



OPEN ACCESS

To trial or not to trial before peripheral nerve stimulation for chronic pain: a retrospective multicenter comparative analysis of temporary-to-permanent and direct-to-permanent implantation approaches

Ryan S D'Souza ,¹ Yue Yu,² Vinita Singh ,³ Jay Karri ,⁴ Saba Javed ,⁵ Yeng F Her,¹ Nita Chai,⁶ Chelsey Hoffmann,¹ David O Warner,¹ Nasir Hussain ⁷

► Additional supplemental material is published online only. To view, please visit the journal online (<https://doi.org/10.1136/rapm-2025-106734>).

¹Department of Anesthesiology and Perioperative Medicine, Mayo Clinic, Rochester, Minnesota, USA

²Center for Biostatistics, College of Medicine, The Ohio State University Wexner Medical Center, Columbus, OH, USA

³Emory University Department of Anesthesiology, Atlanta, Georgia, USA

⁴Orthopedic Surgery, University of Maryland School of Medicine, Hunt Valley, Maryland, USA

⁵The University of Texas MD Anderson Cancer Center, Houston, Texas, USA

⁶Department of Anesthesiology, Emory University School of Medicine, Atlanta, Georgia, USA

⁷Department of Anesthesiology, The Ohio State University Wexner Medical Center, Columbus, Ohio, USA

Correspondence to

Dr Ryan S D'Souza;
DSouza.Ryan@mayo.edu

Received 10 April 2025
Accepted 15 June 2025



© American Society of Regional Anesthesia & Pain Medicine 2025. Re-use permitted under CC BY-NC. No commercial re-use. Published by BMJ Group.

To cite: D'Souza RS, Yu Y, Singh V, *et al.* *Reg Anesth Pain Med* Epub ahead of print: [please include Day Month Year]. doi:10.1136/rapm-2025-106734

ABSTRACT

Background Peripheral nerve stimulation (PNS) is an emerging neuromodulation therapy for chronic pain, yet its use in clinical practice varies significantly. Although temporary PNS is widely incorporated, either as a screening trial or a treatment itself, the evidence supporting the use of temporary PNS prior to permanent implantation is limited. We aimed to compare pain relief, opioid consumption, and adverse events between an approach implementing temporary PNS before permanent implantation (temporary-to-permanent (TTP)) vs proceeding directly to permanent PNS implantation (direct-to-permanent (DTP)).

Methods A multicenter retrospective study was undertaken at seven major academic institutions from January 1, 2014, to January 1, 2024. Adult patients who underwent permanent PNS implantation for the treatment of chronic pain conditions were included and were divided into TTP or DTP cohorts based on their clinical approach. The dual primary outcomes were pain relief and opioid consumption (in oral morphine equivalents) at 6 months compared with baseline before any PNS therapy. Multivariable Tobit regression analysis was performed to identify predictors of pain relief at 6 months using a stepwise approach.

Results A total of 130 patients were analyzed (54 in TTP approach, 76 in DTP approach). Patient-reported percentage pain relief was 56.7%±27.9% at 6 months compared with baseline (before PNS implantation) in the TTP cohort, and 45.1%±33.6% in the DTP cohort. The estimated mean percentage pain relief at 6 months was similar in the TTP and DTP cohorts (between-group difference 15.24%; 95% CI -0.32 to 30.80, p=0.052), with consistent findings after sensitivity analysis with multiple imputation. Opioid consumption declined similarly in the TTP (-3.1±9.9 mg) and DTP (-2.1±8.1 mg) cohorts at 6 months with no statistical difference between cohorts (mean between-group difference: -1.00, 95% CI -4.57 to 2.57, p=0.580), and with consistent findings after sensitivity analysis. Device explantation rates and adverse event profiles were comparable between cohorts.

Conclusion Although temporary PNS is widely performed prior to permanent PNS implantation, there was no evidence that the TTP approach is associated with superior analgesic outcomes compared with the DTP approach. Further, patients in both approaches

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Temporary peripheral nerve stimulation (PNS) is commonly used as a screening tool before permanent PNS implantation, yet evidence supporting its added value in improving long-term outcomes remains limited.

WHAT THIS STUDY ADDS

⇒ This multicenter study compares temporary-to-permanent vs direct-to-permanent PNS approaches, finding no significant difference in pain relief, reduction in opioid consumption, or adverse events between the two strategies. Both approaches demonstrated significant pain relief and opioid reduction compared with baseline prior to PNS therapy.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings challenge the routine use of temporary PNS screening trials and support the potential for streamlined care pathways that proceed directly to permanent implantation in appropriately selected patients. However, due to the potential for confounding variables and selection bias in the current study, future randomized clinical trials on this topic are warranted.

achieved clinically meaningful pain relief at 6 months compared with baseline status prior to PNS therapy.

INTRODUCTION

Peripheral nerve stimulation (PNS) can effectively treat both acute and chronic pain¹⁻⁶ by electrically stimulating peripheral nerves to modulate pain signaling.⁷ Over recent years, PNS has gained increasing traction as an alternative to systemic pharmacological therapy and more invasive neuraxial neuromodulation approaches such as spinal cord stimulation (SCS), dorsal root ganglion stimulation, or intrathecal drug delivery.^{8,9} The US Food and Drug Administration has approved PNS

devices for the treatment of acute or chronic pain involving peripheral nerves in the head, neck, trunk, and upper or lower extremities. However, clinical practice patterns in PNS utilization are highly variable across pain conditions, nerve targets, and procedural protocols.¹⁰ Examples of such heterogeneity include the role of diagnostic nerve blocks and the management of minor and major adverse events. These findings highlight a critical need for further research to elucidate factors driving these variations in clinical practice and optimize periprocedural strategies for improved clinical outcomes.

One debated aspect of clinical practice surrounding PNS therapy is whether to offer temporary PNS prior to performing permanent PNS implantation. This temporary-to-permanent (TTP) approach involves an initial treatment with a temporary PNS device, with durations typically ranging from 7 to 60 days, allowing patients to assess their pain relief before committing to permanent PNS implantation. In contrast, the direct-to-permanent (DTP) approach bypasses the temporary treatment phase, implanting a permanent PNS device without antecedent temporary stimulation. Despite the widespread implementation of both strategies, which approach yields superior pain relief and analgesic consumption has not been evaluated.

The rationale for incorporating a screening trial phase has historically been extrapolated from the SCS literature. However, recent findings from the TRIAL-STIM trial¹¹—the largest to date assessing the utility of SCS screening trials—demonstrated no difference in pain relief, adverse events, or cost-effectiveness between patients who underwent an SCS trial vs those who proceeded directly to SCS implantation. These results challenge the conventional value of screening trials and underscore the need to re-evaluate this paradigm in other neuromodulation modalities, such as PNS.

The primary aim of this study was to test if there was a difference in percentage pain relief and opioid consumption at 6 months between the TTP and DTP approaches. The null hypothesis stated that there is no difference in any of the dual primary outcomes (percentage pain relief and change in opioid consumption at 6 months) between the two approaches, and the alternative hypothesis posited that there is a significant difference in at least one of the primary outcomes at 6 months post-implantation. Secondary aims were to test if there was a difference between the TTP and DTP approaches in other outcomes of interest (eg, percentage pain relief at 12 months) and to identify sociodemographic and clinical predictors of analgesia in patients receiving each approach.

MATERIALS AND METHODS

Study design

This study was a multicenter retrospective chart review conducted across seven major institutions: Mayo Clinic Enterprise (including Mayo Clinic Rochester, Mayo Clinic Phoenix, Mayo Clinic Jacksonville, and associated Mayo Clinic Health System sites), Emory Healthcare, MD Anderson Cancer Center, The Ohio State University Wexner Medical Center, and the University of Maryland. The study protocol was developed *a priori* without formal registration.

Patient selection

The study included adult patients (≥ 18 years) who underwent PNS implantation for chronic neuropathic pain between January 1, 2014, and January 1, 2024. Inclusion criteria were (1) neuropathic pain of at least moderate intensity (defined as $\geq 5/10$ on an 11-point numeric rating scale); (2) pain localized to the

head (eg, occipital neuralgia), trunk (eg, intercostal neuralgia, cluneal neuralgia), or upper/lower extremities (eg, postsurgical neuropathic pain); and (3) failure to respond to conventional medical management, including physical therapy, pharmacological therapy (eg, anticonvulsants, antidepressants, or opioids), and/or injection therapies.

Two cohorts were defined: (1) the TTP cohort consisting of patients who first received a temporary PNS screening trial before proceeding to permanent implantation, and (2) the DTP cohort consisting of patients who received a permanent PNS device without prior temporary stimulation. While clinical judgment determined whether patients received a TTP or DTP approach, the specific decision-making factors were not systematically recorded and remain an area for future study. All eligible patient charts were queried for PNS procedures performed between January 1, 2014, and January 1, 2024. The study commenced on July 1, 2024, ensuring that all included patients had at least 6 months of follow-up data, which was the primary time point for analysis.

Exclusion criteria included patients who declined authorization for medical records review, patients < 18 years old, and those who received only a temporary PNS device without a subsequent or anticipated plan for permanent PNS implantation. Selection of the implantation approach was influenced by several factors, including patient preference for a temporary PNS screening trial before permanent implantation, provider preference for using a trial to assess efficacy, and any concerns about the complexity of explanting permanent PNS devices in cases of therapy failure.

Implantation procedures: temporary PNS screening trial

PNS implantation procedures varied based on the device manufacturer. The study included two primary types of temporary PNS devices: a device placed for 60 days (SPR Therapeutics, Cleveland, Ohio, USA) and devices that were placed for 7–10 days (Nalu Medical, Carlsbad, California, USA; Curonix, Pompano Beach, Florida, USA; Stimwave Technologies, Scottsdale, Arizona, USA). All procedures were performed by experienced physicians using ultrasound and/or fluoroscopic guidance to position the lead near the target nerve.

For the 60-day device, an introducer needle containing a stimulating probe was percutaneously advanced close to the target nerve within 0.5–1.0 cm of proximity. On confirmation of adequate stimulation coverage, the stimulating probe was removed from the introducer needle and replaced with an introducer sleeve containing the PNS lead. The lead was connected to the stimulator and test stimulation was again delivered, while adjusting intensity to deliver comfortable paresthesias in the distribution of pain. The introducer and sleeve were subsequently withdrawn with application of pressure on the skin, which resulted in the lead being deployed and secured with surgical glue. The lead was then connected to an external pulse generator (EPG).

For devices that were trialed for 7–10 days, an introducer needle was inserted close to the target nerve under ultrasound and/or fluoroscopic guidance. Then, the stylet was removed and the lead was threaded through the introducer needle. The introducer needle was then removed, and vendor-specific steps were performed for final deployment, stabilization, and connection of the lead to an EPG.

Implantation procedures: permanent PNS implantation

Permanent PNS implantation used ultrasound and/or fluoroscopic guidance, with some variations depending on device

manufacturer. After local anesthesia, a stab incision was made approximately 5 cm from the intended stimulation site. A stimulation probe was placed through a tunneling needle to confirm appropriate paresthesia coverage. Once confirmed, the introducer needle was removed, leaving the stimulating probe in place. The introducer set was placed over the trial stimulation probe, and the target nerve was again stimulated to ensure proper paresthesia location. Next, the trial stimulation probe was removed and the implantable lead with loader was placed through the introducer set. The system was again tested to ensure proper paresthesia location, and the introducer and loader were removed, leaving the implanted lead in place. The lead was subsequently tunneled to a predetermined location and secured subcutaneously. The single stab incision was closed with surgical glue. A bio-occlusive dressing was applied overlying the incision. This procedural technique was applicable to a specific permanent PNS device (Bioventus, Durham, North Carolina, USA). The tunneling steps were variable, vendor-specific, and differed for other vendors (Nalu Medical, Carlsbad, California, USA; Curonix, Pompano Beach, Florida, USA; Stimwave Technologies, Scottsdale, Arizona, USA), all of which were included in this study.

Data extraction

Electronic medical records were reviewed to extract baseline patient characteristics, including center, age, sex, body mass index (BMI), implanting physician, smoking status (current, prior, never), history of anxiety (yes/no), depression (yes/no), fibromyalgia (yes/no), diabetes mellitus (yes/no), use of anticoagulants or antiplatelets (yes/no), indication for PNS therapy, duration of chronic pain (years), insurance type (commercial, government, international, worker's compensation), baseline numeric rating scale (NRS) pain score, baseline opioid use (yes/no), baseline opioid consumption in oral morphine equivalents (OME), baseline neuropathic pain medication use (yes/no), and whether a diagnostic nerve block was performed before PNS implantation (yes/no).

Data that were extracted to inform outcomes included type of temporary PNS device, type of permanent PNS device, percentage pain relief at 6 and 12 months after permanent PNS implantation (ranging from 0% to 100%), opioid use (yes/no) and consumption (OMEs) at 6 and 12 months after permanent PNS implantation, neuropathic pain medication use (yes/no) at 6 and 12 months after permanent PNS implantation, adverse events at 12 months after permanent PNS implantation, and whether the permanent device was explanted within 12 months of permanent PNS implantation. These data were obtained either electronically from clinical surveys or from documentation from standard postoperative follow-up encounters. Opioid doses were converted to OME using the Mayo Opioid Online Converter tool (<https://kmtprod-opioidui.mayo.edu/#/converter>).

Primary and secondary outcomes

The primary outcomes of this study were the comparison of percentage pain relief and change in opioid consumption (OME) at 6 months between the TTP and DTP cohorts. Secondary outcomes included comparisons between these cohorts regarding percentage pain relief at 12 months, change in opioid use (categorical) at 6 and 12 months, change in opioid consumption (OME) at 12 months, change in neuropathic pain medication use (categorical) at 6 and 12 months, and rates of device explantation and adverse events at 12 months.

Two exploratory secondary analyses were conducted. Change in opioid consumption (OME) at 6 and 12 months was compared between cohorts for the subset of patients that were on opioids at baseline. The other exploratory secondary analysis aimed to identify predictors of pain relief at 6 months.

Statistical analysis

Baseline patient demographics and clinical characteristics were summarized overall and by cohort using appropriate descriptive statistics. Continuous variables were reported as means with SD or medians with IQRs, while categorical variables were presented as frequencies and proportions. Demographics and clinical characteristics were compared between cohorts using Kruskal-Wallis tests for continuous variables and χ^2 tests for categorical variables.

For percentage pain relief at 6 months, the minimum acceptable value was 0 because of how the question was phrased. Tobit analysis was used to model percentage pain relief because this outcome may be subject to censoring at the lower bound (0%) when patients report no improvement or worsening pain yet cannot enter a negative value due to the phrasing of the question. Tobit models are well suited to address such left censoring. Sensitivity analysis was done by including and excluding center/institution as a covariate in the Tobit regression model to check the effect of the center the patient belonged to. Change in opioid consumption (OME) at 6 months was analyzed using a linear mixed effects model with cohort as a fixed effect. Sensitivity analysis was carried out by including and excluding center/institution as a random effect to check the impact of repeated measurement within each center.

Additionally, to address missing data for the primary outcomes at 6 months, multiple imputation using the Markov Chain Monte Carlo method was used as sensitivity analysis, with missing values assumed to be missing at random. Two separate multiple imputations were performed, generating 10 and 20 imputed datasets, respectively. Results from these imputed datasets were then pooled to derive final estimates and standard errors, maximizing robustness in statistical inferences.

For secondary outcomes, changes in categorical variables from baseline (eg, opioid use, neuropathic medication use) were categorized into three groups: no change, discontinuation (yes to no), and initiation (no to yes). Changes in opioid use at 6 and 12 months and changes in neuropathic medication use at 6 and 12 months were compared between the two cohorts using χ^2 tests. Rates of device explantation and adverse events at 12 months were analyzed using general linear mixed effects models with cohort as a fixed effect. Similar sensitivity analyses mentioned above were performed. Percentage pain relief at 12 months was tested using Tobit analysis due to the flooring effect described above, and sensitivity analysis was done by including and excluding center/institution as a covariate. Change in opioid consumption (OME) at 12 months was compared between the two cohorts using a Kruskal-Wallis test.

Change in opioid consumption (OME) at 6 and 12 months for patients who were on opioids at baseline was compared using Kruskal-Wallis tests. For the exploratory analysis identifying predictors of pain relief at 6 months, a multivariable Tobit regression model was constructed to identify predictors of the primary outcome (percentage pain relief at 6 months). A stepwise selection method was employed, incorporating both forward selection and backward elimination with an entry level of 0.15 and a stay level of 0.15. Candidate predictors included cohort, BMI, smoking status, depression, anxiety, baseline NRS, baseline

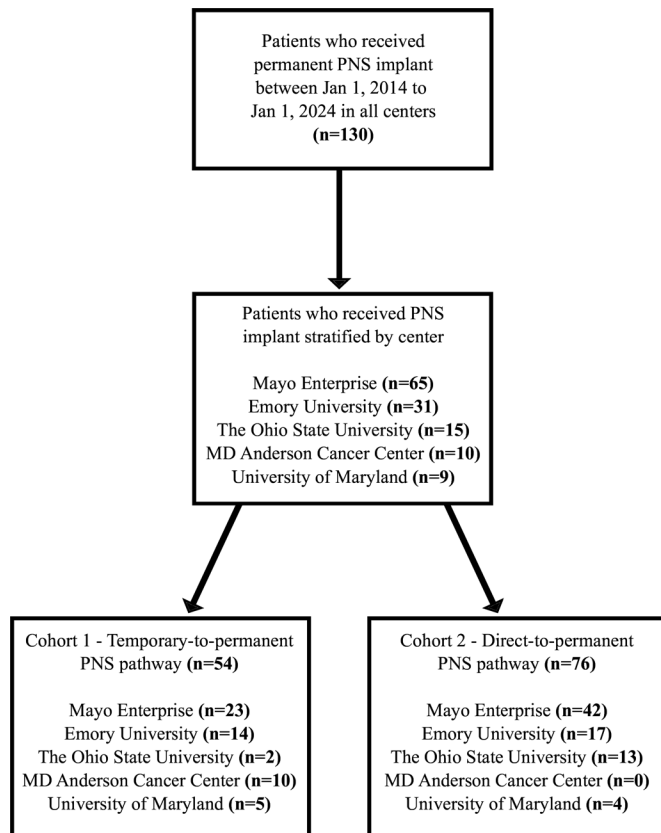


Figure 1 Consolidated Standards of Reporting Trials diagram. Patient selection process stratified by center and cohort is displayed. PNS, peripheral nerve stimulation.

opioid use, and whether a diagnostic block was performed prior to PNS implantation. These variables were selected based on clinical expertise and prior literature identifying potential negative predictors of pain relief. The final model included variables that met the selection criteria, optimizing model parsimony while retaining key predictors.

All tests were two-sided, and statistical significance was defined as $p < 0.05$. All analyses were conducted using SAS V.9.4 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Baseline characteristics

A total of 130 patients were included in the study, with 54 in the TTP cohort and 76 in the DTP cohort. A Consolidated Standards of Reporting Trials diagram (figure 1) illustrates the patient selection process, including cohort assignment and distribution across medical centers. Although the data query spanned from January 1, 2014, to January 1, 2024, the earliest qualifying patient included in this study underwent PNS implantation on March 22, 2018. Notably, 116 of 130 (89.2%) patients were implanted within the 5 years preceding study commencement (July 1, 2024), and all patients included in the cohort received their PNS system within the past 7 years. The median age of the overall cohort was 62.5 years (IQR 48.0–72.0), and 59% were female (table 1). Patient characteristics, including a history of smoking and comorbid psychiatric conditions, were similar. PNS implantation sites varied, with the lower extremity (46.5%) and shoulder (23.3%) being the most frequently targeted regions. A diagnostic block was performed before PNS implantation in most cases (80.0%). Other characteristics, including BMI, race/

ethnicity, history of fibromyalgia, pain duration, insurance type, baseline NRS pain scores, categorical opioid use and opioid consumption, and baseline neuropathic medication use, were similar between cohorts, other than a higher proportion of patients in the DTP cohort having depression (64.5% vs 46.3%, $p = 0.039$). Of the 54 patients who underwent the TTP approach, the type of trial lead included a 60-day temporary percutaneous PNS system in 45 patients (83.3%), and a short-term 7-day to 10-day trial system in 9 patients (16.7%).

Primary outcomes

Descriptive statistics for all primary and secondary variables are presented in online supplemental tables 1, 2. Results did not depend on institution, which was thus excluded from the final models for both primary outcomes. In the original dataset (without imputation), patient-reported percentage pain relief was $56.7\% \pm 27.9\%$ at 6 months compared with baseline (before PNS implantation) in the TTP cohort and $45.1\% \pm 33.6\%$ in the DTP cohort. The estimated mean percentage pain relief at 6 months in the TTP cohort was 15.24% higher than the DTP group (95% CI -0.32 to 30.80 , $p = 0.052$; table 2). This finding remained consistent across sensitivity analyses using multiple imputation, with estimated differences of 15.07% (95% CI -0.35 to 30.50 , $p = 0.055$) with 10 imputed datasets and 14.88% (95% CI -0.34 to 30.10 , $p = 0.055$) with 20 imputed datasets.

Opioid consumption declined similarly in the TTP (-3.1 ± 9.9) and DTP (-2.1 ± 8.1) cohorts with no statistical difference between cohorts (mean between-group difference: -1.00 , 95% CI -4.57 to 2.57 , $p = 0.580$; table 2). These results remained consistent in the multiple imputation models, with a mean difference of -0.89 (95% CI -4.35 to 2.56 , $p = 0.612$) in the 10-fold imputation approach and -0.74 (95% CI -4.27 to 2.79 , $p = 0.681$) in the 20-fold imputation approach.

Secondary outcomes

Comparative analyses for secondary outcomes between cohorts are provided in tables 3 and 4. The average percentage pain relief at 12 months was $54.2\% \pm 41.5\%$ for the TTP cohort and $34.3\% \pm 31.6\%$ for the DTP cohort. After fixing the value of the variable of 'Center' of the patient, the estimated value of percentage pain relief at 12 months in the TTP cohort was 9.44% higher (95% CI -24.49 to 43.37) than the DTP cohort, although the difference was not statistically significant ($p = 0.578$). There was a significantly greater increase in OME consumption from baseline to 12 months in the DTP cohort (9.1 ± 24.3) compared with the TTP cohort (4.1 ± 39.3 ; $p = 0.028$; table 3). However, these analyses were limited by over 50% missing data at the 12-month follow-up. No significant differences were observed in categorical opioid use changes at 6 or 12 months, nor in changes in neuropathic medication use at 6 or 12 months. The variable 'Center' was included as a random effect in the final general mixed effect model for the incidence of an adverse event outcome but was excluded in the final model for the occurrence of device explantation at 12 months. The frequency of adverse events (OR=0.35, $p = 0.098$; table 4) or device explantation did not differ between groups (OR=0.58, $p = 0.447$; table 4).

In the exploratory analysis restricted to the subset of patients who were on opioids at baseline, opioid consumption decreased similarly in the TTP (-9.6 ± 15.7 mg OME) and DTP cohorts (-9.8 ± 10.5 mg OME) at 6 months ($p = 0.555$), and increased similarly in the TTP (5.0 ± 61.5 mg OME) and DTP (10.0 ± 29.0 mg OME) cohorts at 12 months ($p = 0.109$) (online supplemental table 2).

Table 1 Baseline sociodemographic and clinical variables

	Cohort		Total (n=130)	P value
	Cohort 1 (TTP approach) (n=54)	Cohort 2 (DTP approach) (n=76)		
Center, n (%)				0.0003*
Emory Healthcare	14 (25.9%)	17 (22.4%)	31 (23.8%)	
MD Anderson Cancer Center	10 (18.5%)	0 (0.0%)	10 (7.7%)	
Mayo Enterprise	23 (42.6%)	42 (55.3%)	65 (50.0%)	
The Ohio State University	2 (3.7%)	13 (17.1%)	15 (11.5%)	
University of Maryland	5 (9.3%)	4 (5.3%)	9 (6.9%)	
Age				0.9830†
N (missing)	54 (0)	76 (0)	130 (0)	
Median (IQR)	62.5 (47.0–72.0)	61.0 (49.0–73.0)	62.5 (48.0–72.0)	
Range	22.0–92.0	21.0–97.0	21.0–97.0	
Sex, n (%)				0.8371*
Female	31 (57.4%)	45 (59.2%)	76 (58.5%)	
Male	23 (42.6%)	31 (40.8%)	54 (41.5%)	
BMI				0.9865†
N (missing)	53 (1)	75 (1)	128 (2)	
Median (IQR)	28.0 (23.7–34.5)	28.0 (24.1–32.4)	28.0 (24.0–33.1)	
Range	14.0–44.0	2.0–60.0	2.0–60.0	
Race, n (%)				0.4842*
African American	7 (13.0%)	11 (14.9%)	18 (14.1%)	
Asian	1 (1.9%)	0 (0.0%)	1 (0.8%)	
White	46 (85.2%)	63 (85.1%)	109 (85.2%)	
Missing	0	2	2	
Ethnicity, n (%)				0.3911*
Hispanic	0 (0.0%)	1 (1.4%)	1 (0.8%)	
Non-Hispanic	54 (100.0%)	73 (98.6%)	127 (99.2%)	
Missing	0	2	2	
Smoking, n (%)				0.4384*
Current	5 (9.3%)	10 (13.2%)	15 (11.5%)	
Never	31 (57.4%)	48 (63.2%)	79 (60.8%)	
Prior	18 (33.3%)	18 (23.7%)	36 (27.7%)	
Anxiety, n (%)				0.6777*
No	24 (44.4%)	31 (40.8%)	55 (42.3%)	
Yes	30 (55.6%)	45 (59.2%)	75 (57.7%)	
Depression, n (%)				0.0392*
No	29 (53.7%)	27 (35.5%)	56 (43.1%)	
Yes	25 (46.3%)	49 (64.5%)	74 (56.9%)	
Fibromyalgia, n (%)				0.2224*
No	51 (94.4%)	67 (88.2%)	118 (90.8%)	
Yes	3 (5.6%)	9 (11.8%)	12 (9.2%)	
Indication for PNS (eg, location of peripheral neuralgia), n (%)				0.2276*
Low back	2 (3.8%)	3 (3.9%)	5 (3.9%)	
Lower extremity	24 (45.3%)	36 (47.4%)	60 (46.5%)	
Neck	0 (0.0%)	1 (1.3%)	1 (0.8%)	
Occipital	3 (5.7%)	1 (1.3%)	4 (3.1%)	
Shoulder	12 (22.6%)	18 (23.7%)	30 (23.3%)	
Truncal	5 (9.4%)	1 (1.3%)	6 (4.7%)	
Upper extremity	7 (13.2%)	16 (21.1%)	23 (17.8%)	
Missing	1	0	1	
Duration of pain (months)				0.4479†
N (missing)	48 (6)	58 (18)	106 (24)	
Median (IQR)	36.0 (21.5–84.0)	46.0 (24.0–104.0)	42.0 (22.0–96.0)	
Range	9.0–396.0	6.0–480.0	6.0–480.0	
Insurance payor, n (%)				0.1677*
Commercial	15 (27.8%)	21 (27.6%)	36 (27.7%)	
Government	37 (68.5%)	47 (61.8%)	84 (64.6%)	

Continued

Table 1 Continued

	Cohort			P value
	Cohort 1 (TTP approach) (n=54)	Cohort 2 (DTP approach) (n=76)	Total (n=130)	
International	1 (1.9%)	0 (0.0%)	1 (0.8%)	
Worker's compensation	1 (1.9%)	8 (10.5%)	9 (6.9%)	
Performed diagnostic nerve block before PNS, n (%)				0.9291*
No	11 (20.4%)	15 (19.7%)	26 (20.0%)	
Yes	43 (79.6%)	61 (80.3%)	104 (80.0%)	
NRS (pain score) at baseline				0.5134†
N (missing)	51 (3)	75 (1)	126 (4)	
Median (IQR)	8.0 (6.0–9.0)	7.0 (6.0–9.0)	8.0 (6.0–9.0)	
Range	2.0–10.0	3.0–10.0	2.0–10.0	
Baseline opioid use, n (%)				0.4507*
No	35 (64.8%)	54 (71.1%)	89 (68.5%)	
Yes	19 (35.2%)	22 (28.9%)	41 (31.5%)	
Baseline OME				0.4742†
N (missing)	53 (1)	73 (3)	126 (4)	
Median (IQR)	0.0 (0.0–10.0)	0.0 (0.0–7.5)	0.0 (0.0–10.0)	
Range	0.0–200.0	0.0–240.0	0.0–240.0	
Baseline neuropathic pain medication use, n (%)				0.2873*
No	12 (22.2%)	23 (30.7%)	35 (27.1%)	
Yes	42 (77.8%)	52 (69.3%)	94 (72.9%)	
Missing	0	1	1	

* χ^2 p value.
†Kruskal-Wallis p value.
BMI, body mass index; DTP, direct-to-permanent approach; NRS, numeric rating scale; OME, oral morphine equivalent; PNS, peripheral nerve stimulation; TTP, temporary-to-permanent approach.

A stepwise selection process was performed to identify predictors of percent pain relief at 6 months (table 5). The covariates selected through this process included smoking status, the performance of a diagnostic block, and cohort type. In the final multivariable model, after adjusting for relevant covariates, TTP cohort status was a significant predictor of percent pain relief at 6 months compared with the reference DTP cohort ($\beta=16.84$, $SE=7.69$, $p=0.028$). Smoking status was also a statistically significant predictor. Compared with patients with a smoking history (prior), patient with never-smoking status had significantly greater percent pain relief at 6 months ($\beta=20.43$, $SE=9.00$, $p=0.023$). These conclusions remained the same with 10-imputed datasets and 20-imputed datasets.

Table 2 Difference in estimated mean pain relief and opioid consumption at 6 months post-permanent PNS implantation between TTP cohort and DTP cohort

Imputation approach	Estimate	SE	Approximate 95% CI	P value
Pain relief at 6 months				
None	15.24	7.86	−0.32 to 30.80	0.052
10-multiply imputation	15.07	7.87	−0.35 to 30.50	0.055
20-multiply imputation	14.88	7.77	−0.34 to 30.10	0.055
Opioid consumption at 6 months				
None	−1.00	1.80	−4.57 to 2.57	0.580
10-multiply imputation	−0.89	1.76	−4.35 to 2.56	0.612
20-multiply imputation	−0.74	1.80	−4.27 to 2.79	0.681

The reference cohort was the DTP cohort. The estimates provided in this table describe the TTP cohort in comparison to the DTP cohort.
DTP, direct-to-permanent; PNS, peripheral nerve stimulation; TTP, temporary-to-permanent.

DISCUSSION

Main findings

This multicenter retrospective analysis compared the TTP and DTP approaches for percutaneous PNS implantation, evaluating their associations with pain relief, analgesic consumption, and adverse event rates. Our findings indicate that both TTP and DTP approaches yielded clinically meaningful pain reductions of 56.7% and 45.1% at 6 months after permanent PNS implantation, respectively, with no between-group statistical differences (although the p value was close to the statistical significance threshold of 0.05). These findings remained consistent at 12 months post-implantation, highlighting durability and similar analgesic profiles of both approaches. There was a modest decrease in opioid consumption (OMEs) of 3.1 mg and 2.1 mg in the TTP and DTP cohorts at 6 months after permanent PNS implantation, respectively, with no between-group statistical differences. However, there was a modest increase in opioid consumption (OMEs) of 4.1 mg and 9.1 mg in the TTP and DTP cohorts at 12 months after permanent PNS implantation, respectively, with a higher increase favoring the DTP cohort, although this analysis was limited by over 50% missing data.

Taken together, our findings suggest that although the TTP approach allows for an initial assessment of analgesic outcomes prior to permanent implantation, patients in the DTP cohort experienced comparable long-term analgesic outcomes, suggesting that careful patient selection may mitigate the need for a temporary PNS screening trial before proceeding to permanent PNS implantation.

Implications for clinical practice

The prognostic utility of a temporary SCS screening trial has been studied previously in the SCS literature. Eldabe *et*

Table 3 Comparative analysis for secondary outcomes

	Cohort 1 (TTP approach) (n=54)	Cohort 2 (DTP approach) (n=76)	Total (n=130)	P value
6-month change in opioid use, n (%)				0.561*
No to yes	0 (0.0%)	1 (1.6%)	1 (1.0%)	
No change	35 (87.5%)	56 (90.3%)	91 (89.2%)	
Yes to no	5 (12.5%)	5 (8.1%)	10 (9.8%)	
Missing	14	14	28	
6-month change in neuropathic pain medicine use, n (%)				0.088*
No to yes	0 (0.0%)	4 (6.6%)	4 (4.0%)	
No change	38 (97.4%)	51 (83.6%)	89 (89.0%)	
Yes to no	1 (2.6%)	6 (9.8%)	7 (7.0%)	
Missing	15	15	30	
12-month percent pain relief				0.578†
N (missing)	25 (29)	31 (45)	56 (74)	
Mean (SD)	54.2 (41.5)	34.3 (31.6)	43.2 (37.4)	
Range	0.0, 100.0	0.0, 100.0	0.0, 100.0	
12-month change in opioid use, n (%)				0.331*
No to yes	2 (6.9%)	5 (14.3%)	7 (10.9%)	
No change	24 (82.8%)	29 (82.9%)	53 (82.8%)	
Yes to no	3 (10.3%)	1 (2.9%)	4 (6.3%)	
Missing	25	41	66	
Change in opioid consumption at 12 months from baseline				0.028‡
N (missing)	29 (25)	33 (43)	62 (68)	
Median (IQR)	0.0 (−5.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	
Range	−55.0, 195.0	−15.0, 90.0	−55.0, 195.0	
12-month change in neuropathic pain medicine use, n (%)				0.065*
No to yes	0 (0.0%)	2 (5.9%)	2 (3.2%)	
No change	28 (100.0%)	28 (82.4%)	56 (90.3%)	
Yes to no	0 (0.0%)	4 (11.8%)	4 (6.5%)	
Missing	26	42	68	
Adverse events, n (%)				0.098§
No	8 (14.8%)	5 (6.6%)	13 (10.0%)	
Yes	46 (85.2%)	71 (93.4%)	117 (90.0%)	
Device explantation, n (%)				0.447§
No	51 (94.4%)	69 (90.8%)	120 (92.3%)	
Yes	3 (5.6%)	7 (9.2%)	10 (7.7%)	

* χ^2 p value.
†Tobit regression model coefficient p value.
‡Kruskal-Wallis p value.
§General mixed effects model least squares means difference p value.
DTP, direct-to-permanent approach; TTP, temporary-to-permanent approach.

al conducted a multicenter randomized controlled trial that investigated the clinical utility, diagnostic accuracy, and cost-effectiveness of a temporary SCS screening trial followed by permanent implantation compared with direct implantation without a trial in carefully selected patients.¹¹ The study found no significant difference in pain reduction, quality of life, or secondary outcomes between groups at the primary

time point of 6 months. These findings remained consistent in a 36-month follow-up study, where the incorporation of a temporary SCS screening trial did not yield superior analgesia and other patient outcomes compared with the no-trial group.¹² A nested qualitative study¹³ of patient perspectives revealed that most patients strongly preferred a one-stage SCS implantation, citing benefits such as reduced time off work, fewer hospital visits, avoidance of concerns over temporary leads, and a single recovery period. These perspectives align with our study's findings as we similarly demonstrated comparable improvements with the use of antecedent temporary PNS screening trials, compared with directly implanting permanent PNS devices. These findings question the utility and necessity of temporary PNS screening trials in routine practice for patients expected to undergo permanent PNS implantation. Moreover, concordant with findings highlighted by Chadwick *et al*,¹³ we would anticipate a preference for the DTP approach in PNS therapy given its less invasive technique and safety

Table 4 Model results for secondary outcomes (cohort 2 is the reference group)

	Estimate/OR	Approximate 95% CI	P value
12-month percent pain relief	9.44	−24.49 to 43.37	0.578*
Adverse events	0.35	0.10 to 1.22	0.098†
Device explantation	0.58	0.14 to 2.38	0.447†

*Tobit regression model coefficient p value.
†General mixed effects model least squares means difference p value.

Table 5 Predictors of pain relief at 6 months post-permanent PNS implantation

Parameter	Level	Estimate	SE	P value
Original data				
Cohort	Cohort 1 (TTP approach)	16.84	7.69	0.028
Diagnostic nerve block performed	No	-18.99	10.34	0.066
Smoking	Current	10.58	13.26	0.425
Smoking	Never	20.43	9.00	0.023
10-multiply data imputation				
Cohort	Cohort 1 (TTP approach)	16.05	7.65	0.036
Diagnostic nerve block performed	No	-17.45	10.25	0.089
Smoking	Current	9.44	13.82	0.495
Smoking	Never	19.01	8.96	0.034
20-multiply data imputation				
Cohort	Cohort 1 (TTP approach)	15.87	7.59	0.037
Diagnostic nerve block performed	No	-16.95	10.16	0.095
Smoking	Current	10.01	13.13	0.446
Smoking	Never	18.27	8.83	0.039

PNS, peripheral nerve stimulation; TTP, temporary-to-permanent cohort.

profile compared with SCS therapy, although this warrants further investigation.

Although the current study suggests comparable analgesic outcomes between the TTP and DTP approaches, we can only speculate on the preferences of clinicians and patients and other unexplored factors that underlie the selection of a specific implantation strategy. The TTP approach may remain valuable in patients with unclear indications or history of neuromodulation non-responsiveness as it enables clinicians to assess effectiveness and other factors such as patient compliance with treatment and restrictions before committing to permanent implantation. The use of antecedent temporary PNS may especially be helpful given that there is limited prognostic utility of peripheral nerve blocks in evaluating subsequent response to PNS.¹⁴ Therefore, there may be some undefined benefit of trialing before permanent PNS implantation, although the potential risks and associated costs may outweigh this potential benefit. Conversely, the DTP approach may be preferable in patients with well-defined pain generators and a high likelihood of response, reducing procedural burden, healthcare-related costs, and potential complications associated with temporary lead placement. While our study did not specifically assess for predictors of success of either the TTP or DTP approach separately, previous literature suggests that favorable response to neuromodulation may be associated with factors such as younger age, shorter pain duration, localized neuropathic pain, and absence of negative predictors such as untreated psychiatric comorbidities, ongoing tobacco use, and widespread, non-anatomical pain.^{15–18} The reasons for the selection of a specific implantation strategy were not studied, but our findings highlight the need for standardized preimplantation evaluation protocols. For instance, screening for negative predictive risk factors such as smoking status, as was identified in our stepwise regression model, may enhance patient selection, risk stratification, perioperative counseling, and predict treatment response.

Implications for research and policy

This study reinforces the need for future RCTs, similar to the design of the TRIAL-STIM RCT,¹¹ to validate the findings observed in the current multicenter analysis. Future research should aim to clarify the cost-effectiveness of the TTP approach compared with the DTP approach, considering

the added procedural and equipment costs of temporary PNS screening trials. From a policy perspective, insurance coverage for non-pharmacologic treatment¹⁹ including PNS remains inconsistent,²⁰ with significant variability in approval rates for both temporary and permanent devices. The lack of definitive evidence comparing TTP and DTP approaches contributes to this ambiguity. There is a strong need for clearer insurance policies and standardized reimbursement criteria that align with evidence-based clinical practice.

Strengths and limitations

The multicenter design in the current study enhances the generalizability of findings across diverse clinical settings and patient populations. The comprehensive data collection, including baseline sociodemographic, clinical, and procedural variables, allows for robust comparative analysis and identification of key predictors of treatment response. Finally, the use of multiple imputation techniques for missing data supplemented the analysis of our original dataset.

The current study had notable limitations. First, selection bias is a major limitation, including potential factors that explain why clinicians and patients choose one approach or another. Clinical decision-making likely varied across institutions and clinicians, and it is plausible that temporary PNS screening trials were preferentially used in patients where clinicians were uncertain about the likelihood of benefit. Conversely, patients perceived to have a higher chance of success may have been directed to the DTP pathway. Second, as a retrospective study, it is subject to inherent biases including unmeasured confounders. Third, while efforts were made to account for missing data, unaccounted variables may still influence outcomes. Fourth, the lack of long-term follow-up beyond 12 months limits our understanding of the durability of pain relief and potential delayed complications. Fifth, differences in device manufacturers and procedural techniques among participating centers may introduce unmeasured heterogeneity, potentially affecting outcomes. Notably, longer trial periods of 60 days may allow for greater assessment of PNS utility relative to shorter 7–10-day trials, thus potentially inflating TTP effectiveness in patients who undergo longer trial duration. Sixth, the absence of psychometric data limits our assessment of how mental health variables may influence outcomes. Similarly, other pertinent patient-reported outcomes,

including functional metrics (physical activity levels, ambulation, return to work, etc) and quality of life, were not consistently available across all sites, which may limit the comprehensive assessment of the pain experience. Seventh, an important consideration is the inherent difference in technology between temporary and permanent PNS systems, namely that the 60-day temporary PNS device uses monopolar lead systems, whereas permanent PNS systems employ multicontact leads with distinct programming capabilities and electrode configurations. As such, the 60-day temporary PNS treatment may not fully replicate the experience derived from a permanent PNS device, raising the possibility that the two stages are not directly comparable. This distinction could limit the predictive value of a temporary PNS device and calls into question whether it should be used to guide permanent implantation decisions.

Future directions

Prospective, randomized studies directly comparing TTP and DTP strategies with standardized protocols, including trial duration, device type, and patient-centered outcomes, are warranted. Investigators should also study the role of patient-specific factors, such as pain phenotype and psychological comorbidities, in predicting PNS outcomes. Economic evaluations assessing cost-effectiveness and healthcare resource utilization for each approach will be invaluable in informing policy and reimbursement decisions. Long-term follow-up from each approach (TTP and DTP), examining device durability, patient satisfaction, and functional outcomes, will provide a more comprehensive understanding of PNS therapy.

A formal cost-effectiveness analysis was beyond the scope of this study. Relative procedural costs can be inferred using the 2024 Medicare national average reimbursement rates. Under the TTP strategy, patients would undergo two separate procedures: a percutaneous implantation of a temporary PNS lead (current procedural terminology (CPT) code 64555), followed by a percutaneous implantation of a permanent PNS lead (CPT code 64590) with pulse generator placement if applicable (CPT 64590). Notably, billing practices may vary by PNS vendor, with some warranting the use of a pulse generator insertion CPT code and others not, introducing variability into procedural costs. In contrast, the DTP strategy involves a single procedure, combining percutaneous lead placement (CPT 64555) and, if applicable, pulse generator insertion (CPT 64590). While this approach does not capture other cost domains (eg, operating room time, recovery room utilization, and patient time burden), it highlights a potential economic tradeoff associated with trialing. Importantly, our institution does not permit the publication of actual financial cost-of-care data; however, this surrogate framework provides a transparent and reproducible method for preliminary economic comparison. Future studies are warranted to rigorously assess real-world cost, time, and resource utilization implications across variable practices with PNS implantation.

CONCLUSION

This multicenter comparative analysis provides important insights into the clinical outcomes of TTP vs DTP implantation strategies with use of PNS for chronic pain. Although there may be utility in a temporary PNS screening trial, compared with a strategy that does not employ a trial, there is no association with patient outcome benefit. Both approaches demonstrate significant pain relief and opioid reduction compared with baseline prior to PNS therapy. Further prospective research is essential for validating these findings and assessing long-term analgesic

and functional outcomes, cost-effectiveness of each approach, and examining outcomes related to the broader experience of pain, including satisfaction, functional outcomes, and quality of life.

X Ryan S D'Souza @Ryan_S_DSouzaMD, Vinita Singh @VinitaSinghMD, Jay Karri @JayKarriMD, Saba Javed @SabalavedMD and Nasir Hussain @nasir418

Contributors RSD was involved in the study conception and design, data collection, data analysis, manuscript composition, and supervising all aspects of the study. YY was involved in the study design, data analysis, and manuscript composition. VS, JK, SJ, YFH, NC, CH, and NH were involved in the study conception, data collection, and manuscript editing. DOW was involved in the study conception, study design, and manuscript editing. RSD is the guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests RSD received investigator-initiated research grant funding from Nevro Corp and Saol Therapeutics paid to his institution. RSD is expected to be a speaker for Vertex Pharmaceuticals. SJ receives investigator-initiated grant funding from SPR Therapeutics and Averitas. CH provides general consulting services for Nalu Medical. Other authors declare no conflict of interest.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. IRB approval was obtained from all centers involved including Mayo Clinic, The Ohio State University Wexner Medical Center, Emory University School of Medicine, University of Maryland School of Medicine, and the University of Texas MD Anderson Cancer Center. IRB centers deemed that consent was not needed as data were de-identified.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data are available upon reasonable request to the corresponding author (RSD).

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, an indication of whether changes were made, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iDs

Ryan S D'Souza <http://orcid.org/0000-0002-4601-9837>
Vinita Singh <http://orcid.org/0000-0002-8103-1401>
Jay Karri <http://orcid.org/0009-0003-0520-9516>
Saba Javed <http://orcid.org/0000-0002-1028-8904>
Nasir Hussain <http://orcid.org/0000-0003-0353-1002>

REFERENCES

- Gilmore CA, Ilfeld BM, Rosenow JM, *et al*. Percutaneous 60-day peripheral nerve stimulation implant provides sustained relief of chronic pain following amputation: 12-month follow-up of a randomized, double-blind, placebo-controlled trial. *Reg Anesth Pain Med* 2019.;rapm-2019-100937.
- Ilfeld BM, Ball ST, Gabriel RA, *et al*. A Feasibility Study of Percutaneous Peripheral Nerve Stimulation for the Treatment of Postoperative Pain Following Total Knee Arthroplasty. *Neuromodulation* 2019;22:653–60.
- Ilfeld BM, Plunkett A, Vijjeswarapu AM, *et al*. Percutaneous Peripheral Nerve Stimulation (Neuromodulation) for Postoperative Pain: A Randomized, Sham-controlled Pilot Study. *Anesthesiology* 2021;135:95–110.
- West T, Hussain N, Bhatia A, *et al*. Pain intensity and opioid consumption after temporary and permanent peripheral nerve stimulation: a 2-year multicenter analysis. *Reg Anesth Pain Med* 2024.;rapm-2024-105704.
- Strand N, D'Souza RS, Hagedorn JM, *et al*. Evidence-Based Clinical Guidelines from the American Society of Pain and Neuroscience for the Use of Implantable Peripheral Nerve Stimulation in the Treatment of Chronic Pain. *J Pain Res* 2022;15:2483–504.
- Char S, Jin MY, Francio VT, *et al*. Implantable Peripheral Nerve Stimulation for Peripheral Neuropathic Pain: A Systematic Review of Prospective Studies. *Biomedicine* 2022;10:2606:10.

- 7 Strand NH, D'Souza R, Wie C, *et al.* Mechanism of Action of Peripheral Nerve Stimulation. *Curr Pain Headache Rep* 2021;25:47.
- 8 Abd-Elseyed A, D'Souza RS. Peripheral Nerve Stimulation: The Evolution in Pain Medicine. *Biomedicines* 2021;10:18.
- 9 Sivanesan E, Gulati A. Resurgence of peripheral nerve stimulation with innovation in device technologies. *Reg Anesth Pain Med* 2019;44:615–6.
- 10 Karri J, Sivanesan E, Gulati A, *et al.* Peripheral Nerve Stimulation for Pain Management: A Survey of Clinical Practice Patterns. *Neuromodulation* 2025;28:348–61.
- 11 Eldabe S, Duarte RV, Gulve A, *et al.* Does a screening trial for spinal cord stimulation in patients with chronic pain of neuropathic origin have clinical utility and cost-effectiveness (TRIAL-STIM)? A randomised controlled trial. *Pain* 2020;161:2820–9.
- 12 Eldabe S, Nevitt S, Griffiths S, *et al.* Does a Screening Trial for Spinal Cord Stimulation in Patients With Chronic Pain of Neuropathic Origin Have Clinical Utility (TRIAL-STIM)? 36-Month Results From a Randomized Controlled Trial. *Neurosurgery* 2023;92:75–82.
- 13 Chadwick R, McNaughton R, Eldabe S, *et al.* To Trial or Not to Trial Before Spinal Cord Stimulation for Chronic Neuropathic Pain: The Patients' View From the TRIAL-STIM Randomized Controlled Trial. *Neuromodulation* 2021;24:459–70.
- 14 Hoffmann CM, Butler CS, Pingree MJ, *et al.* Is Response to a Pre-implant Diagnostic Peripheral Nerve Block Associated With Efficacy After Peripheral Nerve Stimulation Implantation? A Ten-Year Enterprise-Wide Analysis. *Neuromodulation* 2024;27:873–80.
- 15 Bastiaens F, van de Wijgert IH, Bronkhorst EM, *et al.* Factors Predicting Clinically Relevant Pain Relief After Spinal Cord Stimulation for Patients With Chronic Low Back and/or Leg Pain: A Systematic Review With Meta-Analysis and Meta-Regression. *Neuromodulation* 2024;27:70–82.
- 16 Strauss I, Taha K, Krishna V, *et al.* Younger age predicts greater effectiveness of spinal cord stimulation for chronic pain. *Acta Neurochir (Wien)* 2016;158:999–1003.
- 17 Burchiel KJ, Anderson VC, Wilson BJ, *et al.* Prognostic factors of spinal cord stimulation for chronic back and leg pain. *Neurosurgery* 1995;36:1101–10.
- 18 De La Cruz P, Fama C, Roth S, *et al.* Predictors of Spinal Cord Stimulation Success. *Neuromodulation* 2015;18:599–602; .
- 19 Goertz CM, George SZ. Insurer Coverage of Nonpharmacological Treatments for Low Back Pain-Time for a Change. *JAMA Netw Open* 2018;1:e183037.
- 20 Sheth SJ, Mauck WD, Russo DP, *et al.* Potential Cost Savings with 60-day Peripheral Nerve Stimulation Treatment in Chronic Axial Low Back Pain. *Pain Ther* 2024;13:1187–202.