

Review Article

Spinal Cord Stimulation for Persistent Spinal Pain Syndrome After Lumbar Surgery

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Abstract

Background: Persistent spinal pain syndrome type 2 (PSPS-T2), the modern term for failed back surgery syndrome, affects a substantial minority of patients after lumbar spine surgery.

Objective: To synthesise randomised trials, waveform comparisons, durability data, patient selection practice and cost-effectiveness evidence for spinal cord stimulation (SCS) in PSPS-T2.

Methods: Narrative review of randomised controlled trials, long-term cohort follow-ups, consensus guidelines and health-economic analyses.

Findings: Randomised trials show SCS outperforms reoperation and conventional medical management for leg-predominant pain, with benefit sustained to 24 months. High-frequency and burst waveforms match or exceed conventional tonic stimulation, though a placebo-controlled burst trial found no advantage over sham for axial pain. Complications centre on lead migration and infection, and cost-effectiveness improves once device costs are amortised beyond two to three years.

Conclusions: SCS is well supported for refractory leg pain after lumbar surgery, but axial pain, patient selection and trial-stimulation methodology need further high-quality evidence.

Keywords: Spinal cord stimulation; Persistent spinal pain syndrome; Failed back surgery syndrome; Neuromodulation; Lumbar spine surgery

Abstract

Background: Persistent spinal pain syndrome type 2 (PSPS-T2), the modern term for failed back surgery syndrome, affects a substantial minority of patients after lumbar spine surgery. **Objective:** To synthesise randomised trials, waveform comparisons, durability data, patient selection practice and cost-effectiveness evidence for spinal cord stimulation (SCS) in PSPS-T2. **Methods:** Narrative review of randomised controlled trials, long-term cohort follow-ups, consensus guidelines and health-economic analyses. **Findings:** Randomised trials show SCS outperforms reoperation and conventional medical management for leg-predominant pain, with benefit sustained to 24 months. High-frequency and burst waveforms match or exceed conventional tonic stimulation, though a placebo-controlled burst trial found no advantage over sham for axial pain. Complications centre on lead migration and infection, and cost-effectiveness improves once device costs are amortised beyond two to three years. **Conclusions:** SCS is well supported for refractory leg pain after lumbar surgery, but axial pain, patient selection and trial-stimulation methodology need further high-quality evidence.

Keywords: spinal cord stimulation; persistent spinal pain syndrome; failed back surgery syndrome; neuromodulation; lumbar spine surgery

Introduction

Persistent spinal pain syndrome type 2 (PSPS-T2) is the nomenclature increasingly used, and adopted for the ICD-11 revision, in place of the older term failed back surgery syndrome, describing new or persistent axial and radicular pain following spine surgery [1]. Lumbar discectomy, decompression and fusion are common operations, and a meaningful proportion of patients continue to report significant pain despite technically successful surgery, reflecting a mixture of residual or

recurrent neural compression, epidural fibrosis, adjacent-segment degeneration, altered biomechanics and centrally sensitised neuropathic pain. Repeat surgery in this population carries diminishing returns and rising complication rates, prompting interest in neuromodulation as an alternative.

Spinal cord stimulation delivers electrical current to the dorsal columns via percutaneous or paddle leads connected to an implanted pulse generator, historically producing paraesthesia that overlaps the painful dermatome and is thought, per the gate-control theory, to inhibit nociceptive transmission at the dorsal horn; newer waveforms achieve analgesia without paraesthesia through distinct proposed mechanisms involving differential recruitment of large- and small-diameter afferents and modulation of descending inhibitory pathways. Early case series of dorsal column stimulation for chronic intractable pain, including many patients with prior spine surgery, established feasibility and long-term safety over two decades of experience, with multi-channel devices outperforming earlier single-channel systems on programmable paraesthesia coverage [2].

The clinical problem SCS is designed to address is substantial: a meaningful minority of patients undergoing lumbar discectomy, decompression or fusion continue to report significant axial or radicular pain at one year or beyond, and repeat imaging in this group frequently fails to identify a clearly correctable structural lesion. Where reoperation is attempted without a well-defined target, outcomes are inconsistent and further surgery itself carries a cumulative risk of complications, epidural scarring and diminishing symptomatic return, which has driven interest in neuromodulation as an alternative to serial reoperation rather than merely an adjunct to it.

This review synthesises randomised controlled trial evidence comparing SCS with reoperation and with

conventional medical management, summarises waveform comparisons (tonic, high-frequency 10 kHz, and burst stimulation), reviews patient selection and trial stimulation practice, tabulates complication rates, and considers the health-economic literature relevant to PSPS-T2 after lumbar surgery. Wherever possible, findings are anchored to randomised or long-term prospective data rather than uncontrolled case series, reflecting the maturation of this literature over the past two decades.

Randomised Evidence for Spinal Cord Stimulation

The strongest evidence for SCS in PSPS-T2 comes from three linked randomised trials. North and colleagues randomised patients with persistent radicular pain after lumbar surgery to SCS or reoperation, crossover permitted on failure of the assigned treatment; SCS produced significantly better pain relief and was preferred by most crossover-eligible patients, with a companion cost-effectiveness analysis finding SCS the more economical strategy over the trial horizon once cumulative costs were modelled [3,4]. The subsequent international multicentre EVIDENCE study similarly randomised PSPS-T2 patients to SCS or reoperation and again favoured SCS on the pre-specified pain and function outcomes [5].

The PROCESS trial randomised 100 PSPS-T2 patients with predominant leg pain to SCS plus conventional medical management or conventional management alone, finding significantly more SCS patients achieved 50% pain relief and improved quality of life and function at six months; benefit was sustained at 24-month follow-up, with two-thirds of SCS patients still meeting the primary success criterion despite a minority experiencing device-related complications requiring revision [6,7]. Crossover was again permitted for patients failing their assigned arm, and most patients originally randomised to conventional management alone who later crossed over to SCS achieved similar benefit, reinforcing that the effect

was attributable to stimulation rather than to natural history or expectation alone. Because PROCESS enrolled patients with leg-predominant, not axial, pain, its generalisability to purely axial PSPS-T2 pain is limited, motivating later trials targeting back pain specifically.

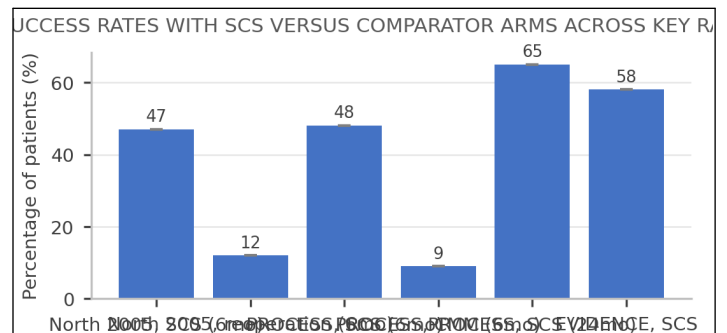


Figure 1: Proportion of patients achieving the primary treatment-success criterion with spinal cord stimulation versus comparator arms across key randomised trials: reoperation trial at 6 months [3], PROCESS trial at 6 and 24 months [6,7], and EVIDENCE study [5].

The PROMISE trial addressed predominant back pain in PSPS-T2 using multicolumn paddle-lead SCS optimised for axial coverage, but did not meet its primary six-month responder endpoint against conventional management, despite improvements in several secondary measures, underscoring that axial back pain in this population responds less predictably to stimulation than leg pain [8]. Most recently, the NORDSTIM trial randomised patients with chronic radicular pain after lumbar spine surgery to burst SCS or blinded placebo stimulation using the same implanted system, with both groups and assessors unaware of allocation; disability, pain and quality-of-life outcomes did not differ significantly between active and sham stimulation groups over the follow-up period, a result that has prompted debate about placebo response, patient selection and outcome heterogeneity in this population and stands in tension with the earlier open-label reoperation-controlled trials [9]. Because NORDSTIM implanted a device in every participant and randomised only the stimulation setting, it isolates the specific analgesic contribution of active current more

rigorously than trials comparing an implanted device against ongoing medical management, and its null result is therefore difficult to dismiss as simply an artefact of blinding failure.

Waveform Comparisons

Conventional tonic SCS delivers stimulation in the 40-60 Hz range producing paraesthesia; alternative waveforms were developed to broaden coverage and reduce paraesthesia-related discomfort. High-frequency 10 kHz stimulation, delivered without perceptible paraesthesia, was compared with traditional low-frequency SCS in the pivotal SENZA-RCT, which found 10 kHz stimulation non-inferior and statistically superior to traditional SCS for both back and leg pain at three months, a difference sustained through 24 months of follow-up [10,11]. Quality-of-life gains associated with 10 kHz stimulation in this trial were substantial and persisted alongside the pain outcomes [12]. European cohort studies of 10 kHz stimulation in predominant low back pain likewise reported sustained responder rates through 24 months [13,14].

Table 1: Randomised and prospective trials comparing spinal cord stimulation waveforms for persistent spinal pain syndrome and related chronic back/leg pain [10,11,12,16,13,14,17,9].				
Trial	Waveform comparison	Design	Follow-up	Key result
SENZA-RCT	10 kHz vs traditional low-frequency	Randomised, parallel	3-24 months	10 kHz superior for back and leg pain
SENZA-RCT QoL	10 kHz vs traditional	Randomised, parallel	12 months	Sustained quality-of-life gains
SUNBURST	Burst vs tonic	Randomised crossover	12 weeks per arm	Burst non-inferior, preferred by most
Van Buyten/Al-Kaisy cohorts	10 kHz, single-arm	Prospective multicentre	24 months	Sustained responder rates
PROCO	Kilohertz-range rate comparison	Randomised crossover	Short-term	Little difference across rates tested

Trial	Waveform comparison	Design	Follow-up	Key result
NORDSTIM	Burst vs blinded placebo	Randomised, sham-controlled	12 months	No significant difference vs sham

Burst stimulation, which delivers closely spaced spikes of five pulses in a burst pattern separated by a quiescent interval, was introduced with the rationale of engaging both medial and lateral pain pathways, including affective components of pain processing, while minimising paraesthesia [15]. The SUNBURST trial, a randomised crossover comparison of burst against tonic stimulation in the same implanted patients, found burst stimulation non-inferior on the primary visual analogue scale endpoint and preferred by most participants who expressed a waveform preference, with a subset reporting meaningful relief from burst after incomplete response to tonic stimulation [16]. A separate randomised comparison of stimulation rate within kilohertz-frequency SCS found relatively little difference in analgesia across tested frequencies, suggesting some waveform effects may plateau above a threshold rather than scaling linearly [17]. A systematic review and meta-analysis of placebo-controlled SCS trials across waveforms concluded that pooled evidence supports superiority over sham for neuropathic pain overall, while highlighting substantial trial heterogeneity and a scarcity of adequately blinded, sham-controlled designs, a gap the subsequent NORDSTIM trial was designed to address [18,9].

Patient Selection and Trial Stimulation

Consensus guidance from the Neurostimulation Appropriateness Consensus Committee recommends a structured pre-implant pathway: psychological screening, exclusion of readily correctable structural pathology on updated imaging, multidisciplinary discussion, and a temporary percutaneous trial period before permanent implantation, typically requiring a clinically meaningful reduction in pain and improvement in function,

commonly a threshold around 50%, before proceeding to permanent implantation [19,20]. The trial period also allows patients to experience the practical burdens of an external device and to report on paraesthesia coverage or, with paraesthesia-free waveforms, on analgesic response alone, before committing to surgery.

Leg-predominant pain, neuropathic quality, and absence of major untreated psychosocial confounders are the classical positive selection criteria, consistent with the enrolment criteria of the PROCESS and EVIDENCE trials [6,5]. The comparatively weaker results of trials enrolling patients with predominant axial back pain reinforce that pain distribution should inform candidacy and expectation-setting during trial stimulation, and that patients whose pain is mainly axial should be counselled that the evidence base for durable benefit is less robust than for radicular pain [8,9].

Complications and Safety

Across two decades of published experience, the most frequent hardware-related complication is lead migration or fracture, historically reported around 13% of implants, followed by infection at roughly 3-5%, with dural puncture, hardware malfunction, generator-site pain and biological complications such as seroma occurring less often [21,22]. Lead migration is more common with percutaneous cylindrical leads than with surgically placed paddle leads, though paddle placement requires a small laminotomy and carries its own, generally low, risk of dural injury. A broader review of neurostimulation safety across indications similarly found hardware-related events as the dominant complication category, with serious neurological injury rare but reported, and most complications managed with lead revision or, for infection, temporary or permanent explantation rather than causing lasting harm [23].

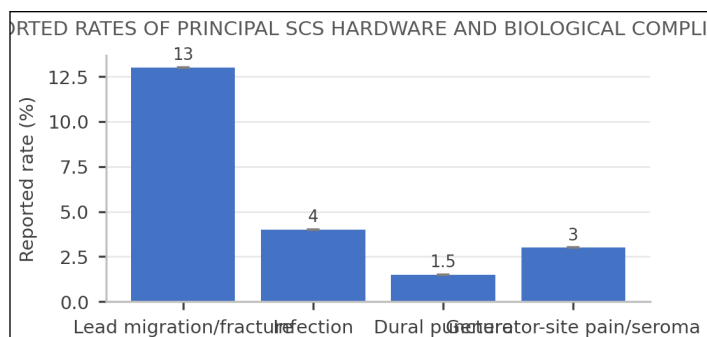


Figure 2: Reported rates of the principal spinal cord stimulation hardware and biological complications across the literature reviewed [21,22,23].

The companion NACC document on complication avoidance recommends anchoring technique, prophylactic antibiotics, meticulous wound closure and structured surgical checklists to mitigate the most common failure modes, along with guidance on managing anticoagulation and diabetes perioperatively given their association with infection and wound-healing complications [24]. Complication rates in the randomised trials discussed above were broadly consistent with this literature, with device-related revision the most common reason for reoperation in the SCS arms, generally without loss of the analgesic benefit once hardware issues were corrected [7,5].

Health Economics and Cost-Effectiveness

Because SCS carries substantial upfront device and implantation costs, its economic case depends on avoided downstream costs of medication, further surgery and lost productivity. An early systematic review of cost-effectiveness studies found SCS costs are recouped within roughly the first two to three years relative to conventional management, after which SCS becomes the less costly strategy [25]. The trial-based cost-utility analysis alongside the North reoperation trial similarly found SCS dominant, being both more effective and, over time, less costly than repeat surgery [4]. A later comprehensive review confirmed favourable incremental cost-effectiveness ratios for SCS across multiple health

systems, while noting that estimates are sensitive to device longevity, revision rates, battery type (rechargeable versus non-rechargeable) and comparator costs, and that newer waveforms with higher energy demands can alter the balance if they require more frequent generator replacement [26]. Health technology assessment bodies have reached concordant conclusions: UK guidance recommended SCS as a treatment option for chronic neuropathic pain, including PSPS-T2, in patients who have had an adequate trial of conventional management and an appropriate psychological assessment, citing the balance of clinical and cost-effectiveness evidence from the trials summarised above [27]. Together, these analyses suggest that the up-front cost of SCS is a barrier to adoption in some health systems even where longer-term modelling favours stimulation, particularly where post-implant follow-up and revision costs are not adequately captured in short-horizon budget assessments.

Table 2: Health-economic evidence for spinal cord stimulation in persistent spinal pain syndrome after lumbar surgery [4,25,26,27].			
Source	Comparator	Cost-effectiveness finding	Notes
North 2007 (trial-based)	Reoperation	SCS dominant over time	Alongside RCT of SCS vs reoperation
Taylor 2004 (systematic review)	Conventional management	Break-even at ~2-3 years	Pooled multiple cost studies
Kumar 2013 (comprehensive review)	Conventional management	Favourable ICERs, sensitive to device factors	Multiple health systems
NICE TA159 (2008)	Conventional management	Recommended after adequate CMM trial	UK health technology assessment

Conclusion

Randomised trial evidence, spanning comparisons against reoperation, against conventional medical management, and across tonic, high-frequency and burst waveforms, supports spinal cord stimulation as an effective, durable

and cost-effective option for leg-predominant persistent spinal pain syndrome after lumbar surgery. The evidence base for predominantly axial back pain is considerably weaker, and the recent placebo-controlled NORDSTIM trial raises important questions about the specificity of stimulation effects that earlier open-label, reoperation-controlled designs could not address. Complication rates, dominated by lead migration and infection, are well characterised and generally modest. Future trials with rigorous sham control, standardised patient selection reflecting pain distribution, and longer economic follow-up are needed to refine which patients with PSPS-T2 are most likely to benefit from stimulation.

References

1. Christelis, N., Simpson, B., Russo, M., Stanton-Hicks, M., Barolat, G., Thomson, S., et al. (2021) Persistent Spinal Pain Syndrome: A Proposal for Failed Back Surgery Syndrome and ICD-11. Pain Medicine, 22(4): 807-818.
2. North, R.B., Kidd, D.H., Zahurak, M., James, C.S., Long, D.M. (1993) Spinal cord stimulation for chronic, intractable pain: experience over two decades. Neurosurgery, 32(3): 384-395.
3. North, R.B., Kidd, D.H., Farrokhi, F., Piantadosi, S.A. (2005) Spinal cord stimulation versus repeated lumbosacral spine surgery for chronic pain: a randomized, controlled trial. Neurosurgery, 56(1): 98-106.
4. North, R.B., Kidd, D., Shipley, J., Taylor, R.S. (2007) Spinal cord stimulation versus reoperation for failed back surgery syndrome: a cost effectiveness and cost utility analysis based on a randomized, controlled trial. Neurosurgery, 61(2): 361-368.
5. North, R.B., Kumar, K., Wallace, M.S., Henderson, J.M., Shipley, J., Hernandez, J., et al. (2011) Spinal cord stimulation versus re-operation in patients with failed back surgery syndrome: an international multicenter randomized controlled trial (EVIDENCE study). Neuromodulation, 14(4): 330-335.

6. Kumar, K., Taylor, R.S., Jacques, L., Eldabe, S., Meglio, M., Molet, J., et al. (2007) Spinal cord stimulation versus conventional medical management for neuropathic pain: a multicentre randomised controlled trial in patients with failed back surgery syndrome. *Pain*, 132(1-2): 179-188.
7. Kumar, K., Taylor, R.S., Jacques, L., Eldabe, S., Meglio, M., Molet, J., et al. (2008) The effects of spinal cord stimulation in neuropathic pain are sustained: a 24-month follow-up of the prospective randomized controlled multicenter trial of the effectiveness of spinal cord stimulation. *Neurosurgery*, 63(4): 762-770.
8. Rigoard, P., Basu, S., Desai, M., Taylor, R., Annemans, L., Tan, Y., et al. (2019) Multicolumn spinal cord stimulation for predominant back pain in failed back surgery syndrome patients: a multicenter randomized controlled trial. *Pain*, 160(6): 1410-1420.
9. Hara, S., Andresen, H., Solheim, O., Carlsen, S.M., Sundstrøm, T., Lønne, G., et al. (2022) Effect of Spinal Cord Burst Stimulation vs Placebo Stimulation on Disability in Patients With Chronic Radicular Pain After Lumbar Spine Surgery: A Randomized Clinical Trial. *JAMA*, 328(15): 1506-1514.
10. Kapural, L., Yu, C., Doust, M.W., Gliner, B.E., Vallejo, R., Sitzman, B.T., et al. (2015) Novel 10-kHz High-frequency Therapy (HF10 Therapy) Is Superior to Traditional Low-frequency Spinal Cord Stimulation for the Treatment of Chronic Back and Leg Pain: The SENZA-RCT Randomized Controlled Trial. *Anesthesiology*, 123(4): 851-860.
11. Kapural, L., Yu, C., Doust, M.W., Gliner, B.E., Vallejo, R., Sitzman, B.T., et al. (2016) Comparison of 10-kHz High-Frequency and Traditional Low-Frequency Spinal Cord Stimulation for the Treatment of Chronic Back and Leg Pain: 24-Month Results from a Multicenter, Randomized, Controlled Pivotal Trial. *Neurosurgery*, 79(5): 667-677.
12. Amirdelfan, K., Yu, C., Doust, M.W., Gliner, B.E., Morgan, D.M., Kapural, L., et al. (2018) Long-term quality of life improvement for chronic intractable back and leg pain patients using spinal cord stimulation: 12-month results from the SENZA-RCT. *Quality of Life Research*, 27(8): 2035-2044.
13. Van Buyten, J.P., Al-Kaisy, A., Smet, I., Palmisani, S., Smith, T. (2013) High-frequency spinal cord stimulation for the treatment of chronic back pain patients: results of a prospective multicenter European clinical study. *Neuromodulation*, 16(1): 59-65.
14. Al-Kaisy, A., Van Buyten, J.P., Smet, I., Palmisani, S., Pang, D., Smith, T. (2014) Sustained effectiveness of 10 kHz high-frequency spinal cord stimulation for patients with chronic, low back pain: 24-month results of a prospective multicenter study. *Pain Medicine*, 15(3): 347-354.
15. De Ridder, D., Vanneste, S., Plazier, M., van der Loo, E., Menovsky, T. (2010) Burst spinal cord stimulation: toward paresthesia-free pain suppression. *Neurosurgery*, 66(5): 986-990.
16. Deer, T., Slavin, K.V., Amirdelfan, K., North, R.B., Burton, A.W., Yearwood, T.L., et al. (2018) Success Using Neuromodulation With BURST (SUNBURST) Study: Results From a Prospective, Randomized Controlled Trial Using a Novel Burst Waveform. *Neuromodulation*, 21(1): 56-66.
17. Thomson, S.J., Tavakkolizadeh, M., Love-Jones, S., Patel, N.K., Gu, J.W., Bains, A., et al. (2018) Effects of Rate on Analgesia in Kilohertz Frequency Spinal Cord Stimulation: Results of the PROCO Randomized Controlled Trial. *Neuromodulation*, 21(1): 67-76.
18. Duarte, R.V., Nevitt, S., McNicol, E., Taylor, R.S., Buchser, E., North, R.B., Eldabe, S. (2020) Systematic review and meta-analysis of placebo/sham controlled randomised trials of spinal cord stimulation for neuropathic pain. *Pain*, 161(1): 24-35.
19. Deer, T.R., Mekhail, N., Provenzano, D., Pope, J., Krames, E., Leong, M., et al. (2014) The appropriate use of neurostimulation of the spinal cord and peripheral nervous

system for the treatment of chronic pain and ischemic diseases: the Neuromodulation Appropriateness Consensus Committee. *Neuromodulation*, 17(6): 515-550.

London: NICE.

20. Deer, T.R., Provenzano, D.A., Hanes, M., Pope, J.E., Thomson, S.J., Russo, M.A., et al. (2017) The Neurostimulation Appropriateness Consensus Committee (NACC) Recommendations for Trial Stimulation. *Neuromodulation*, 20(1): 1-9.
21. Cameron, T. (2004) Safety and efficacy of spinal cord stimulation for the treatment of chronic pain: a 20-year literature review. *Journal of Neurosurgery: Spine*, 100(3 Suppl): 254-267.
22. Eldabe, S., Buchser, E., Duarte, R.V. (2016) Complications of Spinal Cord Stimulation and Peripheral Nerve Stimulation Techniques: A Review of the Literature. *Pain Medicine*, 17(2): 325-336.
23. Bendersky, D., Yampolsky, C. (2014) Is Spinal Cord Stimulation Safe? A Review of Its Complications. *World Neurosurgery*, 82(6): 1359-1368.
24. Deer, T.R., Mekhail, N., Provenzano, D., Pope, J., Krames, E., Thomson, S., et al. (2014) The appropriate use of neurostimulation: avoidance and treatment of complications of neurostimulation therapies for the treatment of chronic pain. *Neuromodulation*, 17(6): 571-597.
25. Taylor, R.S., Taylor, R.J., Van Buyten, J.P., Buchser, E., North, R., Bayliss, S. (2004) The cost effectiveness of spinal cord stimulation in the treatment of pain: a systematic review of the literature. *Journal of Pain and Symptom Management*, 27(4): 370-378.
26. Kumar, K., Rizvi, S. (2013) Cost-effectiveness of spinal cord stimulation therapy in management of chronic pain. *Pain Medicine*, 14(11): 1631-1649.
27. National Institute for Health and Clinical Excellence. (2008) Spinal cord stimulation for chronic pain of neuropathic or ischaemic origin. NICE Technology Appraisal Guidance 159.