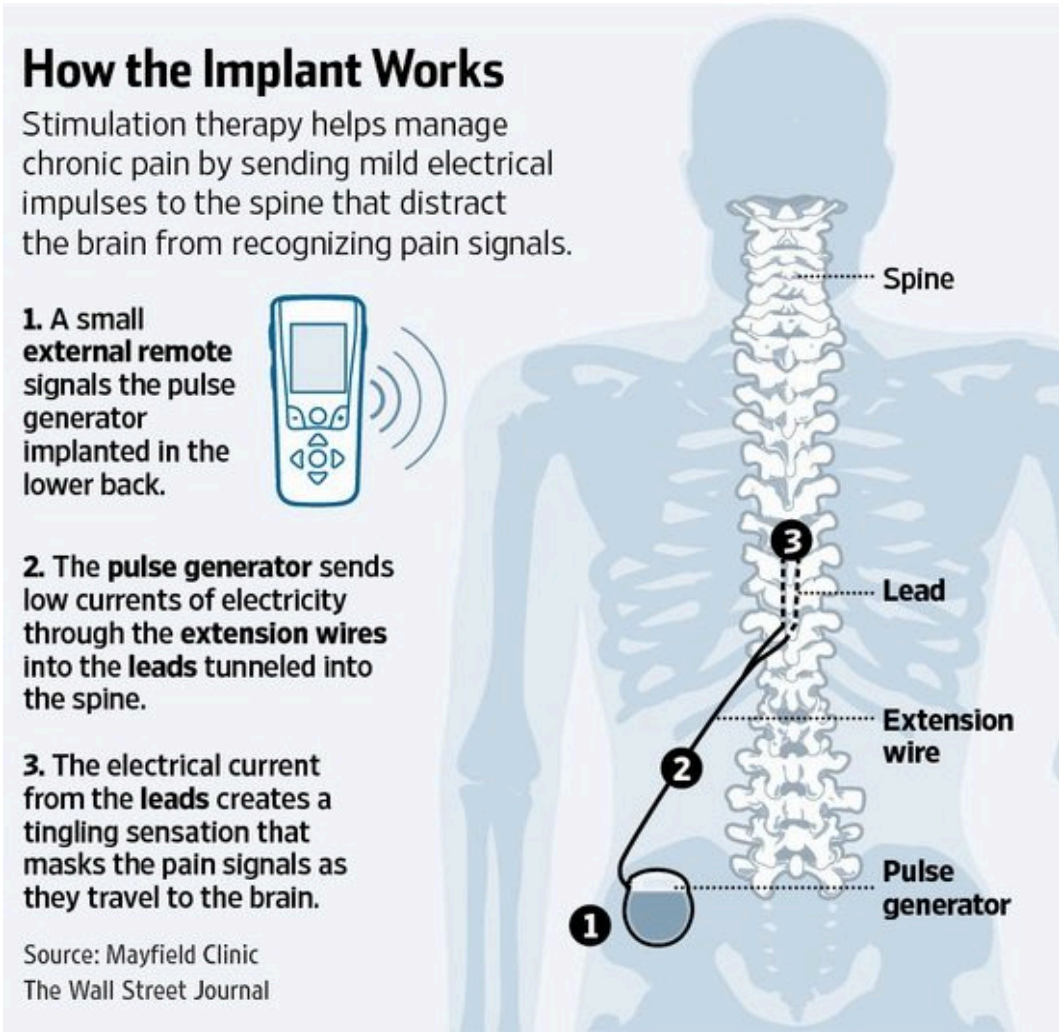
Non-pharmacological treatments are necessary components of comprehensive chronic pain management. These are used as first-line treatments due to their limited risks along with their potential benefits. It is important to remember that pharmacological treatments are not a cure for chronic pain. Chronic pain requires a multifaceted approach, which is key in managing this disease. There is limited evidence for the long-term benefits of pharmacological treatments due to the difficulty of conducting long-term placebo-controlled trials.[2] They also come along with many side effects, tolerance developments, and dependence, especially with opioids. The longer the duration of the prescription the higher the risk.

There is a significant public health burden associated with the opioid crisis. Widespread use of opioids for chronic pain, paired with the potential for misuse, abuse, and overdose has created a health challenge with many consequences. Patients who receive opioids for chronic pain have a higher probability of developing OUD. OUD disrupts normal functioning affecting one's ability to meet responsibilities at work, school, and within one’s family. Factors such as psychiatric comorbidity, stress, and specific pain conditions can elevate the risk for OUD.[9] Patients who try to stop using opioids have an elevated risk of suicide, which is already significantly elevated in the chronic pain population.[3] On top of this, there is a significant financial burden that is caused by decreased productivity, healthcare expenses, and costs associated with the criminal justice system.

There are extreme health inequities when it comes to access to appropriate pain management resources. To mitigate opioid dependence, there is a need for complementary treatments. All individuals, regardless of their background, deserve to have access to appropriate, affordable, and effective pain care. Failure to address this inadequacy allows the opioid crisis to continue to flourish, especially among vulnerable populations.

One pain management option that could help the problems of chronic pain and OUD is spinal cord stimulators. SCS is a treatment that uses an electrical device with leads that are implanted in the epidural space of the spinal canal, delivering precise electromagnetic waves to the spinal cord to disrupt the transmission of pain signals to the brain (refer to Image 1).[10] The precise mechanisms by which spinal cord stimulation provides pain relief are not fully understood, given the extreme complexity of the interaction of the spinal cord and supraspinal effects that modulate pain-signaling pathways.

Image 1: Mechanism of Spinal Cord Stimulator



The initial theory behind SCS was dorsal column stimulation based on the gate control theory of pain. This happens through the stimulation of large AB fibers in the dorsal columns which inhibit the transmission of pain signals carried by C fibers in the dorsal horn blocking the perception of pain.[11] The stimulation induces paresthesias through the stimulation of sensory nerve fibers in the skin.[11] This form of SCS provides relief for chronic neuropathic pain with little impact on acute nociceptive pain which contradicts the gate control theory's prediction.

SCS modulates pain through a variety of mechanisms involving multiple anatomical and neurochemical processes. Dorsal column stimulation is a key component in the mechanism behind SCS, and it contributes through presynaptic inhibition (PSI). PSI decreases neurotransmitter release from afferent fibers and can induce plastic changes in presynaptic inhibitory neurons over time.[11] The dorsal horn is crucial for pain processing, and it is the primary target site of SCS.[11] This site is strongly influenced by electromagnetic fields generated by the leads in the midline epidural space, and the superficial dorsal horn stimulation is seen to be more potent than the adjacent dorsal roots.[11] The hyperexcitability of wide dynamic range neurons in the dorsal horn is suppressed through stimulation which is critical for neuropathic pain.[11] A new hypothesis suggests that SCS may stimulate the dendrites of dorsal horn islet cells which are inhibitory interneurons that further regulate pain signaling.[11] SCS also induces neurochemical changes. Neurotransmitters like GABA, serotonin, noradrenaline, and dopamine have increased activity, helping to modulate pain. Other supraspinal effects alter activity and functional connectivity in brain regions associated with pain perception.[11] This can reduce the negative emotional aspects of pain, and it can adjust pain thresholds.

SCS has been employed for chronic pain management since the late 60s and continues to go through tremendous advancements. There is now a wide array of stimulation methods,

programming options, and waveform modalities, as well as the use of a trial stimulation period before the permanent placement of SCS. Allowing patients to experience the stimulator and see if it is effective in reducing their pain.

The installation and settings on the devices have improved drastically. Anatomically guided neural targeting uses three-dimensional imaging to position the leads and deliver stimulation to specific nerve fibers associated with the pain.[10] Sub Perception-based electric field targeting utilizes electric fields to stimulate the spinal cord without creating a tingling sensation reported by some patients.[10] This allows pain relief without a noticeable side effect. Fast acting sub perception therapy is similar, however, it is the delivery of rapid, subsensory electrical pulses, which may provide faster pain relief compared to the traditional methods.[10] Multiple waveform programming in modern devices can deliver a variety of waveforms, high frequency, burst, and tonic stimulation.[10] Being able to alter these components allows for personalized therapy as every pain is different. Despite these improvements, there are still gaps in understanding the long-term effectiveness, patient selection, and optimal stimulation.

Methods

The literature review was conducted by performing comprehensive searches of multiple databases, including PubMed, Scopus, Cochrane Library, and others**.** Keywords like “chronic pain”, “opioid use disorder”, “pain management”, “spinal cord stimulation”, “treatment efficacy”, and “clinical trials” were used to gather the collected information. The inclusion criteria for studies were clinical trials and observational studies that evaluated treatment options for chronic pain, studies that were published in a peer-reviewed journal between 2015 and 2025, and studies that provided quantitative data on pain relief, opioid use, and correlated demographic information.

Studies included in this review focused on adults with chronic pain not originating from cancer. Studies that investigated the efficacy of spinal cord stimulators and reducing pain and opioid consumption were the main focus.

Relevant data including participant demographics, intervention details (e.g., type of spinal cord stimulator, duration of use, protocols), and outcomes were collected. Outcome measures of interest were pain relief, quality of life, opioid consumption reduction, and functional improvements.

The evidence was then synthesized where applicable to assess the overall trends and outcomes across studies. Limitations of this review include the potential for bias within the studies, as well as differences amongst outcome measures, treatment protocols, and patient populations. Combining the results from all of the studies to provide a general analysis of the effectiveness of spinal cord stimulators in chronic pain management was the primary method of this review.

Results

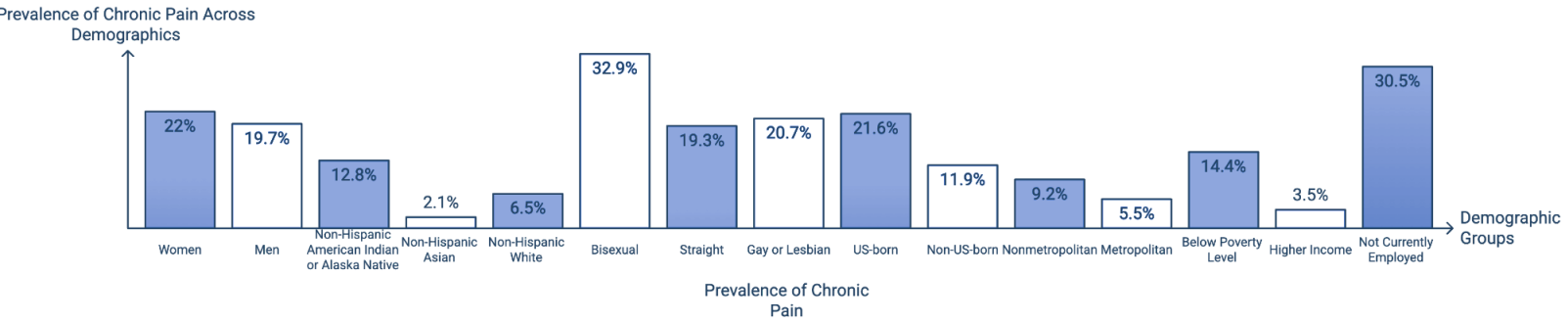
In 2021, 20.9 percent of US adults, around 51.6 million people, reported experiencing chronic pain.[1] Of these, 6.9% (17.1 million people) were diagnosed with high-impact chronic pain, a subset of chronic pain defined as pain that limits life or work activities on most or every day.[1]

Certain demographic groups experience chronic pain more frequently than others. Women are more likely than men to experience chronic pain, with 22% of women reporting this condition compared to 19.7% of men.[1] As age increases chronic pain prevalence increases, and it is higher among certain racial and ethnic minorities. Non-Hispanic American Indian or Alaska Native adults have a significantly higher prevalence of chronic pain (12.8%) when compared with non-Hispanic Asian adults (2.1%) and non-Hispanic White adults (6.5%).[1]

Sexual orientation appears to influence chronic pain prevalence, with 32.9% of bisexual adults reporting chronic pain compared to 19.3% of heterosexual adults and 20.7% of gay or lesbian adults.[1] Marital status is another factor; individuals who are divorced or separated have a higher prevalence of chronic pain compared to those who are married.[1]

Geographical and socioeconomic factors further contribute to disparities (refer to Figure 1). US-born adults have a higher prevalence of chronic pain (21.6%) when compared to those born outside of the US (11.9%).[1] Adults who live in nonmetropolitan areas (9.2%) and families with incomes below the federal poverty level (14.4%) report higher rates than those who live in large metropolitan areas (5.5%) and those with higher incomes (3.5%).[1] High-impact chronic pain is more prevalent in these groups. Veterans are a group that is disproportionately affected by chronic pain. Individuals who are not currently employed but have previously worked have a higher prevalence of chronic pain (30.5%) and high-impact chronic pain (13.4%).[1]

Figure 1: Geographical and Socioeconomic Factors Contributing to Prevalence of Chronic Pain



Those who are affected by this disease tend to have worsening mental health conditions, in turn worsening pain conditions. This cycle leads to increased suicidal ideations and attempts. 20% of those with chronic pain experience suicidal thoughts while 5 to 14% have attempted suicide.[5] This

is twice the rate found in the general population. Sleep disorders further complicate life for those affected by this disease, decreasing one's performance during the day.[5] Social interactions can become minimal, and being unable to perform tasks at work can make it hard to stay employed.[5] The economic burden has a large impact on someone managing chronic pain as healthcare costs continue to increase, and those with chronic pain often cannot work leading to further financial strain. In some cases, this causes patients to turn to opioid medications for pain management, potentially contributing to the opioid epidemic in the United States.

Statistics reveal the extent of opioid misuse and its consequential relationship to public health. Recent data shows that there has been a decline in opioid prescriptions in the United States. In 2019, the opioid dispensing rate was 46.8 prescriptions per 100 persons, compared to 37.5 per 100 persons in 2023.[12] Although there has been a decline in opioid prescribing in recent years, the overall impact opioids have is still significant. A 2018 study found that approximately 6% of U.S. adults had used one or more prescription opioids in the past 30 days.[3] Data from the CDC shows approximately 727,000 people died from opioid overdoses, from both illicit and prescription opioids between 1999 and 2022.[13] The prevalence of opioid addiction has increased throughout the years. A 2015 meta-analysis estimated the prevalence of opioid analgesic addiction in the US population was around 8-12%.[9] While more recent studies, using DSM-5 diagnostic criteria, have reported prevalence estimates of 23.9-26.5% of long-term opioid therapy patients having prescription OUD, with 5.2-9.0% experiencing moderate to severe OUD.[3] These findings show the ongoing need for effective pain management interventions to address opioid misuse and addiction.

Spinal cord stimulators can assist in the decrease of the ongoing opioid epidemic among the chronic pain population. According to a digital health platform analysis of 7,000 patients who were experiencing chronic pain, 90.1% had a successful trial period with their SCS, and 80.4% of those

chose to receive a permanent implant.[14] In order to be considered a successful trial the patient must receive at least 50% pain relief. Proving that SCS is an adequate pain management option. After 2 years, one study saw that close to 60% of patients retained a significant pain reduction.[15] Patients acknowledged an improvement in pain relief (89%) and daily life activity (82%), and were satisfied (91%) and willing to undergo the treatment again (93%).[15] Clinical trials have proven the efficacy of SCS in chronic lower back and leg pain, failed-back-surgery-syndrome, complex regional pain syndrome, and painful diabetic neuropathy.[14] Further research is needed in regards to long term effects of SCS.

There have been some studies completed in regards to SCS direct effect on the use of opioids. A study from 2023 saw that patients, before SCS treatment, had an average morphine milligram equivalent (MME) of 52.63, then at the time of SCS implant their MME decreased to 35.73.[16] After six months of implantation, the average MME was 24.64.[16] It is clear that the amount of opioids being used by patients decreased, and the MME was reduced by more than 50% from baseline to the 6-month mark. Half of those participating were able to terminate their opioid use entirely after six months of having their SCS.[16] Multiple studies show that patients have improved quality of life, were able to become more active, had a decrease in opioid usage, and the negative impact of pain on their daily life decreased.

There are specific demographic factors that affect the rates of success for SCS. For example, older patients are more likely to explant their SCS.[4] Those with active psychological disorders, ongoing substance abuse, obesity, smoking, and high baseline opioid use tend to have less success with SCS.[17] There are significant racial disparities when it comes to those who receive SCS. Black, Asian, Hispanic, and North American Native patients were significantly less likely to receive SCS compared to White patients.[18] Those with lower socioeconomic status were also significantly less

likely to receive this management option.[18]

There is still room for improvement as this is a new management technique. Nearly 30-40% of patients report inadequate relief beyond 24-36 months.[4] Long-term effects need to be researched further to improve the success of this device. It is seen that in approximately 2-5% of cases, there is potential for procedural pain, infection, lead fracture, lead migration, and headache due to inadvertent dural puncture.[4] As with any long-term implanted treatment device, adequate follow-up, re-programming, wound management, and device care is necessary.[17]

A comprehensive pain management plan is still needed. Chronic pain is an everlasting disease that likely will never have 100% pain relief. Implementing multiple management options on top of SCS, excluding opioids, will help provide the most adequate pain relief.

Discussion

The results of this review highlight the potential for spinal cord stimulators to serve as a non-opioid pain management strategy for chronic pain patients, ultimately reducing opioid dependence. The high success and permanent implantation rate of SCS shows that it provides meaningful pain relief for many patients, while staying away from the dependence that is seen with opioids.

Studies indicate a substantial reduction in opioid use after SCS implantation. The average decrease in MME being greater than 50%, shows the potential to alleviate opioid dependence in chronic pain patients. Further data supports SCS in opioid reduction, as a study showed half of the patients eliminated opioid use entirely after implantation.

The opioid epidemic continues to be a significant public health crisis with over 700,000 related deaths between 1999 and 2022. While opioid prescription rates have declined in recent years many

still remain dependent. Some studies estimate that around a quarter of long-term opioid therapy patients meet the criteria for prescription opioid use disorder. Expanding access to SCS could play a critical role in decreasing opioid dependency by providing a safer long-term alternative for pain relief.

However, there are disparities in accessibility to SCS. Certain racial, socioeconomic, and demographic groups (Black, Asian, Hispanic, Native American, and those with lower income levels) are significantly less likely to receive SCS treatment. Those who live in non metropolitan areas also have limited access to SCS. Moreover, not all patient populations have the same success rate. Older adults and those with comorbidities tend to have poorer outcomes. Addressing these disparities and success rates through targeted education, advocacy, and policy reform could enhance the impact of SCS on the opioid epidemic.

To promote greater adoption of SCS, partnering with organizations such as the American Academy of Pain Medicine and the American Society of Anesthesiologists is crucial. Working with them is necessary to help promote SCS in treatment guidelines in order to help decrease the opioid epidemic. Additionally, providing continuing medical education courses on SCS to make sure providers know the benefits and improvements that these devices continue to see every year will allow for the best outcome. Offering these courses in nonmetropolitan and low socioeconomic areas could help increase access to this treatment where specialists are limited.

Having people who are a part of these organizations attend government hearings or insurance meetings will be the best way to ensure equitable access to SCS. Specifically, proposing policy amendments to Medicare and Medicaid that justify the device as a cost-saving intervention for the disease compared to long-term opioid usage. The device also helps decrease emergency room visits

and hospitalizations in turn saving insurance companies money. Advocating for laws mandating insurance coverage for SCS will help as well, as we have seen this done for other chronic conditions.

In order to reach the patients directly, developing educational materials and campaigns to inform those with chronic pain that this is an option could help spread interest in use of the device. Using the news and social media campaigns to highlight those who have had success with the device and how it has helped reduce or eliminate their use of opioids is a strong method. In order to increase access in rural areas, partnering or developing a nonprofit to provide mobile pain clinics, telemedicine consultations, and more funding for rural hospitals to provide SCS implantation and follow up care could cause an extreme decline in the rate of opioid usage.

There are still limitations in the current research surrounding SCS. There are inconsistencies amongst study methods, especially in regards to follow up measures. The long term effectiveness is still not well researched, and there are complications and risks that need to be studied in order to find solutions and prevention methods. Future studies should focus on standardizing long term outcome measures for SCS effectiveness, assessing the durability of opioid reduction over years, and personalized patient selection criteria.

Conclusion

This review demonstrates that spinal cord stimulators provide a significant reduction in opioid use among chronic pain patients, making them a promising non-opioid pain management option. Studies show that patients experience substantial opioid reduction and many eliminate use entirely. Given the ongoing opioid epidemic and the limitations and side effects of pharmacologic treatments, SCS could be an important aspect in the mitigation of opioid dependence.

Barriers to accessibility remain, which is why targeted interventions to promote SCS are necessary. Initiatives should focus on expanding insurance coverage to reduce cost barriers, integrating SCS into clinical guidelines as a first-line treatment, providing continued education to medical professionals and patients to increase awareness and access, and investing in rural healthcare to improve implantation and follow up care. These strategies will help target the vulnerable populations (racial minorities, low socioeconomic groups, rural residents).

Further research should focus on long term outcomes, patient selection strategies, and cost effectiveness to define the role of SCS in chronic pain management. Taking these steps will ensure that SCS becomes a widely accessible and effective alternative, ultimately reducing opioid dependence and improving patient lives.

References

1. Rikard SM. Chronic Pain Among Adults — United States, 2019–2021. *MMWR Morb Mortal Wkly Rep*. 2023;72. doi:10.15585/mmwr.mm7215a1
2. Cohen SP, Vase L, Hooten WM. Chronic pain: an update on burden, best practices, and new advances. *The Lancet*. 2021;397(10289):2082-2097. doi:10.1016/S0140-6736(21)00393-7
3. Dowell D, Ragan KR, Jones CM, Baldwin GT, Chou R. CDC Clinical Practice Guideline for Prescribing Opioids for Pain — United States, 2022. *MMWR Recomm Rep*. 2022;71(3):1-95. doi:10.15585/mmwr.rr7103a1
4. Shanthanna H, Eldabe S, Provenzano DA, et al. Evidence-based consensus guidelines on patient selection and trial stimulation for spinal cord stimulation therapy for chronic non-cancer pain. *Reg Anesth Pain Med*. 2023;48(6):273-287. doi:10.1136/rapm-2022-104097
5. Cáceres-Matos R, Gil-García E, Barrientos-Trigo S, Porcel-Gálvez AM, Cabrera-León A. Consequences of Chronic Non-Cancer Pain in adulthood. Scoping Review. *Rev Saúde Pública*. 2020;54:39. doi:10.11606/s1518-8787.2020054001675
6. Chou R, A. Turner J, B. Devine E, et al. The Effectiveness and Risks of Long-Term Opioid Therapy for Chronic Pain: A Systematic Review for a National Institutes of Health Pathways to Prevention Workshop. *Ann Intern Med*. Published online February 17, 2015. doi:10.7326/M14-2559
7. Moore RA, Derry S, Aldington D, Cole P, Wiffen PJ. Amitriptyline for neuropathic pain in adults. *Cochrane Database Syst Rev*. 2015;2015(7):CD008242. doi:10.1002/14651858.CD008242.pub3
8. Williams AC de C, Fisher E, Hearn L, Eccleston C. Psychological therapies for the management of chronic pain (excluding headache) in adults. *Cochrane Database Syst Rev*. 2020;2020(8):CD007407. doi:10.1002/14651858.CD007407.pub4
9. López-Arteaga T, Moreno-Rubio C, Mohedano-Moriano A. Risk factors for opioid addiction in chronic non-cancer pain. *Heliyon*. 2023;9(9):e19707. doi:10.1016/j.heliyon.2023.e19707
10. Rauck RL, Loudermilk E, Thomson SJ, et al. Long-term Safety of Spinal Cord Stimulation Systems in A Prospective, Global Registry of Patients With Chronic Pain. *Pain Manag*. 2023;13(2):115-127. doi:10.2217/pmt-2022-0091
11. Jensen MP, Brownstone RM. Mechanisms of spinal cord stimulation for the treatment of pain: Still in the dark after 50 years. *Eur J Pain Lond Engl*. 2018;23(4):652. doi:10.1002/ejp.1336
12. CDC. Understanding the Opioid Overdose Epidemic. Overdose Prevention. November 1, 2024. Accessed February 4, 2025. https://www.cdc.gov/overdose-prevention/about/understanding-the-opioid-overdose-epidemic.html
13. CDC. Opioid Dispensing Rate Maps. Overdose Prevention. November 7, 2024. Accessed February 4, 2025. https://www.cdc.gov/overdose-prevention/data-research/facts-stats/opioid-dispensing-rate-maps.html
14. Venkatraman V, Bharmi R, Coletti F, et al. Real World Characterization of Chronic Pain, Success Rates and Implant Rates: Evidence from a Digital Health Platform of Patients Undergoing Spinal Cord Stimulation Evaluations. *J Pain*. 2023;24(12):2228-2239. doi:10.1016/j.jpain.2023.07.008
15. Brinzeu A, Cuny E, Fontaine D, et al. Spinal cord stimulation for chronic refractory pain: Long-term effectiveness and safety data from a multicentre registry. *Eur J Pain*. 2019;23(5):1031-1044. doi:10.1002/ejp.1355
16. Jacobs BM, Kerr MS, Broadnax JP, Anderson E. Spinal Cord Stimulation (SCS) reduces Morphine Milligram Equivalents (MME) in patients using Opioid analgesics for Chronic Non-Cancer Pain. *Interv Pain Med*. 2023;2(3):100275. doi:10.1016/j.inpm.2023.100275

17. Garcia K, Wray JK, Kumar S. Spinal Cord Stimulation. In: *StatPearls*. StatPearls Publishing; 2024. Accessed November 19, 2024. http://www.ncbi.nlm.nih.gov/books/NBK553154/
18. Jones MR, Orhurhu V, O'Gara B, et al. Racial and Socioeconomic Disparities in Spinal Cord Stimulation Among the Medicare Population. *Neuromodulation Technol Neural Interface*. 2021;24(3):434-440. doi:10.1111/ner.13373