REVIEW

The effect of spinal cord stimulation on pain medication reduction in intractable spine and limb pain: a systematic review of randomized controlled trials and meta-analysis

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Objective: To synthesize the evidence regarding the effect of spinal cord stimulation (SCS) on opioid and pain medication reduction in patients with intractable spine or limb pain.

Methods: A comprehensive literature search was conducted to identify RCTs of patients with chronic back and/or limb pain of greater than one year duration. Only comparative studies were included (ie, conventional SCS vs medical therapy, conventional SCS vs high-frequency SCS) and were required to have a minimum follow-up period of 3 months. Random effect meta-an alysis was used to compare the three interventions. Results were expressed as odds ratio (OR) or weighted mean difference (WMD) with 95% confidence intervals (CI).

Results: We identified five trials enrolling 489 patients. Three of the trials reported the results as a number of patients who were able to reduce or eliminate opioid consumption in the SCS vs medical therapy group. The odds of reducing opioid consumption were significantly increased in the SCS group compared to medical therapy (OR 8.60, CI {1.93–38.30}). Two of the trials reported the results as mean medication dose reduction as measured by the Medication Quantification Scale (MQS) in the SCS group vs medical therapy group. MQS score significantly decreased in the SCS group and not in the medical group (WMD −1.97, 95% CI {−3.67, −0.27}). One trial reported a number of patients in high-frequency SCS who were able to reduce opioids vs number of patients in conventional SCS group who were able to reduce opioids. Thirty-four percent of the patients in the high-frequency group and 26% of the patients in the conventional SCS group were able to reduce opioid consumption; however, there was not a significant difference between groups (OR 1.43, 95% CI {0.74, 2.78}). This trial also quantified the opioid reduction in morphine equivalent dosage (MED). In the high-frequency SCS group, average MED decreased by 24.8 mg vs average MED decrease of 7.3 mg in the conventional SCS group. Again, the difference between groups did not reach statistical significance (−17.50, CI {−66.27, 31.27}).

Conclusions: In patients with intractable spine/limb pain, SCS was associated with increased odds of reducing pain medication consumption. However, results should be treated with caution as available data were limited, and clinical significance of these findings requires further study.

Keywords: spinal cord stimulation, chronic back pain, painful diabetic neuropathy, chronic limb pain, high-frequency spinal stimulations, opioids, pain medications

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Introduction

The treatment of chronic non-cancer pain with opioid medications has increased dramatically.[1] In the late 1990s, the Joint Commission on Accreditation of Healthcare Organizations instituted pain as the fifth vital sign.[2] At the time, it was a commonly held belief that there was no ceiling on the dose of opioid medications required to treat pain. Beginning in the mid-1990s, opioid-related morbidity and mortality increased as the prevalence of opioid therapy for chronic non-cancer pain increased.[3] Since the mid-1990s, there have been over 100,000 opioid-related deaths in the United States.[3] From 1999 to 2010, the number of opioid deaths increased each year.[4] A Cochrane review concluded there is some evidence of very low to moderate quality for short-term efficacy of opioids to treat chronic low back pain, but no difference between opioids and non-steroidal anti-inflammatory drugs or antidepressants. The review ultimately advises that the initiation of long-term opioid use be done with extreme caution.[1] Given the high risk and questionable benefit of chronic opioid therapy for chronic pain, alternative pain management therapies are desirable.

Spinal cord stimulation (SCS) has been used as a therapy for chronic pain for over 40 years.[5] The Food and Drug Administration in the United States has approved SCS for chronic pain of the trunk and limbs. The most common indications for SCS include complex regional pain syndrome (CRPS), failed back surgery syndrome (FBSS), and intractable angina pectoris.[6] Over the past 20 years the number of spinal cord stimulators implanted has greatly increased; from 1997 to 2006 there was a 159% increase in spinal cord stimulator implants in the Medicare population alone.[7] Studies have demonstrated symptomatic improvement in patients with SCS. The PROCESS trial demonstrated the health-related quality of life increased in patients with FBSS who had spinal cord stimulators.[8] CRPS patients who undergo spinal cord stimulator implant in addition to physical therapy have significantly less pain than patients enrolled in physical therapy alone.[9] However, the evidence comparing the effect of SCS on opioid and pain medication reduction in chronic pain patients has not been well established. We conducted a systematic review and meta-analysis to synthesize the evidence about the effect of SCS on opioid and pain medication consumption.

Methods

The reporting of this systematic review follows the statement of Preferred Reporting Items for Systematic Reviews and Meta-Analysis.

Study eligibility

We limited the inclusion criteria to RCTs that enrolled patients with chronic and intractable back and/or limb pain of greater than one year duration. We used the definition of intractable or refractory pain as proposed by Deer et al: "Pain is defined as refractory when 1) multiple evidence-based biomedical therapies used in clinically appropriate and acceptable fashion have failed to reach treatment goals that may include adequate pain reduction and/or improvement in daily functioning or have resulted in intolerable adverse effects, and when 2) psychiatric disorders and psychosocial factors that could influence pain outcomes have been assessed and appropriately addressed".[10] Studies had to be comparative: comparing SCS to medical treatment or comparing one method of SCS to another method of SCS. The studies were required to have a minimum patient follow-up period of 3 months.

Literature search

A comprehensive literature search was conducted by a reference librarian. The principal investigator provided input on search terms. The search included the electronic databases MEDLINE, Embase, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, CINAHL, and Scopus, using various combinations of controlled vocabulary supplemented with keywords and key authors to search for studies of spinal stimulation, SCS, dorsal root ganglion stimulation, and neurostimulation. The detailed search strategy is in the Supplementary materials Table S1.

Reviewers worked independently to identify original studies eligible for further review by screening abstracts and titles in duplicates method. If a study was determined to be relevant, the full-text manuscript was obtained and reviewed for further assessment. Any inclusion or exclusion disagreements were discussed and reconciled by the senior investigators. Data sources, including citing articles and relevant systematic reviews, were searched manually for possible additional studies, and duplicates were excluded. Our literature search encompassed January 1, 1995– December 31, 2017. Our search included all languages. Figure 1 delineates further details of our search.

Data extraction and outcomes assessment

Two reviewers independently extracted data from each study, including patient demographics, baseline characteristics, study design variables, sample size, description of interventions, and outcome measures. The outcome measure of interest in this study was pain medication reduction. Pain medication outcomes were of two types in all of the manuscripts reviewed: 1) A binary outcome of achieving a reduction or elimination in opioids or 2) Reduction in pain medication as measured by the Medication Quantification Scale (MQS) or morphine equivalent dosing (MED).[11]

The risk of bias was assessed using the Cochrane Collaboration's Risk of Bias tool.[12] This tool assesses the risk of bias attributed to the method of randomization, allocation concealment, blinding of patients and all research personnel, baseline imbalance, and inclusion of all study subjects in primary and secondary data analyses consistent with intent-to-treat principles.

Data and statistical analysis

From each trial, we extracted a 2×2 table for binary outcomes and the mean, sample size and standard deviation for continuous outcomes. The effect size was pooled across trials using a random effects model and heterogeneity was expressed using the I squared statistic.[13] Results were expressed as odds ratio (OR) or weighted mean difference (WMD) with 95% confidence intervals (CIs). Statistical analysis was performed using Stata 15 software (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC).

Results
Literature search

The initial search resulted in 1,080 references. The first stage of article selection removed 1,033 references. There were many reasons for exclusion, the most common were: trials were not RCTs, trials did not study SCS, or the trial follow-up period was too short. Eventually, 12 trials reported in a total of 17 manuscripts were included. Three of the trials had two manuscripts and one had three, reporting outcomes for multiple follow-up periods. The selection process is shown in Figure 1. These 12 trials are reported in a separate paper examining pain outcomes.[14–16,18–26] The baseline characteristics of these 12 trials are included in Table 1. A total of five of these

trials reported outcomes of opioid or pain medication reduction. It was a secondary outcome in all trials (pain relief was the primary outcome). Follow-up ranged from 6 months to 2 years. The baseline characteristics of the included studies are shown in Table 2, and the quality assessments of the studies are shown in Table 3.

Risk of bias

Although the method of randomization was described in all trials, allocation concealment was reported in two of the five studies. None of the five trials blinded subjects or research personnel to group allocation. All five trials included an intent-to-treat analysis. Four of these trials were funded by companies that manufactured the neurostimulation device(s). One trial was funded by government or private research foundation. Overall, the risk of bias across all the trials for the outcome of opioid reduction was considered to be moderate.

Conventional SCS compared to medical therapy: number of patients decreasing pain medications

Three of the trials, Slangen, de Vos, and Kumar reported the results as a binary outcome: number of patients who were able to reduce or cease opioid consumption in the SCS group vs medical therapy group.

The Slangen trial randomized 36 patients with painful diabetic peripheral neuropathy in a 2:1 ratio to intervention (SCS) vs control (medical therapy).[14] At a follow-up of 6 months, 7 of 22 in the SCS group were able to reduce opioid use while none of the 14 in the medical therapy group reduced opioids. The difference between groups did reach statistical significance (OR 20.41, CI {1.08, 385.57})

The de Vos trial also included patients with painful diabetic peripheral neuropathy.[15] Sixty patients were randomized in a 2:1 randomization to either SCS or medical therapy. At baseline, 18 of 40 patients randomized to SCS used opioids and 11 of 20 patients randomized to medical therapy used opioids. 6 months after intervention, 3 of the 18 SCS patients ceased opioids vs 0 of the medical therapy patients. The difference between groups did not reach statistical significance (OR 2.83, CI {0.19, 77.76}).

The Kumar trial is a study of 100 patients with FBSS randomized 1:1 to intervention (SCS) or control (medical therapy).[16] This trial also demonstrated a trend

Table 1 Baseline characteristics of studies, pain outcomes

Intervention group				Control group				
Study	No. of patients	Age, years, mean	Male gender, %	No. of patients	Age, years, mean	Male gender, %	Follow-up months	Setting
De Vos, 2014[15]	40	58	62.5	20	61	65	6	Multicenter
Kemler, 2004[20]	36	40	39	18	35	17	24	Single Center
Kumar, 2007[16]	52	42.9	58	48	52	44	24	Multicenter
Slangen, 2014[14]	52	57.1	68	14	65.5	64	6	Two centers
De Andres, 2017[21]	26	51.6	57.7	29	53.4	37.9	12	Single Center
Spincemaille, 2000[18]	60	73	55	54	72	52	18	Multicenter
Jivegard, 1995[22]	51	73	56	26	73	53.8	18	Two centers
Deer, 2017[23]	66	52.4	48.7	66	52.5	48.7	12	Multicenter
Kapural, 2015[19]	92	54.6	38	87	55.2	41.4	12	Multicenter
North, 2005[25]	24	52	48	25	52	48	6	Single Center
North, 2005[26]	12	52	83.3	12	62	50	12	Single Center
Deer, 2017[24]	100	58.8	42.2	100	60.4	43.6	6	Multicenter

Table 2 Baseline characteristics of included studies

Intervention group				Control group				
Study	No. of patients	Age, years, mean	Male gender, %	No. of patients	Age, years, mean	Male gender, %	Follow-up months	Setting
De Vos, 2014[15]	40	58	62.5	20	61	65	6	Multicenter
Kumar, 2007[16]	52	42.9	58	48	52	44	24	Multicenter
Slangen, 2014[14]	52	57.1	68	14	65.5	64	6	Two centers
Spincemaille, 2000[18]	60	73	55	54	72	52	18	Multicenter
Kapural, 2015[19]	92	54.6	38	87	55.2	41.4	12	Multicenter

Table 3 Quality assessment and risk of bias

Study	Method of randomization	Allocation concealment	Blinding	Baseline imbalance	Intent-to-Treat analysis	Source of funding
Spincemaille 2000[18]	Yes	Yes	NR	No	NR	Grant from Sickness Funds Council (Health Insurance Executive Board), the Netherlands
Kumar 2007[16]	Yes	Yes	NR	Yes	Yes	Medtronic, Inc.
Slangen 2014[14]	Yes	NR	NR	Yes	Yes	Medtronic, Inc.
De Vos 2014[15]	Yes	NR	NR	No	Yes	St. Jude Medical
Kapural 2015[19]	Yes	Yes	NR	No	Yes	Nevro Corp.

toward greater odds of reducing opioids in the SCS group as compared to the medical therapy group. Nine of 50 patients in the SCS group ceased opioids vs 1 of 44 patients in the medical therapy group, but this did not reach statistical significance (OR 8.19, CI {0.98, 68.37}). This study also recorded average MED at 6 months based on survey data that included ranges, so patients were categorized by either "low" or "high" morphine equivalent scores. No baseline MED data was reported. At 6 months, the medical therapy patients in the "low" group averaged 96.9 MED vs 68.3 MED in the "low" SCS group. Medical therapy patients in the "high" group averaged 125 MED and SCS patients in

the "high" group averaged 76.8 MED. Again, the difference between groups did not reach statistical significance. It should be noted that the Kumar trial was extended to 24 months and reported in a separate paper with similar results.[17] We used the 6-month Kumar trial data rather than the 24-month data as there was a cross over component after 6 months and 30 medical therapy patients eventually crossed over to spinal stimulation.

As illustrated in Figure 2, when we pooled this data across these three trials using a random effects model, the odds of decreasing or eliminating opioid dose in the SCS group as compared to the medical therapy group
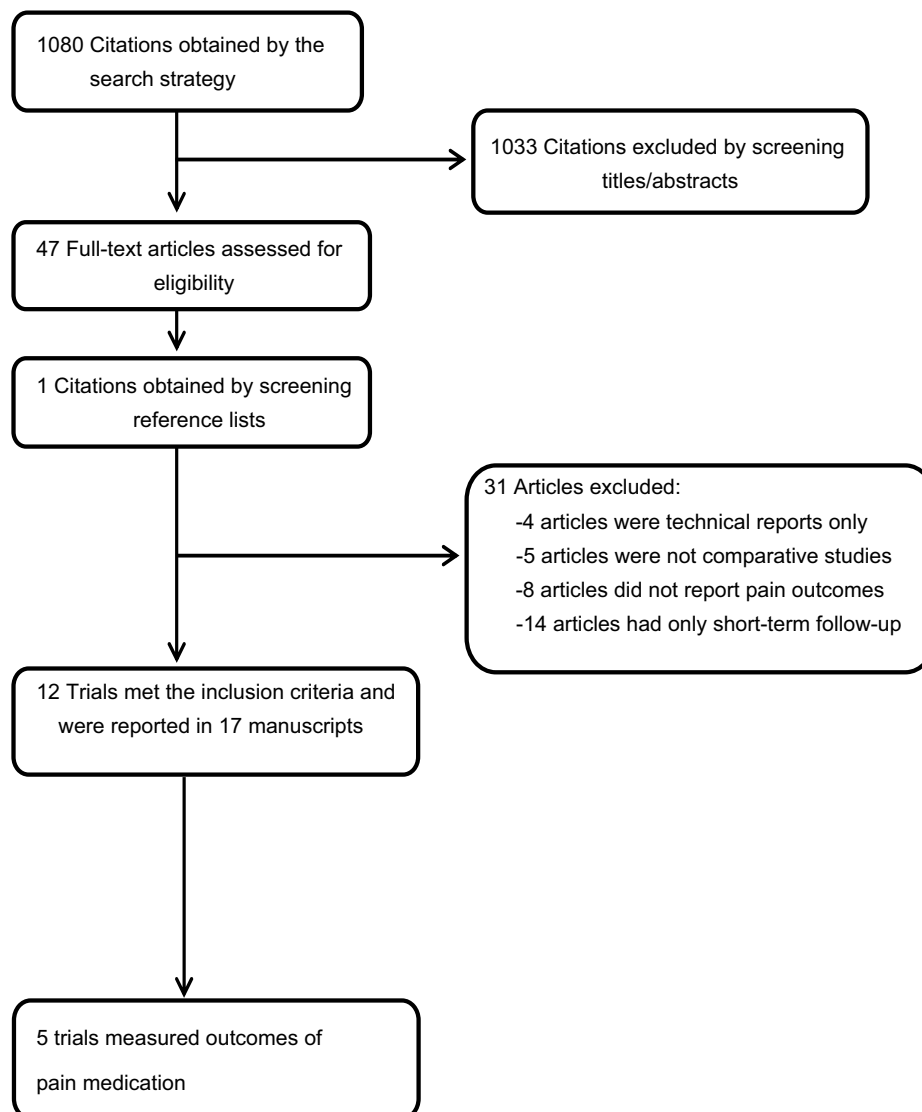

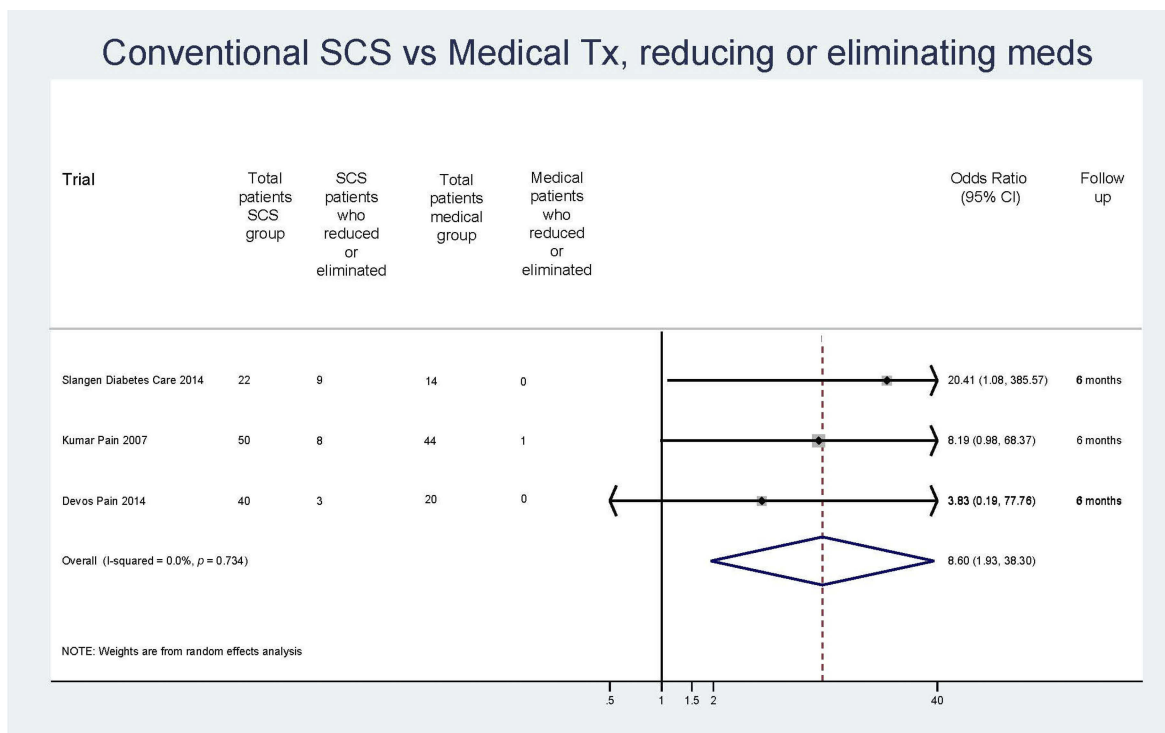
Figure 1 PRISMA Flow diagram.

Figure 2 Number of patients who decreased or eliminated pain medication who received conventional spinal cord stimulation with medical therapy vs medical therapy alone.
Abbreviations: SCS, spinal cord stimulation; OR, odds ratio; CI, confidence interval.

did reach statistical significance with a 95% CI (OR 8.60, CI {1.93, 38.30}).

Conventional SCS compared to opioids: MQS reduction

Two trials reported continuous outcomes of mean medication dose reduction as measured by the MQS. Spincemaille randomized 114 patients with critical limb ischemia 1:1 to SCS vs medical therapy.[18] MQS was measured before and 18 months after intervention, and the mean difference (MD) of these measures was calculated. The results show a statistically significant decrease in MQS in the SCS patients compared to medical therapy patients (MD –1.90, CI {–3.73, -0.07}).

De Vos randomized 60 patients with painful diabetic peripheral neuropathy in a 2:1 randomization to either SCS or medical therapy. MQS was measured before and 6 months after intervention. A trend toward decreased MQS was demonstrated in the SCS group vs the medical therapy group, but it was not statistically significant (MD –2.40, CI {–6.89, 2.09}).[16]

Figure 3 reveals the results of applying random effects analysis and calculating WMD for these two trials. The pooled WMD is statistically significant,

indicating the SCS group was able to reduce MQS as compared to medical therapy group (WMD –1.97 {– 3.67, –0.27}).

New SCS technology compared to conventional SCS: effect on reducing opioids

The SENZA trial by Kapural enrolled 179 patients with chronic back and/or leg pain and randomized them 1:1 to conventional SCS vs high-frequency SCS.[19] The outcome of interest was the number of patients who decreased opioid use after 12 months. There was a trend toward greater reduction in opioid use in the high-frequency SCS group (30/89 patients compared to 21/80 in the conventional SCS group), though these findings were not statistically significant (OR 1.43, CI {0.74, 2.78}). This is graphically represented in Figure 4. Opioid use was quantified as average MED and was recorded at baseline and 12 months after randomization to either high-frequency SCS or conventional SCS. The average MED change was –24.8 mg in the high-frequency SCS group and –7.3 mg in the conventional SCS group. While this result suggests a trend toward greater opioid reduction in high-frequency SCS patients, the difference between groups was not statistically significant (–17.50, {–66.27, 31.27}). This is

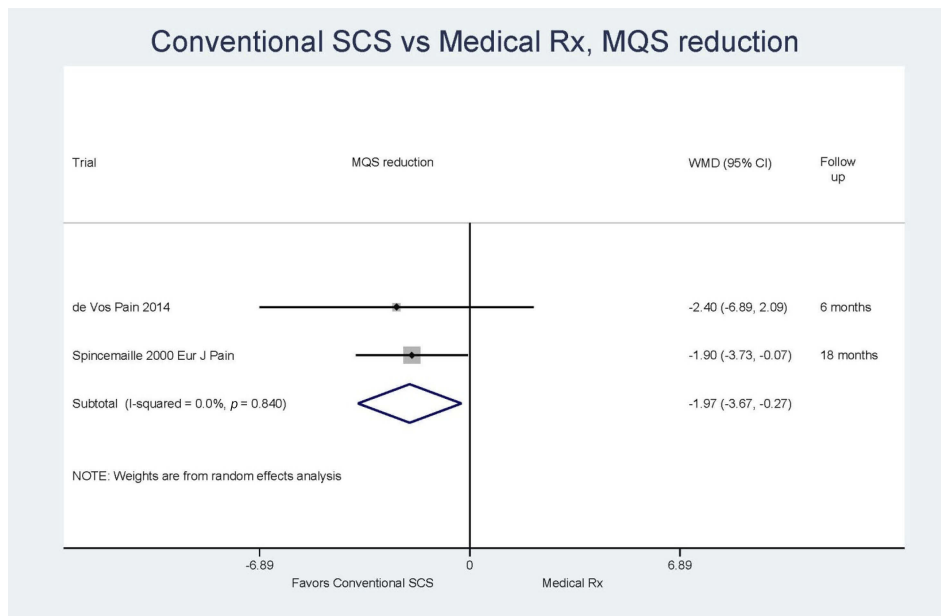## Conventional SCS vs Medical Rx, MQS reduction

Figure 3 Medication Quantification Scale (MQS) reduction in patients who received conventional spinal cord stimulation with medical therapy vs medical therapy alone.
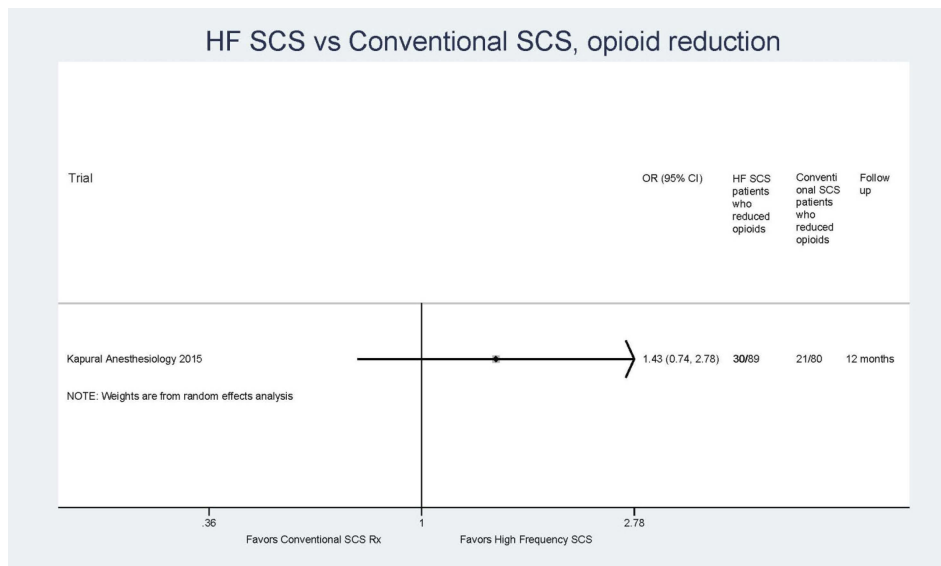**Abbreviations:** SCS, spinal cord stimulation; WMD, weighted mean difference; CI, confidence interval.

HF SCS vs Conventional SCS, opioid reduction

Figure 4 Number of patients who reduced opioids in high-frequency spinal cord stimulation group vs number of patients who reduced opioids in conventional spinal cord stimulation group.
Abbreviations: HF SCS, high-frequency spinal cord stimulation; OR, odds ratio; CI, confidence interval.

shown in Figure 5. There was not another randomized control trial comparing high frequency to conventional SCS with the outcome of opioids.

Adverse events

Adverse event reporting details differed considerably among the different trials. Serious neurological complications were rare with one report of subdural hematoma associated with patient death. Most of the adverse events in the spinal stimulator groups were hardware related to hardware implant site related pain/discomfort and spinal stimulator lead migration being most frequent. Table 4 lists the adverse events reported in each of the trials.
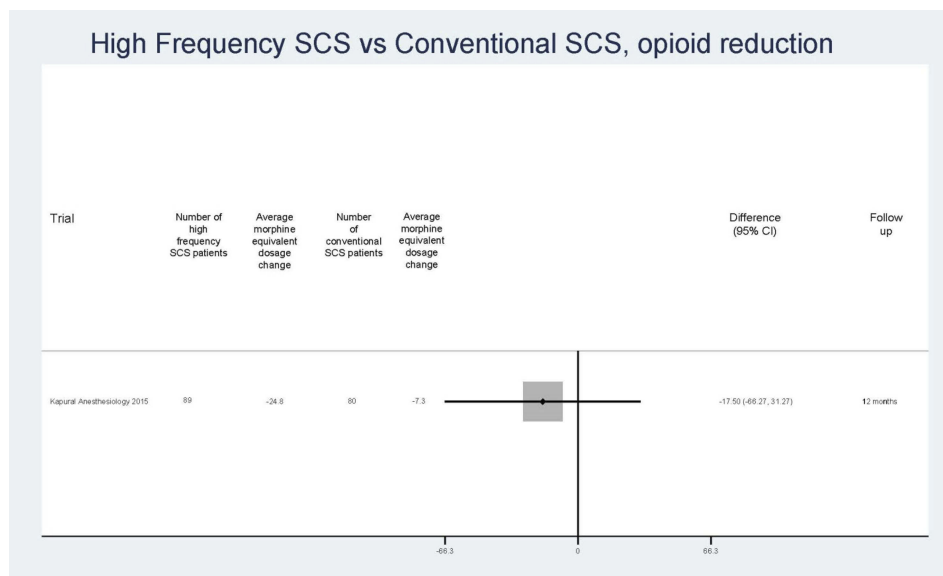
Figure 5 Average morphine equivalent dosing change in patients who received high-frequency spinal cord stimulation vs patients who received conventional spinal cord stimulation.
Abbreviation: SCS, high-spinal cord stimulation.

Discussion

We performed a systematic review and meta-analysis of RCTs assessing opioid and pain medication use in patients with intractable back or limb pain treated with conventional SCS vs medical therapy or conventional SCS vs high-frequency SCS. In the four randomized controlled trials that looked at pain medication use, patients receiving conventional SCS experienced greater odds of reducing opioid or pain medication use compared to patients receiving medical therapy alone. Additionally, one trial suggested a trend of decreased opioid therapy after high-frequency SCS as compared to conventional stimulation but this did not reach statistical significance. While the purpose of this systematic review was to determine the effect of SCS on pain medication consumption, we recognize that SCS has many other potential therapeutic effects. Other potential benefits of SCS include pain relief, improved function, and improve quality of life. In the largest SCS RCT published to date by Kapural and colleagues, SCS demonstrated significant improvement in pain, function, and quality of life in addition to reduced opioid consumption.[19]

The quality of evidence derived from this study is limited by multiple factors which deserve further mention. First, due to the nature of the stimulation intervention, neither the patients nor the investigators were blinded. Secondly, only a small number of RCTs were available for analysis, with each trial limited by small

sample sizes. The Kapural study was the largest, with 171 patients successfully implanted after 1:1 randomization to high-frequency SCS or conventional SCS. The smallest trial was the Slangen study, with 22 patients randomized to stimulation and 14 patients randomized to medical management only. The three remaining trials had sample sizes as follows: the de Vos study includes 60 patients randomized 2:1 to medical management with SCS or without SCS, the Kumar study randomized 100 patients 1:1 to medical management with SCS or without SCS, and the Spincemaille study randomized 120 patients 1:1 to medical management with SCS or without SCS.

A third limitation is the heterogeneity of the cohorts studied. The trial populations include patients with painful diabetic neuropathy (de Vos and Slangen), FBSS (Kumar), chronic back or leg pain (Kapural), and painful peripheral vascular disease (Spincemaille). It is difficult to draw definitive conclusions about SCS effect on pain medication use given the confounder of patient populations with widely varying pathology, and likely widely varying baseline pain medication use.

The citations ranged from 2000 to 2015, thus advancing technology may play a role in recent studies. The Kapural study looked at high-frequency SCS compared to conventional SCS, while the other four trials looked at conventional SCS as compared to medication management alone. Kapural was the only trial to explicitly define the

Table 4 Adverse events in the included studies

Study	Neurological injury	Post-dural puncture headache	Infection/wound complications	Reoperation/revision	Hardware/incision site pain	Lead migration	Loss of paresthesia	Non-SCS group adverse events	
Kapural, 2015[19] HF10 group	None	0	5	3.0%	12.9%	3.0%	–	N/A	Uncomfortable stimulation in 0.0% of HF10 patients and 11.3% of conventional SCS patients.
SCS Group	None	1	3	5.2%	13.4%	5.2%	–	N/A	
De Vos, 2014[15] SCS group	None	–	1 (during trial phase)	Unclear	2	–	–	AE related to diabetic health care. These were even between the groups.	1 SCS group patient had complications related to coagulopathy. Details unknown.
Slangen, 2014[14] SCS Group	1 (subdural hematoma/death)	1	1	1 (explant due to infection)	–	–	–	None reported	
Kumar, 2007[16] SCS group	–	–	7 (8%)	20 (24%)	5 (6%)	8 (10%)	6 (7%)	62% of medical management group experienced an adverse event	18 (35%) of SCS group experienced a non-device related adverse event
Spincemaille, 2000[18] SCS group	0	0	0	0	0	3 lead fractures reported	Not reported	None reported	

Abbreviation: SCS, high-spinal cord stimulation.

stimulation waveform parameters in terms of frequency, pulse width, and amplitude. While none of the other trials included information regarding waveform parameters, given the published dates of those trials, it can be assumed that the SCS parameters in the other four trials were likely to be conventional paresthesia-based low frequency, low pulse width stimulation.

Additionally, the studies have a varied geographic distribution. The de Vos trial included patients from the Netherlands, Denmark, Belgium, and Germany. The Slangen and Spincemaille trials included only patients from the Netherlands. The Kumar trial included patients throughout Europe, Canada, Australia, and Israel. The Kapural trial included American patients only. This broad geographic difference may create challenges when trying to apply the findings of this systematic review to certain populations.

Another important limitation to note is the length of follow-up varied widely between studies. The length of time patients was followed for each study is as follows: 6 months for the de Vos and Slangen studies, 12 months for the Kumar study, 18 months for the Spincemaille study, and 12 months for the Kapural study. Given the chronic disease states of the studied populations, even 18 months is a relatively short amount of time from which to draw conclusions.

Finally, none of the trials looked at opioid or pain medication use as a primary outcome. Two studies (Kumar and Slangen) reported the number of patients able to decrease or cease opioid consumption but did quantify the dosing changes. With no quantitative information, we are left to wonder if the decrease in opioid use was clinically significant for these patients. Two studies (Spincemaille and de Vos) reported mean pain medication dose reduction by utilizing the MQS. While this is an attempt to provide quantitative information, the MQS assesses 22 classes of medications, including opioids, NSAIDs, and paracetamol. It is difficult to determine if a change in MQS is clinically significant. The Kumar trial quantified average morphine equivalent dosage (MED) at 6 months but unfortunately did not provide baseline information. Only one trial quantified opioid doses both before and after the intervention. The Kapural trial recorded MED at baseline and 12 months after intervention. Ultimately, the inconsistency and heterogeneity with which pain medication changes were reported make it difficult to draw conclusions.

There are several studies of the effect of SCS on opioid use that are not included in this meta-analysis because they are non-randomized, but deserve mention. A retrospective case series by Sanders et al of 199 patients recorded oral morphine equivalents (OME) at baseline and 1 year after spinal cord stimulator implantation.[27] Mean preimplantation OME for this population was 50.19 and 1 year after implantation mean OME decreased to 28.91 ($p<0.001$). The indications for implantation for the patients in this study were divided into four categories: failed back surgery syndrome and chronic radiculopathy (FBSS), complex regional pain syndrome (CRPS), angina, and other. When pre- and post-implantation OME was examined for each of these 4 categories, there was a statistically significant decrease in the FBSS and CRPS groups.

Al-Kaisy et al, published a prospective study with the objective to explore the effectiveness of 10 kHz high-frequency SCS (HF10 therapy) for chronic low back pain.[28] Twenty-one patients with chronic low back pain and no history of prior back surgery were successfully implanted with a permanent high-frequency stimulator. These patients were followed for 12 months after the initiation of HF10 therapy. Average daily opioid intake was recorded for all 21 patients before implantation and at 12 months post-implantation. Average daily opioid intake decreased by 64% over the 12 months, from 112 to 40 morphine milligram equivalent; this reduction in opioid intake was statistically significant ($p=0.0833$). Three patients completely stopped their use of opioids. Despite the small sample size of only 21 patients, the reduction in opioid use was of great enough magnitude to reach statistical significance.

The North trial is a randomized controlled trial which was included in our group's systematic review of SCS on pain outcomes and deserves to mention in further detail here.[25] Fifty patients with chronic back pain who met standard criteria for spine reoperation were randomized to either SCS or reoperation. Success was based on pain satisfaction and pain relief as reported by the patients; opioid use was also reported. After 2 years, 87% of the patients randomized to SCS had stable or decreased opioid use vs 58% of the patients randomized to reoperation. Opioid use increased by 13% of the SCS group and 42% of the reoperation group. A major confounder is that the patients could cross over to the alternative treatment if the results of the randomized treatment were unsuccessful after 6 months. There was significant crossover effect; 54% of

the patients randomized to reoperation crossed over and 21% of the patients randomized to SCS crossed over. While the opioid use data at long-term follow-up suggests SCS promotes decreased opioid use compared to reoperation, the crossover effect makes it difficult to attribute any opioid or pain medication reduction to either intervention.

Additionally, there are several other case series and non-randomized trials looking at pain medication use with SCS. While the patient populations, study designs, and measured outcomes vary widely, they show similar findings and suggest SCS can aid in the reduction of pain medications including opioids.[29,30,31]

Conclusion

We conducted a systematic review and meta-analysis of changes in opioid and pain medication use following SCS in those with chronic low back and/or limb pain, finding statistically significant decreases in opioid and pain medication use following SCS. However, available data were limited, and the clinical significance of these findings will require further study. Future studies should be randomized control trials with opioid reduction as a primary endpoint in order to allow meaningful comparison of SCS to other pain therapies and apply that information to the broad spectrum of patients with chronic pain. Additionally, quantitative measures of opioid intake, such as morphine milligram equivalents, should be measured so that the clinical significance of any pattern of change of opioid use can be ascertained.

Prior Presentations

The abstract was presented at Midwest Anesthesia Residents' Conference on April 14, 2018 in Cincinnati, OH. The abstract was accepted for presentation at American Society of Anesthesiology Annual Meeting on October 14 in San Francisco, CA.

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Disclosure

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Supplementary materials

Table S1 Search strategy

#	Searches		Results
1	Dorsal root ganglion stimulator.mp.		3
2	Electric stimulation therapy/ or spinal cord stimulation/ or transcutaneous nerve stimulation/ or electrodes, implanted/		37,833
3	(neurostimulat* or neuromodulat*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]		14,769
4	Neurostimulators, implantable/ or neural prosthesis/		671
5	(spinal adj2 stimulat*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]		3,366
6	Or/1-5		52,267
7	Chronic pain/th		1,733
8	Neuralgia/ or back pain/ or low back pain/		43,397
9	Reflex sympathetic dystrophy/ or complex regional pain syndromes/ or causalgia/		5,167
10	Failed back surgery syndrome/ or crps.mp. or fbss.mp. or "failed back surgery".mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]		2,536
11	(back adj pain).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]		50,309
12	("reflex sympathetic" or "complex regional pain" or spin*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]		605,066
13	Spinal cord/ or "spinal adj2 cord".mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]		74,623
14	Exp Diabetic Neuropathies/ or exp peripheral nervous system diseases/pc, th or exp spinal cord diseases/th		42,064
15	8 or 9 or 10 or 11 or 12 or 14 or 13		672,763
16	6 and 15		8,594
17	7 and 13 and 6		44
18	16 or 17		8,594
19	18 and random*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]		814
20	18 and randomized controlled trial.pt.		389
21	19 or 20		814
22	Remove duplicates from 21		787
23	Limit 22 to yr="1995–2017"		734
CENTRAL – same strategy = 477, no conference abstract - 412			
EMBASE			
1	Spinal cord stimulation/	5,098	Advanced
2	Electrotherapy/	153	Advanced
3	Exp peripheral neuropathy/	54,696	Advanced

(Continued)

Table S1 (Continued).

	EMBASE		
4	Neuralgia/ or exp cervicobrachial neuralgia/ or exp complex regional pain syndrome/ or exp deafferentation pain/ or exp ischialgia/ or exp meralgia paresthetica/ or exp neuropathic pain/ or exp radicular pain/ or exp sciatica/	49,321	Advanced
5	Exp complex regional pain syndrome/	7,329	Advanced
6	Failed back surgery syndrome.mp. or failed back surgery syndrome/ or low back pain/	45,448	Advanced
7	Exp backache/	81,990	Advanced
8	(1 or 2) and (3 or 4 or 5 or 6 or 7)	2,196	Advanced
9	Exp clinical trial/ or exp "clinical trial (topic)"/	1,404,239	Advanced
10	8 and 9	460	Advanced
11	8 and random*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading]	323	Advanced
12	10 or 11	529	Advanced
13	.l/ 12 hu=y and yr=1995–2017	491	Advanced
14	13 not (letter or editorial or note or conference abstract).pt.	367	Advanced
15	remove duplicates from 14	346	Advanced

Scopus

1 (TITLE-ABS-KEY (("root ganglion" OR dorsal OR sacral OR caudal OR spinal) W/4 (neurostimulat* OR stimulat* OR neuromodulat* OR electrotherap* OR electric*)

2 TITLE-ABS-KEY ("chronic pain" OR "leg pain" OR neuralgi* OR neuropath* OR backache* OR "back pain" OR crps OR fbss OR "failed back" OR "complex regional pain" OR "reflex sympathetic")

3 TITLE-ABS-KEY (random*)) AND PUBYEAR > 1994

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