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T12 Dorsal Root Ganglion Stimulation to Treat Chronic Low Back Pain: A Case Series

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Introduction: Dorsal root ganglion stimulation (DRG-S) is a neuromodulation technique for treating neuropathic pain syndromes. Research has demonstrated DRG-S to be more effective than conventional SCS in treating RSD/CRPS, particularly of the lower extremities. Results from recent case series and prospective studies suggest that DRG-S may be effective in treatment of pain syndromes considered to have non-neuropathic components and characteristics (e.g. nociceptive). There have been multiple, small studies demonstrating efficacy of DRG-S for axial low back pain. There has, however, been no consensus regarding the best location for DRG lead placement in the treatment of low back pain.

Methods: Patients presenting with refractory low back pain in a private pain management practice were considered for DRG-S. Patients were provided a trial stimulator prior to potential implantation. Per standard practice, pain intensity, disability, general health status, and quality of life were followed using the visual analog scale (VAS), Oswestry Disability Index, EQ-5D index, and the SF-36 survey, respectively. Data were collected prior to implantation and at variable follow-ups after DRG-S initiation.

Results: Seventeen consecutive patients presented with predominantly axial low back pain with/without a secondary component of lower extremity pain. All were trialed and subsequently implanted for DRG-S. Leads were placed at T12 to target the low back. Stimulation levels were set very low, below that of which patients experienced paresthesias. Last follow-up times averaged 8.3 months. More than half of the patients experienced pain relief ≥80%, with an average low back pain relief of 78% at last follow-up. Additionally, substantial improvements in physical and mental functioning, disability, and quality of life were reported.

Conclusions: T12 DRG-S can be an effective treatment for chronic axial low back pain. Stimulation results in reduced pain and disability, while improving quality of life. These outcomes can be achieved without paresthesias.

Keywords: Dorsal root ganglion stimulation, DRG, failed back surgery syndrome, non-operated back, low back pain, neuromodulation

Conflict of Interest: Kiran V. Patel is a consultant and educator for Abbott Neuromodulation and a consultant to Vertos Medical. The other authors have no conflict of interest to declare.

INTRODUCTION

Low back pain is one of the most common sources of morbidity worldwide and the fifth most common reason for visits to a physician in the United States (1–3). Low back pain usually resolves without treatment or with conservative measures such as physical therapy (2). However, in a subset of patients, low back pain persists and becomes chronic. Interventional treatment options such as epidural steroid injections, medial branch ablations, or surgical intervention may resolve chronic back pain in these patients, depending on the underlying etiology (4).

Over the past 40 years, spinal cord stimulation (SCS) has emerged as a therapeutic option for patients suffering from chronic pain intractable to other treatments (5–7). Although traditional SCS

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has shown to be associated with improvements in pain and quality of life in some studies (8), 40–50% of low back pain patients treated with traditional SCS do not experience substantial pain relief (9,10). Generally, pain relief also decreases over time (11). The overall lower efficacy of traditional SCS in low back pain patients may be due to the fact that SCS tends to provide greater analgesic benefit in neuropathic pain conditions compared to nociceptive or mixed pain syndromes (5–7). Moreover, low-frequency, tonic SCS also may less consistently target the essential neural elements within the dorsal column and surface of the spinal cord to effectively manage pain within the low back. Thus, the mechanisms by which traditional SCS evokes pain relief may, then, also be less effective. In prospective, randomized, controlled studies SCS paradigms using higher frequency stimulation or bursting patterns have been shown to be superior to traditional low-frequency SCS (12,13). However, published reports of these approaches in "real-world" settings with more heterogenous low back pain patient populations have demonstrated less robust or variable findings (14). Thus, it is unclear if these forms of SCS are appropriate for all low back pain patient populations, or if other neuromodulation approaches might be more appropriately utilized for long-term benefit.

Since nociceptive sensory information is carried in the anterolateral sensory pathways and spinothalamic tract, and not in the dorsal column, afferent pain signaling from low back structures may not be efficiently altered by conventional dorsal column SCS (15,16). More recently, however, dorsal root ganglion stimulation (DRG-S) has become available (17–19). Since the DRG houses the primary sensory neurons transmitting afferent nociception, it may be a better target for treating more nociceptive or mixed nociceptive/neuropathic pain syndromes, such as persistent low back pain (20). Preliminary studies with DRG-S in patients with low back pain have yielded promising results (17–19,21,22). One question that remains, however, is which spinal level(s) should be targeted with this therapeutic approach. We hypothesized that, due to the innervation patterns and afferent pathways from sensory neurons in the low back (23), T12 may be an important vertebral level to target for low back pain.

METHODS

Clinical outcomes from a series of patients implanted with DRG-S for low back pain were collected. The primary goal of treatment was the alleviation of axial low back pain. All patients were offered, and agreed, to try DRG-S to treat their intractable low back pain. The Northwell Institutional Review Board approved this study and the requirement to obtain written informed consent was waived.

Patients suffering from chronic back pain with or without leg pain for at least 6 months were treated in a multidisciplinary pain management center. Multiple diagnostic procedures targeting the zygapophyseal and sacroiliac joints, as well as the intervertebral discs, were conducted as a part of the standard work-up. Patients were considered for neuromodulation treatment following failure of multiple, conservative and interventional treatment options such as medication, physical therapy, epidural steroid injections, radiofrequency lesioning, lumbar medial branch blocks, and injections at the sacroiliac and hip joint.

Consecutive patients underwent a DRG-S trial using the Proclaim system (Abbott Laboratories, Abbott Park, IL, USA.) between November 2017 and July 2018; methods have been described previously (24). All patients underwent bilateral epidural T12 DRG lead placement to cover their primary complaint of low back pain. Several patients required additional leads, which were placed at the L1 or S1 levels, depending on their pain distribution. Trials lasted 7 days (except for one patient with a trial of two days due to anticoagulant use), after which patients were asked to evaluate the outcomes. Pain relief of 50% or more was considered successful and predicated implantation of a permanent system.

Multiple clinical outcome domains were collected as is suggested by the IMMPACT recommendations (25). Questionnaires were completed at standard clinical checkups at 1, 3, 6, and 12 months postimplantation and compared with preimplantation (baseline) values. The primary outcome measure was pain rating on a 100-mm visual analog scale (VAS). Secondary outcome measures included disability ratings with the Oswestry Disability Index (ODI) (26), health-related quality of life outcomes with the Short Form-36 (SF-36) Health Survey (27) and general health status ratings were measured with the EuroQOL 5-dimensions (EQ-5D)

Table 1. Patient Demographics and Baseline Characteristics.

Variable	
Age in years, mean (range)	57 (range 34–71)
Gender, N (%)	7 (41%) male / 10 (59%) female
Location of pain, N of patients (%)	5 (29%): low back pain alone
	3 (29%): low back pain + sacroiliac joint or hip pain
	9 (53%): low back pain + leg or foot pain
Prior treatments for low back pain,	7 (41%): Lumbar fusion
N of patients (%), (more than one selection possible)	5 (29%): Laminectomy or discectomy without fusion
	4 (24%): Failed tonic or high-frequency SCS trial (lack of back pain coverage/relief)
	17 (100%): Injections or procedures in the two years prior to baseline
Number of injections at the target levels during the two years prior to baseline, per patient	6.1 (total: 104; range: 1–13)
Opioid usage at baseline, N of patients (%)	10 (59%): No opioid use
	0 (0%): Low dose (<40 morphine equivalents [MEQ])
	7 (41%): Moderate dose (40–100 MEQ)
	0 (0%): High dose (>100 MEQ)

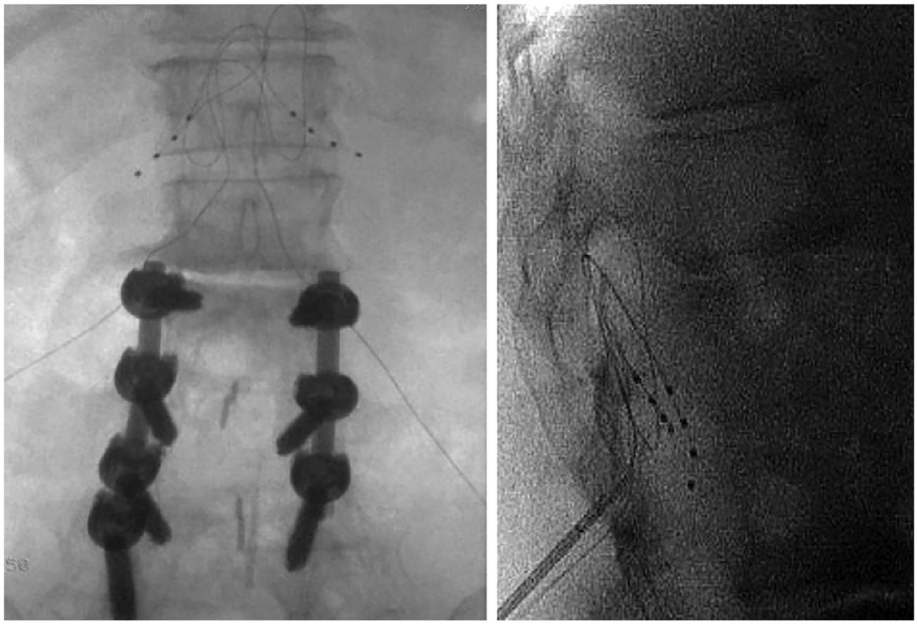

Figure 1. Exemplar preimplant anteroposterior and lateral X-rays of the thoracolumbar spine, showing instrumentation following surgical procedures and T12 DRG leads.

Table 2. DRG Stimulator Implant Details.

Number of leads per patient (mean)	3.2
Location of leads	
Bilateral leads at T12	17 patients (100%)
At least one lead at L1	3 patients (18%)
At least one lead at S1	10 patients (59%)

instrument (28). Collection of adverse events (AE) was performed during the study.

Descriptive (means, medians, and variances) statistics were calculated for reporting. Within group statistical analyses of the outcomes postimplantation were compared to baseline using paired *t*-tests for normally distributed values and the Wilcoxon signed rank test for non-normally distributed data. A type I error rate (alpha) of 0.05 was used for statistical significance. Values reported are means $\pm$ standard deviation (SD).

RESULTS

Patients (n = 17) presented with predominant back pain with or without lower extremity pain secondary to the back anatomy. Patient demographics and characteristics are summarized in Table 1. Most patients had extensive back pain management histories, including instrumentation (n = 7) (see Fig. 1) and previous laminectomy or discectomy without fusion (n = 5). All patients had a successful trial of DRG-S and subsequently received permanently implanted systems with lead placement details as described in Table 2. In all cases, DRG-S was programmed at subperceptive levels, such that patients did not feel paresthesias. Typically, patients were programmed with standard bipolar contact configurations spanning the DRG. The average parameters were pulse width of 260 msec, frequency of 14 Hz, and amplitude of 0.35 mA. Patients were instructed to decrease their amplitude in the event that paresthesias were perceived.

Of the 17 patients, one completed questionnaires through three months postimplantation, 9 through 6 months, and 7 through 12 months. On average, the last follow-up for each patient was completed after 8.3 months of DRG stimulation.

Between pretrial baseline and last postimplant follow-up, the overall pain scores of the patients improved by 80% decreasing from a mean of 92.5 $\pm$ 8.0 mm at baseline (n = 17) to a mean of 22.3 $\pm$ 16.6 mm after 1 month of treatment (n = 15), 29.4 $\pm$ 15.4 mm after 3 months of treatment (n = 16), 20.6 $\pm$ 12.8 mm after 6 months of treatment (n = 16), and 19.3 $\pm$ 16.4 mm after 12 months of treatment (n = 7). See Figure 2. The pain rating at patients' last follow-up was 20.0 $\pm$ 13.5 mm (n = 17), a statistically significant difference from baseline ($p < 0.001$). This represented a mean 77.8% pain reduction relative to baseline, with all patients reporting a minimum of 50% pain relief and nine of the 17 patients reporting 80% or more pain relief. The need for interventional spinal injections decreased after implantation; the mean number of injections in the treated levels during the follow-up period was 0.7 per patient (total: 13; range: 0–4), with 10 patients (59%) needing no injections. Similarly, of the seven patients using opioid pain medications at baseline, three decreased their usage and two completely discontinued opioids. Two patients who had comorbid pain conditions in addition to that which was treated by DRG-S needed to continue their baseline regimen.

General health ratings significantly improved at follow-up compared to baseline. EQ-5D index scores improved from a mean of 0.30 $\pm$ 0.16 at baseline (n = 17) to a mean of 0.85 $\pm$ 0.10 after one month of treatment (n = 15), 0.83 $\pm$ 0.11 after three months of treatment (n = 16), 0.86 $\pm$ 0.07 after six months of treatment (n = 16), and 0.85 $\pm$ 0.13 after 12 months of treatment (n = 7). The mean EQ-5D index score at patients' last follow-up was 0.84 $\pm$ 0.12 (n = 17), a statistically significant difference from

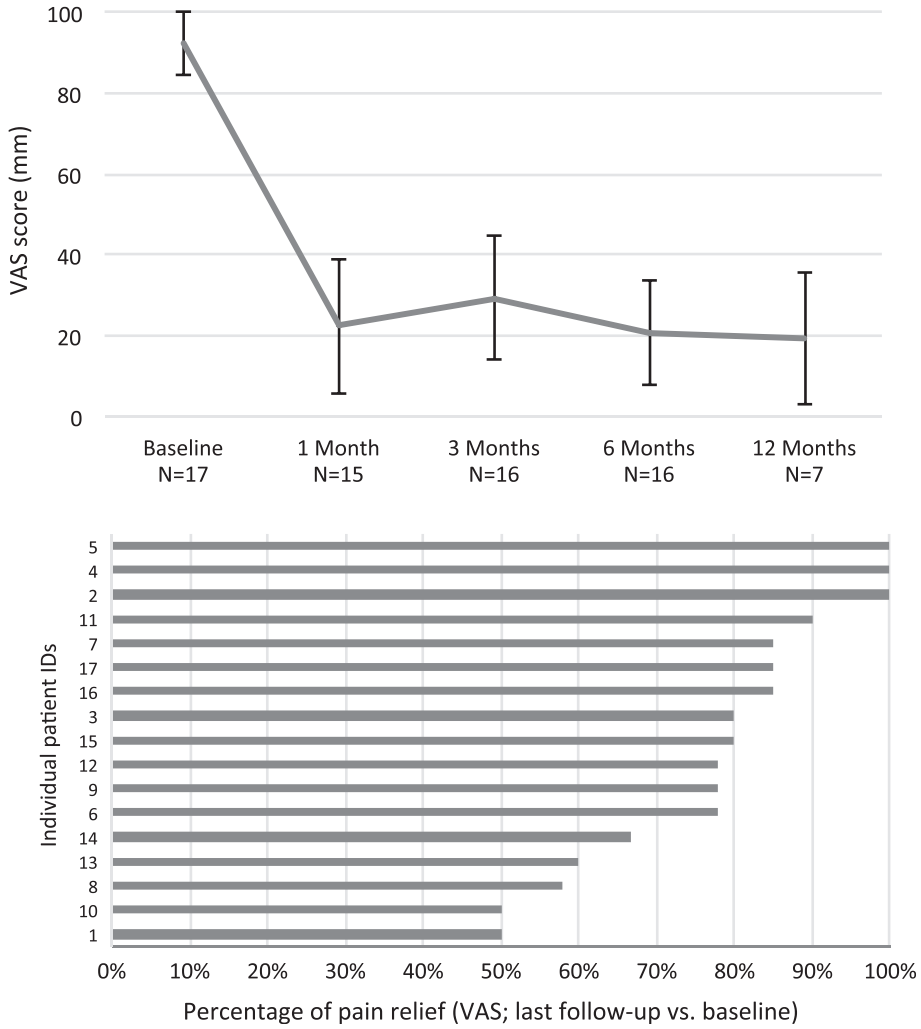

Figure 2. Top: VAS ratings were reduced relative to baseline. Markers indicate mean ± SD. Bottom: Percentage of pain reduction at the last follow-up relative to baseline for each of the 17 patients. All achieved at least 50% pain relief, and more than half had at least 80% pain relief.

baseline ($p < 0.001$). This represents a greater than 180% improvement in general health rating. See Figure 3.

DRG-S also significantly reduced disability in the patient cohort. The ODI scores improved from a mean of 67.7% ±14.2 at baseline ($n = 17$) to a mean of 18.8% ±11.5 after one month of treatment ($n = 15$), 16.6% ±12.7 after three months of treatment ($n = 16$), 10.0% ±8.4 after six months of treatment ($n = 16$), and 14.7% ±13.1 after 12 months of treatment ($n = 7$). The mean ODI score at patients' last follow-up was 14.7 ± 13.1 ($n = 17$), a statistically significant difference from baseline ($p < 0.001$). See Figure 4. All but one patient (94%) rated their back pain-related disability as severe or worse at baseline according to standard categorization (29). At the last follow-up, all patients reported a numerical decrease in ODI score and all but four patients (76%) rated their disability as minimal (Fig. 5).

Measures of health-related quality of life also significantly improved in this patient group, as rated by the SF-36 physical component summary (PCS) and mental component summary (MCS). Mean PCS ratings improved from a mean of 23.8 ± 5.4 at baseline ($n = 17$) to a mean of 47.8 ± 5.3 after one month of treatment ($n = 15$), 47.0 ± 10.1 after three months of treatment ($n = 16$), 51.2 ± 5.7 after six months of treatment ($n = 16$), and 50.0 ± 7.4 after 12 months of treatment ($n = 7$). The mean PCS summary score at patients' last follow-up was 49.4 ± 9.0 ($n = 17$), a 108% improvement and statistically significant difference from baseline ($p < 0.001$). Similarly, mean MCS ratings improved from a mean of 30.8 ± 5.7 at baseline ($n = 17$) to a mean of 58.2 ± 8.8 after one month of treatment ($n = 15$), 59.7 ± 7.9 after three months of treatment ($n = 16$), 61.3 ± 3.0 after six months of treatment ($n = 16$), and 58.4 ± 4.3 after 12 months of treatment ($n = 7$). The mean MCS summary score at patients' last follow-up was 59.5 ± 4.3 ($n = 17$), a 93% improvement and statistically significant difference from baseline ($p < 0.001$). See Figure 6.

Adverse events were reported in four patients. Three experienced significant lead migrations in which imaging indicated that the leads moved completely into the epidural space. Migration was likely due to overly-enthusiastic return to physical activity in two cases and a rear-impact motor vehicle collision in one case. All required surgical revision and all revisions were followed by a return to pre-migration levels of function and pain relief, although one patient developed temporary groin pain following the revision surgery, which was likely due to the presence of extensive scar tissue in the epidural space. The fourth patient complained of pain at the IPG pocket

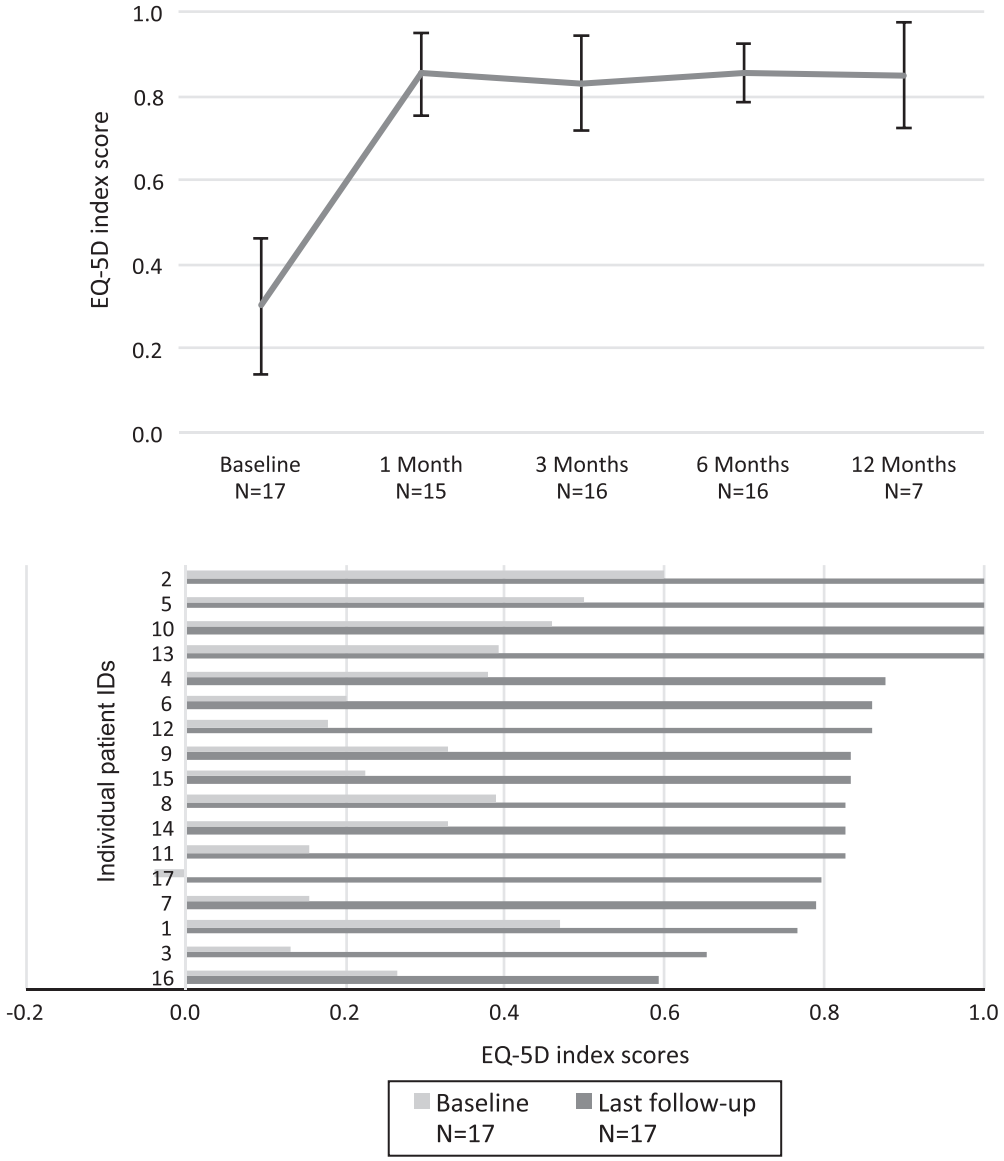

Figure 3. Top: Mean EQ-5D index scores improved with treatment. Bottom: For each of the 17 patients, baseline EQ-5D index scores improved at the last follow-up.

approximately four months after implantation. The pain persisted despite conservative treatment, but the patient declined surgical pocket revision.

DISCUSSION

To the authors' knowledge, this is the first report describing the application of T12 DRG-S for treating chronic low back pain. In the current consecutive case series of 17 patients, T12 DRG-S was associated with an average pain relief of 79% with concomitant significant improvement in disability, measures of general health and quality of life. More than half of the patients showed greater than or equal to 80% pain relief suggesting that most individuals achieved significant pain relief. The need for ongoing interventional procedures was reduced, and a number of patients reduced or eliminated their opioid pain medications. Implantation of the DRG-S leads was readily achieved despite previous fusion surgery in many patients.

Our patients averaged 8.3-months follow-up, with preliminary results that were superior to those previously reported utilizing DRG-S to treat chronic back pain. Huygen et al. (22) showed an average pain relief of 45.5% in 50% of the patients with FBSS at 12 months postimplant. In that study, leads were placed at the L2-L3 level(s). Kallewaard et al. also described, with bilateral L2 DRG leads, that stimulation relieved low back pain arising from post-discectomy FBSS (30) as well as from non-operated discogenic pain (31). These patients were highly screened with diagnostic injections to specifically focus on discogenic pain, so in these cases placement of DRG-S leads at the L2 spinal level may represent a treatment focal point for pain originating from the intervertebral disc (30,31). Another report documented 61% back pain relief with high frequency DRG/nerve root stimulation at either the L2 or T9 levels, with patients generally preferring T9 lead placement (32). Another report utilizing tonic stimulation at lumbar DRGs delivered significant relief of chronic back pain over approximately six weeks (21).

Additionally, the patients in the current cohort showed marked improvements in quality of life as well as physical and emotional

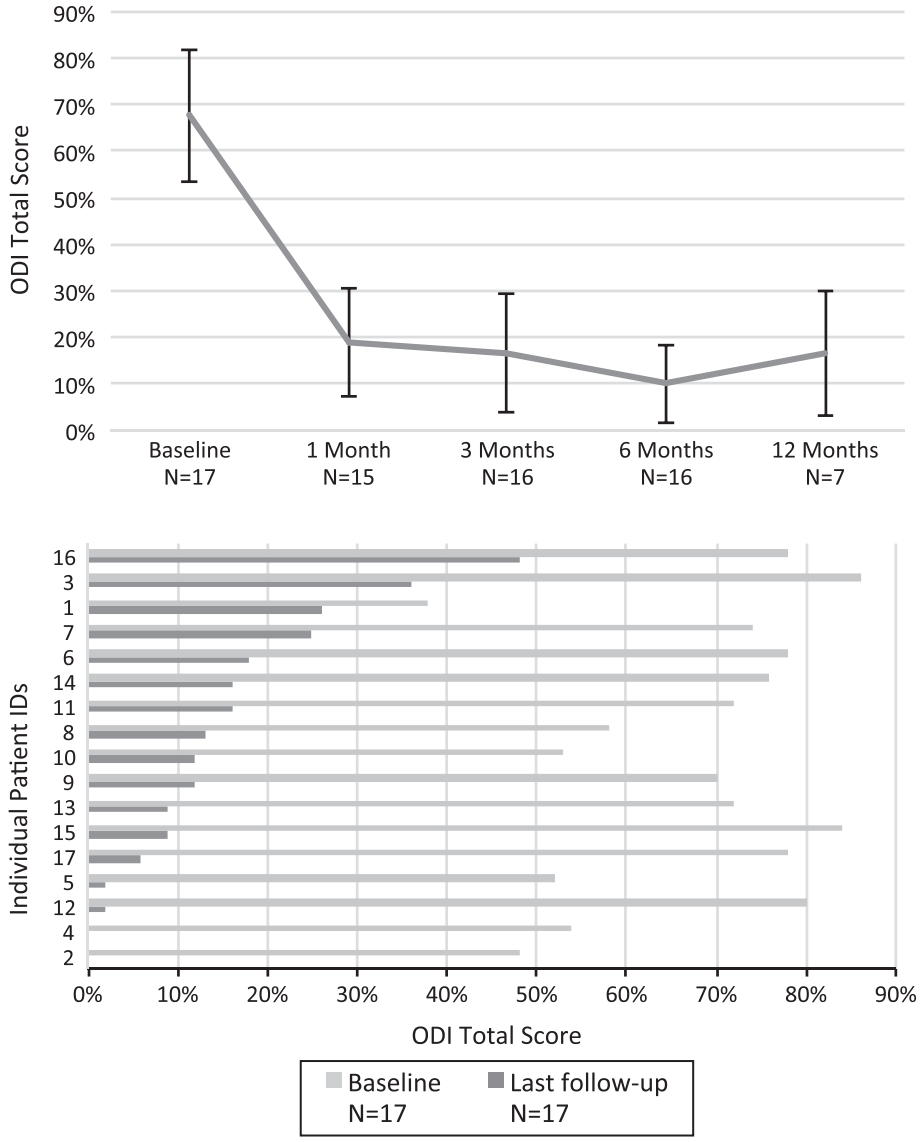

Figure 4. Top: Mean ODI scores improved with treatment. Bottom: For each of the 17 patients, baseline ODI scores improved at the last follow-up.

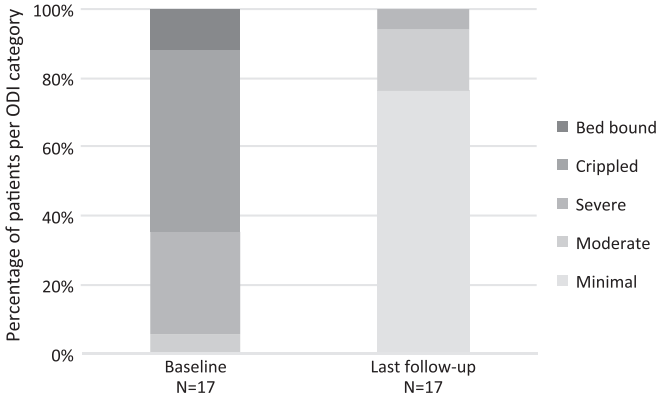

Figure 5. At baseline, nearly all patients had ODI disability scores rated "severe" or worse, while at the last follow-up, nearly all patients had "minimal" disability.

functioning. General health was rated by the EQ-5D instrument (28) and improved by an absolute average index score of 0.56. These pre- and post-values roughly correspond to normalized values from patients with morbid chronic disease to healthy individuals, respectively (33). The patients included in Huygen et al. (22) showed an EQ-5D increase from 0.31 to 0.50, similar to the findings in the recent Kallewaard et al. publications, with index values increasing from 0.34 to 0.82 and 0.61 to 0.84 at 12 months, respectively, in the FBSS and non-operated cohorts (30,31). Our patients pretreatment demonstrated a similar baseline of 0.30, however, the index score improved to 0.86, with four reporting maximal index values of 1.0. This latter value obtained when patients were being treated with DRG-S is consistent with those reported by normal, healthy individuals: the general population normative value in the United States (all ages) is 0.867 (34). The larger increases in general health index is consistent with the larger effects on pain relief. Prior work has documented that these variables can co-vary with one another in chronic pain studies, so these results are not surprising (35,36). As a part of routine care, we estimated physical and emotional quality of life using the SF-36 Health Survey (27), which showed an absolute average improvement of 25.7 in PCS and 30.0 in MCS, to 49.4 and 59.5, respectively.

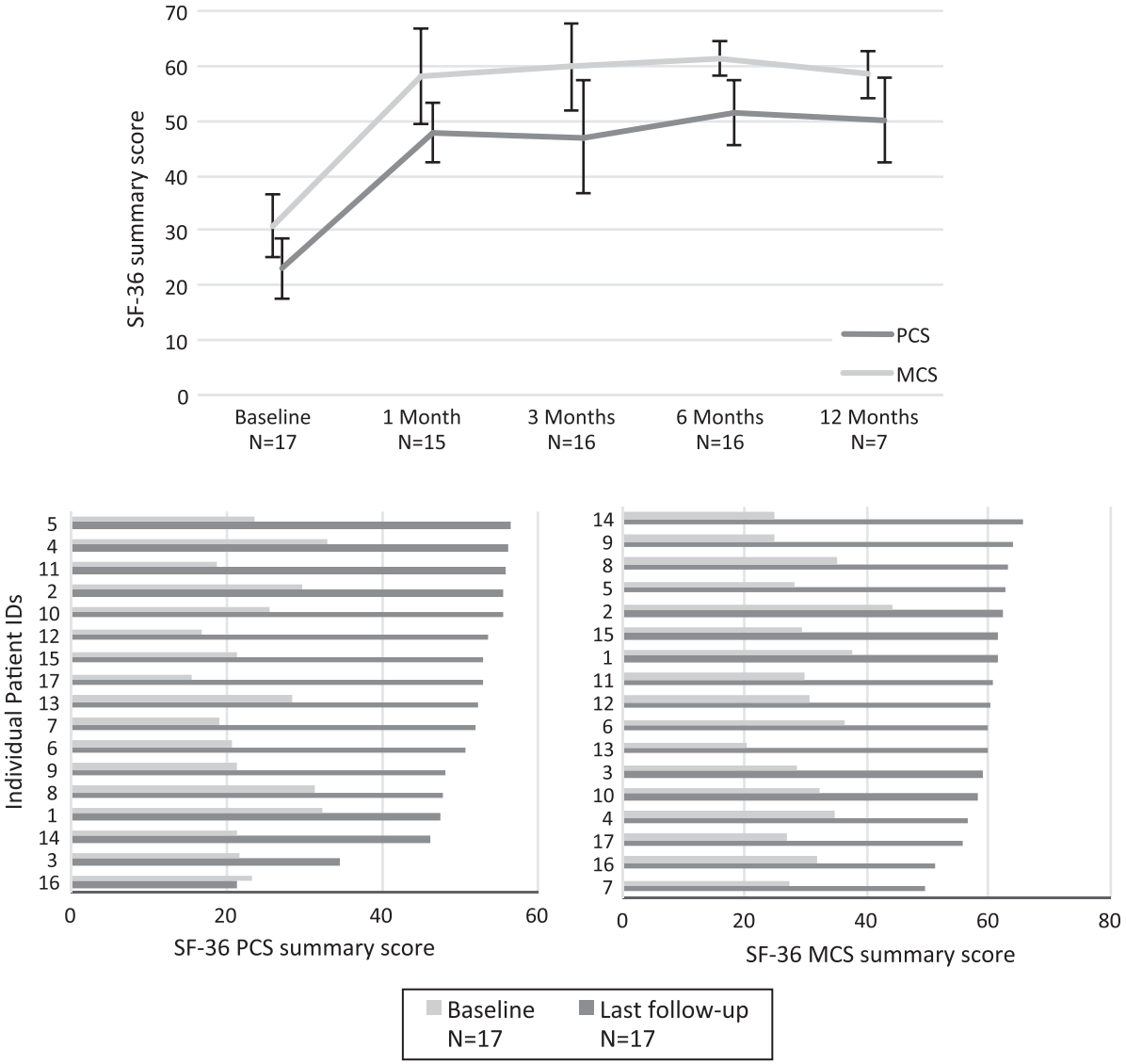

Figure 6. Top: Mean SF-36 PCS and MCS summary scores improved with treatment. Bottom: In general, the 17 patients' baseline SF-36 PCS and MCS summary scores improved at the last follow-up.

This represents 108% and 97% increases in the physical and mental components. Considering that SF-36 summary scale scoring is normalized to a mean of 50 (37,38), this represents considerable improvement in health-related quality of life. Patient disability was estimated using the Oswestry Disability Index (26), which showed an average improvement from 68% to 12% (ODI scores of 60-80% is described as "crippled," while 0–20% is "minimal disability"; 29). Pooled across multiple studies, the mean ODI score for a normal (i.e., without medical conditions) population is 10.19% (26). These findings demonstrate that within an average of 8.3-month treatment period (ranging from 3 to 12 months), patients showed significant clinical improvement across multiple domains of well-being including pain relief, disability, general health, and well-being as well as quality of life.

In results from a prospective, multicenter, randomized controlled trial (SENZA) examining high-frequency SCS (HF-SCS), Kapural et al. (12) found that at 3 months 68.6% of the patients treated with HF-SCS therapy showed "minimal" or "moderate" disability whereas 51.9% of the patients treated with traditional SCS showed this outcome. In comparison, 94% of our patients showed 'minimal' or 'moderate' disability over a longer follow-up time period, although it should of course be acknowledged that this is a different patient population. Similarly, this study reported that 84.3% and 43.8% of the subjects treated with HF or traditional SCS, respectively, demonstrated at least 50% pain relief at 3 months. Results from this case series showed a 100% response rate (≥50% pain relief). Moreover, results from the SENZA study documented that 65.2% of the subjects were classified as "remitters," indicating that they had a VAS score at follow-up of 25 mm or less. In the current cohort, similar findings were found with 68.8% of the patients meeting these criteria. While the current patient cohort was not a part of a prospective study, these results do reflect a "real-world" patient group from a private clinical practice environment where results from SCS studies utilizing high-frequency SCS have reflected weaker results than the highly controlled studies (14). This may be due to a patient population that is more heterogenous outside a controlled clinical study. The current cohort is also reflective of a broader low back pain patient

population and therefore more reflective of the types of patients that are regularly treated in pain management clinics. The severe pain and functional limitations experienced by this patient group at baseline is reflective of the experience of many chronic back pain patients. It is notable that although a majority of patients had undergone extensive back surgeries prior to DRG-S, five patients had not. Thus, the excellent treatment outcomes described here, in which pain was substantially relieved and mean function and quality of life was improved to approach that of non-pain populations, may be indicative of the potential outcomes that are achievable with this intervention for all patients. Thus, it may be reasonable to consider DRG-S earlier in the pain management algorithm, as has been noted elsewhere (31).

The patients in this case series all suffered from, primarily, severe chronic low back pain, although some patients suffered from additional pain in the lower extremities. These patients with low back and joint pain might be classified as mixed nociceptive (somatic) pain rather than primarily neuropathic pain, for which conventional dorsal column SCS is traditionally less effective (39). The significant pain relief and improvement in function as shown in the current data suggests that DRG-S may affect not only mechanisms underlying neuropathic components of chronic pain but also, potentially, neurons transmitting nociceptive afferent information. In the case of conventional SCS, the sensory neural pathways that travel in the dorsal columns are activated sending interfering activity back toward the dorsal horn thus indirectly impacting pain processing (40). This results in conventional SCS having minimal direct influence on primary sensory neurons transmitting nociceptive signals (15,16). In contrast to this, due to the location of the DRG leads, the electrical fields can directly impact nociceptive neural traffic flowing through the ganglia. Prior work in models of chronic neuropathic pain has indeed shown that DRG-S results in modulation of the T-junction of the primary sensory neuron and alteration in cell body function, thereby suppressing the conduction of action potentials through this sensory structure (20). The current data show promising implications of DRG-S in patients with severe chronic low back pain with putative nociceptive components (and therefore potentially other traditionally somatic pain syndromes), in addition to its effects on neuropathic pain.

Given the small number of studies, there is no consensus in regard to DRG lead placement for the treatment of low back pain. In traditional dermatomal maps, the low back seems to be primarily innervated by L1-L5 dermatomal levels (41). Correspondingly, prior groups placed DRG-S leads at the L4-5 level (17,19,21). In contrast, Huygen et al. (22) and Kallewaard et al. (30,31) performed DRG-S on the L2 level based on the notion that a portion of the intervertebral disc and vertebral body sensory innervation is transmitted through sympathetic afferents to the L2 spinal nerve root (42–46). This concept for the treatment of low back pain does not support the benefit for patients who have pain that is originating from the posterior aspect of the intervertebral disc and vertebral body, and facet joints, as they are innervated by small sensory branches of the spinal nerve of the adjacent spinal levels (47,48). The study of Huygen et al. (22) showed promising results, but considering the greater improvement in both pain relief and quality of life scores with T12 placement, it appears that the T12 DRG may be a better choice for broad low back pain coverage. Lee et al. (23) proposed a novel dermatomal map based on an analysis of all the dermatomal maps published in the past 120 years. The results of this analysis showed that a portion of the skin and subcutaneous tissue of the low back is covered by the T12 spinal level. Other research based on shingles studies of Head et al. also demonstrated the same coverage of the T12 spinal nerve root (49,50). It is unclear which potential low back structures contributed to the low back pain observed in the current cohort and this may be an important consideration for future research studies to help identify which patients may best benefit from T12 DRG-S.

In response to the lead migrations observed, the implantation method was considered. Initial implants at the T12 level were implanted with a tunneled epidural catheter technique. It was determined that given the distance of the leads to the generator side and the mobility of the spine at the thoracolumbar segment, that we would make a 2–3 cm incision in the midline and anchor the thoracic leads. Since that time there have not been any migrations noted.

Current limitations of this study are the relatively short follow-up duration and the small sample size. Prior SCS studies and DRG studies have demonstrated ability to maintain coverage and pain relief at the one-year period and beyond (19,22). Consistent with clinical practice, it is anticipated that these patients will be followed up longer term allowing us to compare our results to the other DRG and SCS studies focusing on low back pain. Another limitation is that several of our patients required leads at additional levels for pain coverage in the lower extremities. Several patients also had sacroiliac joint or hip pain requiring an L1 DRG lead, and a substantial number of patients suffered from leg and/or foot pain, which required an S1 lead. This is broadly consistent with back pain populations who are seen for neuromodulation. Although the coverage areas of these other leads, namely the L1 and S1, are generally accepted to be the hip and the foot, it is possible that those leads also contributed to the observed improvements in back pain. The patients without back pain related surgical history ("virgin backs") only required T12 leads to cover their back pain, supporting the notion that the T12 DRG may be a target for low back pain specifically.

CONCLUSIONS

Results from the current consecutive case series of 17 low back pain patients show statistically and clinically significant pain relief from T12 DRG-S. Concomitant improvement in disability and quality of life after treatment with DRG-S further validates the findings. The heterogenous cohort of patients in this case series suggests that T12 lead placement for DRG-S may yield promising clinical outcomes for mixed neuropathic and nociceptive chronic lower back pain. Compared to other SCS modalities and previously examined DRG lead placement, T12 DRG-S may be more applicable to treating the "average patient" under "real world" conditions. Longer terms outcomes and further study will help validate this therapeutic approach.

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Authorship Statement

Kenneth B. Chapman and Noud van Helmond designed the study. Kenneth B. Chapman, Pauline S. Groenen, and Noud van Helmond conducted the study, including data collection, and data analysis. Kenneth B. Chapman prepared the manuscript draft with important intellectual input from Pauline S. Groenen Kiran V. Patel, Kris C. Vissers, and Noud van Helmond. Pauline S. Groenen, Kiran V. Patel, Kris C. Vissers, and Noud van Helmond edited the manuscript. All authors approved the final manuscript.

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COMMENTS

I believe this work to be of vital importance for the field of neuromodulation. It is true that as a relatively emerging field, we still

have much to learn about the applications and mechanisms of action in neuromodulation; this is particularly true for DRG-SCS. This article certainly sheds more light on the many applications of this treatment modality.

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This is a breakthrough for the neuromodulation community, providing an accessible new target to treat intractable back and leg pain.

Paul Verrills, MD
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The DRG is an exciting target for neuromodulation. The therapy is still relatively young with a high potential clinical impact. We have only just started to unravel the exact mechanism of action regarding neuromodulation and its effect on the central nervous system in all kinds of pain syndromes. This study can take us one step further down the road and is an encouragement for clinicians and researchers to keep pushing the envelope.

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Comments not included in the Early View version of this paper.

