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Evaluating Dorsal Root Ganglion Stimulation in a Prospective Dutch Cohort

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Objectives: Dorsal root ganglion (DRG) stimulation is a recent neuromodulation option that has delivered safe, effective pain relief for a number of etiologies. This prospective observational study was intended to establish the effectiveness of this treatment in a typical real-world clinical context.

Materials and Methods: Participants with chronic, intractable pain of the trunk or lower limbs were recruited from multiple pain clinics in the Netherlands. Subjects were trialed and implanted with DRG stimulation systems. Pain, function, mood, and quality of life, ratings were collected through 12 months postimplant.

Results: Of the 66 subjects enrolled, failed back surgery syndrome, peripheral nerve injury, and complex regional pain syndrome formed the largest etiologies. Permanent implants were placed in 86.2% subjects (56/65). After 12 months of treatment, average pain ratings in subjects' primary area of pain decreased from 8.0 cm at baseline to 4.1 cm, and 49% of subjects had \geq 50% reduction in pain (visual analog scale). In addition, functional capacity was increased, and mood and quality of life improved. No confirmed lead migrations were observed, and there was a low rate of infection.

Conclusions: DRG stimulation significantly reduced the severity of subjects' pain and enabled participatory changes that improved quality of life through 12-months postimplant.

Keywords: spinal cord stimulation, dorsal root ganglion, pain, quality of life, function, neuropathic

Conflict of Interest: Dr. Frank J. P. M. Huygen is a consultant for Abbott, Medtronic, and Grunenthal. Dr. Nijhuis is a consultant for Abbott and Saluda. Drs. Cusack and Kramer are employees of Abbott Laboratories.

INTRODUCTION

A spinal cord stimulation (SCS) system, specifically targeting the dorsal root ganglion (DRG) of the spinal level associated with the painful anatomic area, has recently become available to treat chronic neuropathic pain. DRG stimulation has been demonstrated to be safe and effective in a previous prospective, multicenter, single arm clinical trial (1,2). In that study, 63% of the subjects who had a trial system were permanently implanted, subsequent to which overall baseline pain was relieved by 58.1% and 56.3% at 6 and 12 months postimplant, respectively. The resumption of preimplant pain ratings during a temporary stimulation-off period and the restoration of analgesia after the stimulation was turned back on confirmed the effectiveness of the treatment.

A recent randomized, controlled, comparative effectiveness trial of DRG stimulation in subjects with chronic neuropathic pain due to CRPS I and II found that DRG stimulation resulted in superior treatment success compared to tonic dorsal column stimulation (DCS) at all time points through 12 months (3). At three months postimplant, 81.2% of DRG subjects had \geq 50% reduction in pain while 55.7% of SCS subjects had a \geq 50% reduction. At 12 months postimplant, 74.2% of DRG subjects and 53.0% of SCS subjects had a \geq 50% reduction.

In addition, several small case series also have reported outcomes with DRG stimulation, including for complex regional pain syndrome (CRPS) of the lower limbs (N = 11) (4), CRPS of the knee (N = 1) (5), and groin pain (N = 3 and N = 29) (6,7). In these case series, the trial-to-permanent ratio was between 73% and 86% (4,7), and average pain relief ranged between 62% and 100% with follow-ups of a year or less (4–7).

To further characterize outcomes, this report presents data from the first postmarket, prospective, observational clinical study of DRG stimulation since the device received CE-marking allowing its sale in Europe. Widely inclusive enrollment criteria (intractable pain of more than six months) were employed to establish conditions of patient selection and device usage that are representative of the typical clinical pain population. The wealth of postmarket research existing in the neuromodulation literature, generated over the span of several decades, has served to well-characterize SCS and other neurostimulation modality outcomes across both typical-use and highly controlled scenarios (8–10); this report aims to provide similar real-world evidence for DRG stimulation.

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Table 1. List of Inclusion/Exclusion Criteria.

Inclusion

- At least 18 years old.
- Psychologically appropriate for the implantation for an active implantable medical device in the opinion of the investigator.
- Pain limited to the lower body: in the thoracic, lumbar, and/or sacral distributions.
- Chronic: Pain at least for six months' duration.
- Intractable: previously been inadequately responsive to conservative treatments for chronic pain including but not limited to pharmacological therapy, physical therapy, and interventional pain procedures for chronic pain.
- Of significant severity: minimum baseline pain rating of 60 mm on the VAS in the primary region of pain.

METHODS

All study activities were conducted under the approval of local Ethics Committees and with the full informed consent of all participants. The clinical trial followed good clinical practice and data quality was assured by periodic source data and compliance monitoring.

Subjects

Participants were recruited during 2012 and 2013 from three investigators' pain management practices in the Netherlands. A complete list of inclusion and exclusion criteria used in the study is summarized in Table 1.

Intervention

The AxiumTM neurostimulation system (Abbott Laboratories, Sunnyvale, CA, USA) was used to place electrodes at the target DRG(s). A period of trial stimulation to assess the likelihood of good long-term outcomes was employed. Good trial outcomes were considered predictive of the long-term effectiveness of the intervention; subjects with positive trials (\geq 50% pain relief on the visual analog scale [VAS]) were offered permanent implants in which all external hardware was replaced with a fully implanted system featuring a primary cell battery and voltage-controlled stimulation.

Assessments and Follow-Ups

At baseline, the regional distribution of each subject's primary area of pain was mapped, as was its intensity (on a standard 10 cm VAS). Measures of functioning (Brief Pain Inventory, Short Form [BPI; (11)]), quality of life (EQ-5D-3L; (12)), and mood (Profile of Mood States [POMS; (13)]) also were administered. Outcomes at the end of the trial stimulation period were quantified by the percentage change in VAS scores relative to baseline. One week after permanent implantation, pain ratings were collected again. Follow-up visits were conducted prospectively at 1, 3, 6, and 12 months postpermanent implant. At each of these visits, the baseline assessments were repeated, and subjects were evaluated for any adverse events (AEs). Investigators reported all AEs regardless of their relatedness to the DRG neurostimulator system. AEs were defined as any undesirable experience occurring to a subject during the study. Serious adverse events (SAEs) were defined as any AE that results in death, is immediately life threatening, requires an inpatient hospitalization or prolongation of an existing hospitalization, or results in significant disability or incapacity. Investigators determined seriousness and relatedness of each event to the DRG system.

Exclusion

- Pain primarily in cervical distribution.
- Unstable pain condition.
- Recent corticosteroid or radiofrequency treatment at the intended site of stimulation.
- Presence of an active implantable device.
- Coagulation disorder or use of anticoagulants.
- Cancer.
- Current/planned pregnancy.

Table 2. Of 66 Subjects, Most had FBSS, Peripheral Nerve Injury, or CRPS.							
Etiology		Ν	%				
FBSS		25	37.9				
Peripheral nerve	e injury/causalgia	13 ²	19.7				
CRPS		11	16.7				
Postamputation	pain	4	6.0				
Radicular pain		2	3.0				
Failed neck surg	gery syndrome ³	1	1.5				
Other/idiopathio	<u>c</u>	10	15.1				
Total		66	100.0				

Data were pooled across all sites for analysis. For each outcome measure, the change from baseline to each follow-up visit was assessed including all patients with evaluable data at each study visit. Unless otherwise noted, data are presented as means \pm standard deviation or percentages. Single factor analysis of variance (ANOVA) with the main effect of time was performed, and if significant, six pairwise comparisons (baseline compared to the End of Trial, 1-week, 1-, 3-, 6-, 12-month follow-up visits) were completed utilizing the Bonferroni correction for multiple comparison. A *p*-value of 0.05 was required for statistical significance. Statistical analyses were performed with MATLAB R2016b (The Mathworks, Natick, MA, USA).

RESULTS

Subjects

The study enrolled 66 subjects. The most common etiology of pain was failed back surgery syndrome (FBSS), followed by peripheral nerve injury/causalgia¹ and CRPS I (Table 2). The majority of FBSS patients stemmed from failed surgeries on herniated discs. Average age was 52 years (\pm 11.5), ranging from 30 to 80 years, and females comprised 64% of subjects.

Figure 1 presents the subject distribution through 12 months. A total of 65 subjects underwent a trial stimulation. Following the trial, nine subjects exited the study. Seven subjects had inadequate pain relief at trial. One subject, had 50% reduction in VAS score at trial, but was dissatisfied with the extent of pain relief

¹ Also known as CRPS II.

²Ten postsurgical, three traumatic.

³A protocol deviation to include this subject was granted by the study sponsor.



Figure 1. Subject disposition through 12 months.

and refused permanent implant. One subject had a trial attempted but was unsuccessful due to a previously undetected schwannoma in the epidural space. The remaining 56 subjects received the permanent DRG stimulation system (86.2%). Following INS implant, seven subjects exited the study: four due to infection requiring explant of the system, one death that was not device related, one protocol noncompliance, and one subject withdrew with no reason given.

Visual Analog Pain Scale

Across all subjects, DRG stimulation significantly reduced pain at all follow-up visits through 12 months (Fig. 2). In the primary area of pain, VAS scores were reduced from 8.0 at baseline to 4.10 at 12-months, a mean percent reduction of 48.8% (\pm 3.27). At 12 months, 49% (24/49) of subjects achieved \geq 50%



Figure 2. VAS ratings demonstrated significant reduction in pain (VAS) at all follow-up visits (p < 0.0001) relative to baseline. Data presented are means \pm standard deviations. [Color figure can be viewed at wileyonlinelibrary.com]

reduction, and 82% (32/39) achieved at least a 30% reduction (Fig. 3).

VAS scores also were assessed for each of the major etiology subgroups (Table 3 and Fig. 4). Subjects with a complaint of FBSS reported an average reduction in VAS of 54.7% (\pm 36.9%, N = 22) at 12 months postimplant, with 13/22 subjects (59.1%) with 50% or better pain relief. Subjects with peripheral nerve injury/causalgia had an average reduction of 43.7% (\pm 69.26%, N = 10) pain relief at 12 months postimplant, with 6/10 subjects (60%) reporting 50% or better pain relief. Subjects with CRPS I had an average reduction of 46.8% (\pm 33.9%, N = 9) pain relief at 12 months postimplant, with 3/9 subjects (33.3%) reporting 50% or more pain relief.

Brief Pain Inventory

Average scores on the BPI showed significant improvements on both the Severity and Interference indices (Figs. 5 and 6). At baseline, 8 subjects (12.3%) rated their "worst pain in the last 24 hours"





Figure 3. The proportion of subjects that achieved ≥50% reduction in VAS at each follow-up visit. [Color figure can be viewed at wileyonlinelibrary.com]

Table 3. VAS Pain Ratings are Presented at Baseline and for Each of the End-of-Trial and Postimplant Follow-Up Visits for All Subjects and for Three Etiologies.								
Etiology	Baseline	End of TNS	1 week	1 month	3 months	6 months	12 months	
FBSS	7.98	3.74	3.59	2.01	2.54	3.55	3.86	
	±1.42	±2.49	±2.6	±2.24	±2.39	±3.01	±3.28	
	N = 25	N = 21	N = 20	N = 22	N = 22	N = 21	N = 22	
Peripheral nerve injury/causalgia ^a	7.38	2.86	2.29	2.01	3.7	4.03	3.53	
	±1.97	±2.04	±2.37	±2.24	±2.84	±3.11	±3.19	
	N = 15	N = 11	N = 11	N = 9	N = 10	N = 8	N = 10	
CRPS I	8.44	1.88	2.75	2.87	3.12	4.34	4.62	
	±1.23	±1.67	±2.56	±2.41	±2.90	±3.3	±3.07	
	N = 11	N = 9	N = 10	N = 9	N = 8	N = 7	N = 9	
All subjects	8.0	3.19	3.19	3.20	3.10	3.82	4.10	
	±1.49	±2.5	±2.68	±2.89	2.68	±3.08	3.27	
	N = 66	N = 52	N = 50	N = 48	N = 47	N = 45	N = 49	

Data are presented as means (\pm standard deviations); the number of subjects that provided ratings also is provided. For all subjects, DRG stimulation significantly reduced pain relative to baseline at all follow-up visits through 12 months (p < 0.0001). ^aAlso known as CRPS II.

as mild or moderate; by 12 months postimplant, 18 subjects (36.7%) did. Similarly, the numbers of subjects rating the interference of pain with their general activity, walking, work, and sleep as mild or moderate increased between baseline and 12 months postimplant (Fig. 7).

Quality of Life

Quality of life as indicated by the EQ-5D index scores (range from 0 to 1.0) significantly improved during DRG stimulation treatment and, importantly, improvement was sustained over time (Fig. 8). The EQ-5D index scores increased from 0.36 at baseline to 0.62 at 12 months, almost doubling the subject's ratings of quality of life.

Profile of Mood States

Subjects also demonstrated improvement in the POMS questionnaire. The composite Total Mood Disturbance scale improved significantly at all follow-up visits relative to baseline (Fig. 9). Total Mood Disturbance improved from 27.8 (\pm 17.9) at baseline to 13.3 (\pm 18.3) at 12 months.



Figure 4. VAS ratings as a function of the major etiologies treated. Data presented are means \pm standard deviations. For all indications, DRG stimulation significantly reduced pain relative to baseline at all follow-up visits through 12 months (p < 0.0001). [Color figure can be viewed at wileyonlineli brary.com]

Safety Outcomes

There were 15 SAEs in 14 subjects. There was one death in the study. At 131 days after the six month study visit, the subject was admitted to the hospital due to a medication overdose, went into a coma and passed away. This event was attributed to a preexisting condition of depression. One SAE (INS implant site infection) was related to the presence of the device. When oral antibiotics did not resolve the infection, the patient was admitted to the hospital, the INS extension was removed and the battery was relocated. The subject continued in the study and completed the 12-month follow-up. There were six SAEs related to the permanent implant procedure. These events included four INS pocket infections, one transient motor deficit, and one dural puncture. The remaining seven SAEs were unrelated to the presence or operation of the device and/or procedure. The events included one bladder infection, one incidence of pain following a gutenza application, one perianal fistula, one knee cyst, one transient ischemic attach, one worsening of preexisting CRPS, one bowel obstruction. During the study, five DRG systems were explanted. Four were explanted due to an INS implant site infection, and one was removed as a precaution for a difficult to treat bladder infection.



Figure 5. BPI scores exhibited a sustained decrease in pain severity. Data are composite scores combining all pain domains as means \pm standard deviations. There were significant decreases at each follow-up visit relative to baseline (p < 0.0001). [Color figure can be viewed at wileyonlinelibrary.com]



Figure 6. BPI scores exhibited a sustained decrease in the interference of pain. Data are composite scores combining all interference domains as means \pm standard deviations. There were significant decreases at each follow-up visit relative to baseline (p < 0.0003). [Color figure can be viewed at wileyonlineli brary.com]

There were nine non-SAEs in eight subjects. Two AEs were related to the presence or operation of the device. One subject had loss of stimulation and increased pain possibly due to a lead migration; programed settings were changed and pain coverage was reestablished, and no revision was required. One subject had loss of stimulation with return of pain when the battery software went into upgrade mode. The battery was reset and the pain subsided. There were four AEs related to the permanent implant procedure. These events included two pain at the INS implant site, one INS implant site wound infection, and one post-TNS procedure headache. The remaining three (3) AEs were unrelated to the presence or operation of the device by the investigators. The events included, knee pain (1), depression (1), and accidental burn wounds on leg (1).

DISCUSSION

Outcomes in this postmarket study of DRG stimulation for pain were positive. The stimulation trial success rate of 86.2% (56 out of 65 subjects) is at the upper range of similar statistics for SCS implants (14,15). FBSS, peripheral nerve injury/causalgia and CRPS I formed the major etiologies treated; with average pain relief of 54.7%, 43.7%, and 46.8%, respectively after 12 months of treatment. This suggests that DRG stimulation is a treatment option amenable to several common neuropathic pain conditions. There was a low rate of loss-to-follow-up after permanent implant (12.5%; 7/56), which is less than the 20% identified as a neuromodulation study quality requirement (9).

When pain relief outcomes are considered within the broader context of subject ratings on the secondary outcomes of pain experience (BPI), mood (POMS), and quality of life (EQ-5D-3L), a more complete picture of the corollaries of pain relief emerges.

There was a sustained improvement through 12 months in BPI severity ratings (decrease of 1.7 points) and composite ratings of pain interference (decrease of 1.4 points). A decrease of one to three points on the BPI is a clinically meaningful change in noncancer pain ratings (16,17); thus, results in this report represent clinically important reductions. Further, while only 12.3% of subjects had rated their "worst pain in 24 hours" as mild or moderate (0–6) at baseline, 36.7% did so at 12 months postimplant. Pain interference also improved significantly from 5.0 at baseline to 3.6 at 12 months. This shows a consistent pattern of the reduction of severe pain and its interference with everyday activities to more manageable levels.

Total mood disturbance (POMS) improved during the study from 27.8 at baseline to 13.3 at 12 months. Subjects' low mood at baseline is an expected consequence of living with the burden of chronic pain conditions, and, although depression has been



Figure 7. At baseline, the majority of subjects rated the impact of their pain as "severe" across all BPI domains. After 12 months of treatment, however, the majority of subjects reduced their ratings to "mild" or "moderate." [Color figure can be viewed at wileyonlinelibrary.com]



Figure 8. Significant improvement in quality of life (EQ-5D index scores) relative to baseline was sustained at each follow-up visit through 12 months (p < 0.0001). Data presented are means ± standard deviations. [Color figure can be viewed at wileyonlinelibrary.com]

identified as prognostic of poor outcomes (18,19), it could not, by itself, ethically be considered an exclusionary factor in the patient selection process for DRG stimulation. All subjects were adequately screened prior to enrollment to ensure they did not have serious or untreated psychologic and/or psychiatric conditions that could rule out implantation.

Subjects' improvement in quality of life was maintained more than 12 months. The EQ-5D index value for the general Dutch population is 0.892 (20). At baseline, subjects in this study reported a considerably lower-than-average quality of life (0.357), but after 12 months of treatment the mean score, 0.621, was approaching national averages. Notably, EO-5D scores were stable across the 1-, 3-, 6-, and 12-month time points, in contrast to the VAS scores which exhibited a slight increase over time, as has been observed in many SCS studies (21-23). The tempering over time of initially enthusiastic pain relief reports may be a psychologic phenomenon, or the loss of effectiveness may be a neural process such as accommodation or "tolerance," in which everincreasing levels of stimulation are required to elicit pain control (24). Irrespective of this effect on pain relief, however, quality of life improvements did not decrease over time. This suggests that the benefits afforded to subjects' lives by reduction in pain severity are durable and self-sustaining.

There is a need for more information about the functional consequences of pain relief in the neuromodulation literature. For example, it could be surmised that pain that is reduced from "severe" to "mild" or "moderate" also would be accompanied by a



Total Mood Disturbance

Figure 9. Total mood disturbance scores improved significantly at each follow-up visit relative to baseline through 12 months (p < 0.003). Data presented are means \pm standard deviations. [Color figure can be viewed at wileyonlinelibrary.com]

concomitant decrease in opioid consumption as has been observed in a recent study (23), resumption of physical activity as demonstrated in an animal model (25), and resumption of life roles (26). These changes would undoubtedly contribute to further improvements in quality of life. Detailed quantitative and qualitative assessments may shed further light on the rehabilitative contribution of neuromodulation and its personal impact. Further, investigation into partial responders to DRG stimulation also is necessary, as mean reduction in pain score in this group never exceeded 30% in the current study.

The DRG device exhibited a good safety profile in this study. Wound infections (a total of 5 in 65 subjects; 7.7%) occurred at a similar rate to that reported in the SCS literature (27,28). There were no confirmed lead migrations in this study. This low rate of lead migration is similar to other reports on DRG stimulation (1,2,29). This lack of migration is in stark contrast to DCS. In the SCS literature, lead migrations occur in up to 13% of cases (27).

This observational, postmarket study was designed with wide inclusion criteria to emulate the typical clinical environment. As such, however, the broader interpretation of the data is limited by the relatively small number of subjects within each grouping of etiologies and regions of the body and cannot be compared directly with those of randomized controlled trials for SCS (22,30) or DRG (3). While the overall effects on pain outcomes and all secondary measures were largely maintained at 12 months, the percentage of subjects receiving ≥50% pain relief was variable in the range of 49%-70%. This average pain relief, at 12 months, was slightly less efficacious (56% vs. 48.8% mean pain relief) when compared to a previous observational study with DRG stimulation in a similar chronic intractable pain population (2). A possible cause for this observation is that some pain conditions may have a more robust response to DRG than others (CRPS I vs. FBSS, for example). Another possible reason for this observation could be that the patient population in the current study was not limited to limb pain as in previous DRG studies (2,3).

CONCLUSIONS

These converging real-world clinical outcomes support the notion that DRG stimulation can provide safe and clinically significant pain relief, minimized interference of pain with daily activities, and improved quality of life at 12 months postpermanent implant. The results of this multicenter, prospective, postmarket study of DRG stimulation support further investigation into the functional impact of DRG stimulation as well as longerterm outcomes beyond 12 months. Additional prospective, statistically powered studies also are warranted to further expand the clinical indications of DRG stimulation in targeted regions of the body.

Authorship Statements

Drs. Huygen, Liem, and Nijhuis conducted the clinical aspects of this work, including patient recruitment, implantation, followups, and data collection. Drs. Cusack and Kramer designed the prospective study, analyzed the data, and interpreted the results. Dr. Cusack coordinated preparation of the manuscript with important intellectual input from all other authors. All authors approved the final manuscript. The authors thank Linda Johnson, PhD, for medical writing assistance in drafting this manuscript.

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REFERENCES

- Liem L, Russo M, Huygen FJPM. A multicenter, prospective trial to assess the safety and performance of the Spinal Modulation dorsal root ganglion neurostimulator system in the treatment of chronic pain. *Neuromodulation* 2013;16:471–482.
- Liem L, Russo M, Huygen FJPM et al. One-year outcomes of spinal cord stimulation of the dorsal root ganglion in the treatment of chronic neuropathic pain. *Neuromodulation* 2015;18:41–48.
- Deer TR, Levy RM, Kramer J et al. Dorsal root ganglion stimulation yielded higher treatment success rate for complex regional pain syndrome and causalgia at 3 and 12 months: a randomized comparative trial. *Pain* 2017;158:669–681.
- Van Buyten JP, Smet I, Liem L, Russo M, Huygen F. Stimulation of dorsal root ganglia for the management of complex regional pain syndrome: a prospective case series. *Pain Practice* 2015;15:208–216.
- van Bussel CM, Stronks DL, Huygen FJPM. Successful treatment of intractable complex regional pain syndrome type I of the knee with dorsal root ganglion stimulation: a case report. *Neuromodulation* 2015;18:58–60.
- Zuidema X, Breel J, Wille F. Paresthesia mapping: a practical workup for successful implantation of the dorsal root ganglion stimulator in refractory groin pain. *Neuromodulation* 2014;17:665–669.
- 7. Schu S, Gulve A, Eldabe S et al. Spinal cord stimulation (SCS) of the dorsal root ganglion (DRG) for groin pain—a retrospective review. *Pain Pract* 2015;15:293–299.
- Song JJ, Popescu A, Bell RL. Present and potential use of spinal cord stimulation to control chronic pain. *Pain Physician* 2014;17:235–246.
- Taylor RS, Desai MJ, Rigoard P, Taylor RJ. Predictors of pain relief following spinal cord stimulation in chronic back and leg pain and failed back surgery syndrome: a systematic review and meta-regression analysis. *Pain Pract* 2014;14:489–505.
- Kumar K, Caraway DL, Rizvi S, Bishop S. Current challenges in spinal cord stimulation. Neuromodulation 2014;17:22–35.
- 11. Tan G, Jensen MP, Thornby JI, Shanti BF. Validation of the Brief Pain Inventory for chronic nonmalignant pain. *J Pain* 2004;5:133–137.
- 12. The EuroQol Group. EuroQol—a new facility for the measurement of health-related quality of life. *Health Policy* 1990;16:199–208.

- Pollock V, Cho DW, Reker D, Volavka J. Profile of Mood States: the factors and their physiological correlates. J Nerv Ment Dis 1979;167:612–614.
- Mekhail NA, Mathews M, Nageeb F, Guirguis M, Mekhail MN, Cheng J. Retrospective review of 707 cases of spinal cord stimulation: indications and complications. *Pain Pract* 2011;11:148–153.
- Chincholkar M, Eldabe S, Strachan R et al. Prospective analysis of the trial period for spinal cord stimulation treatment for chronic pain. *Neuromodulation* 2011;14: 523–529.
- Dworkin RH, Turk DC, Wyrwich KW et al. Interpreting the clinical importance of treatment outcomes in chronic pain clinical trials: IMMPACT recommendations. J Pain 2008;9:105–121.
- Cleeland C, Mendoza T, The Brief Pain Inventory: meaningful changes in pain interference. Washington, DC: Paper Presented at: 4th Meeting of the Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials (IMMPACT-IV), 2004.
- Sparkes E, Raphael JH, Duarte RV, LeMarchand K, Jackson C, Ashford RL. A systematic literature review of psychological characteristics as determinants of outcome for spinal cord stimulation therapy. *Pain* 2010;150:284–289.
- North RB, Kidd DH, Wimberly RL, Edwin D. Prognostic value of psychological testing in patients undergoing spinal cord stimulation: a prospective study. *Neuro*surgery 1996;39:301–311.
- Parkin D, Rice N, Devlin N. Statistical analysis of EQ-5D profiles: does the use of value sets bias inference? *Med Decis Making* 2010;30:556–565. doi: 10.1177/0272989X09357473
- 21. Kemler MA, de Vet HCW, Barendse GAM, van den Wildenberg FA, van Kleef M. Effect of spinal cord stimulation for chronic complex regional pain syndrome Type I: five-year final follow-up of patients in a randomized controlled trial. *J Neurosurg* 2008;108:292–298.
- Kumar K, Taylor RS, Jacques L et al. Spinal cord stimulation versus conventional medical management for neuropathic pain: a multicentre randomised controlled trial in patients with failed back surgery syndrome. *Pain* 2007;132:179–188.
- Al-Kaisy A, Van Buyten JP, Smet I, Palmisani S, Pang D, Smith T. 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 Med* 2014;15:347–354.
- Kumar K, Hunter G, Demeria D. Spinal cord stimulation in treatment of chronic benign pain: challenges in treatment planning and present status, a 22-year experience. *Neurosurgery* 2006;58:481–496.
- Sato KL, Johanek LM, Sanada LS, Sluka KA. Spinal cord stimulation (SCS) improves decreased physical activity induced by nerve injury. *Behav Neurosci* 2014;128:625–632.
- Reneman MF, Beemster TT, Edelaar JA, van Velzen JM, van Bennekom C, Escorpizo R. Towards an ICF- and IMMPACT-based pain vocational rehabilitation core set in the Netherlands. J Occup Rehabil 2013;23:576–584.
- Deer TR, Mekhail N, Provenzano D et al. The appropriate use of neurostimulation: avoidance and treatment of complications of neurostimulation therapies for the treatment of chronic pain. *Neuromodulation* 2014;17:571–598.
- Cameron T. Safety and efficacy of spinal cord stimulation for the treatment of chronic pain: a 20-year literature review. J Neurosurg 2004;100:254–267.
- Kramer J, Liem L, Russo M, Smet I, Van Buyten JP, Huygen F. Lack of body positional effects on paresthesias when stimulating the dorsal root ganglion (DRG) in the treatment of chronic pain. *Neuromodulation* 2015;18:50–57.
- 30. Kemler MA, Barendse GAM, van Kleef M et al. Spinal cord stimulation in patients with chronic reflex sympathetic dystrophy. *NEJM* 2000;343:618–624.