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Explantation Rates and Healthcare Resource Utilization in Spinal Cord Stimulation

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Abstract

OBJECTIVES—Certain patients ultimately undergo explantation of their spinal cord stimulation (SCS) devices. Understanding the predictors and rates of SCS explantation has important implications for healthcare resource utilization (HCRU) and pain management. The present study identifies explant predictors and discerns differences in HCRU for at-risk populations.

METHODS—We designed a large, retrospective analysis using the Truven MarketScan Database. We included all adult patients who underwent a SCS trial from 2007 to 2012. Patients were grouped into cohorts that remained explant-free or underwent explantation over a 3-year period, and multivariate models evaluated differences in healthcare resource utilization.

RESULTS—A total of 8,727 unique instances of trial implants between 2007 and 2012 were identified. Overall, 805 (9.2%) patients underwent device explantation. One year prior to SCS implantation, the explant cohort had significantly higher median baseline costs (\$42,140.3 explant vs. \$27,821.7 in non-explant groups; $p < 0.0001$), total number of pain encounters (180 vs. 103 $p < 0.0001$), and associated costs (\$15,446.9 vs. \$9,227.9; $p < 0.0001$). The explant cohort demonstrated increased use of procedures (19.0 vs. 9.0; $p < 0.0001$) compared to non-explanted patients. For each month after initial SCS implantation, explanted patients had a slower decrease in total costs (4% vs. 6% in non-explant; $p < 0.01$). At the month of explant, explant patients were expected to have incurred 2.65 times the total cost compared to the non-explant cohort (CR 2.65, 95% CI [1.83, 3.84]; $p < 0.001$). Medium volume providers had lower rates of explantation at 1-year and 3-years compared to low volume providers ($p = 0.042$). Increased age and Charlson index were independent predictors of explantation during the same periods.

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Authorship Statement:

Siyun Yang, Jichun Xie, Jing L. Han, Kelly R. Murphy, Beth Parente, Promila Pagadala, and Shivanand P. Lad designed and conducted the study, data collection, and data analysis. Jing L. Han prepared the manuscript draft with important intellectual input from Kelly R. Murphy and Syed Mohammed Qasim Hussaini. All authors approved the final manuscript. Sin Yang and Jichun Xie had complete access to the study data.

Disclosure of Interests Statement

The remaining authors report no conflicts of interest or financial disclosures.

CONCLUSIONS—In this nationwide analysis, we identified that SCS device explantation is correlated with patients who have higher baseline costs, higher total cost post-SCS implantation, and increased use of procedures to control pain. The higher rates of explantation at 3-years post-implant among low volume providers suggest that variations in provider experience and approach also contributes to differences in explantation rates.

Keywords

Spinal cord stimulator (SCS); device explantation; explant rate; chronic pain; healthcare resource utilization

INTRODUCTION

Spinal cord stimulation (SCS) has been proven to be a safe and sustained therapy for refractory chronic pain^{1–4}, and has been shown to have a real effect in reducing healthcare expenditures over time⁵. Interest in SCS and its increased implementation in practice for multiple pain disciplines have grown in response to the increasing need for non-pharmacologic, multimodal approaches for long-term pain management⁶. Studies in 2006–07 reported over 20,000 spinal cord stimulators implanted annually^{7–9}, a number that can be presumed to have grown with increasing patient and clinician awareness. Since its first introduction in the 1970s, and subsequent FDA approval in 1989 for treatment of trunk and extremity pain, there have been numerous studies in the literature demonstrating SCS efficacy to exceed that of conventional medical management alone in the treatment of a myriad of chronic pain symptoms^{1,10,11}. SCS technology has made significant advancements in the past 10–15 years, such as novel stimulation settings (burst, high-frequency, continuous, position-adaptive) to better tailor coverage¹². Recent studies have reported 70% of patients achieving >50% pain relief, greatly improved from the 40% reported in the 1970s¹².

The ability to predict patient-by-patient success of SCS involves a variety of factors, including the success of trial implant, judicious patient selection, and post-procedure programming^{13–21}. Nevertheless, lead migration and device failure are possible complications that can produce patient dissatisfaction^{22–25}. When SCS fails or becomes refractory over time, patients and providers must decide whether to leave the device in place or to remove the device through an explantation procedure. Though a relatively simple procedure, this necessitates return to the OR, with its associated risks and increased costs to the healthcare system. Newer interventions include novel stimulation paradigms that may provide renewed pain relief in such patients. Beyond considering patient and practitioner preference, there is limited data supporting one choice over the other with respect to improved patient outcome and healthcare expenditures.

We designed a retrospective analysis of the Truven Marketscan® Database to explore the impact of explantation on healthcare resource utilization (HCRU) and to better understand the predictive factors leading to SCS explantation. Patients were analyzed pre-SCS, 1-year post-SCS, and 3-years post-SCS implant, with and without subsequent explant. We

hypothesized that explantation occurs more frequently in medically complex patients, and results in higher HCRU costs at both 1-year and 3-year follow-up.

METHODS

Data Source

We utilized the Truven MarketScan® Database, containing information on more than 200 million unique patients in the United States. This database culls from Commercial Claims and Encounters, Medicare Supplemental and Coordination of Benefits, and Medicaid, producing an aggregate of fully integrated patient-level data, including inpatient, outpatient, drug, and lab information. We performed a retrospective review of SCS patients from the years 2007–2012.

Patient Population

International Classification of Diseases, Ninth Revision, [ICD-9] diagnosis and Current Procedural Terminology (CPT-4) procedure codes were used to identify patients with permanent SCS implantation with or without subsequent explant. For inclusion in the study, patients had the diagnosis of chronic pain (including ICD-9 codes for post-laminectomy syndrome, CRPS, neuritis/radiculitis, limb pain, degenerative spine disease, back pain, and chronic pain) and underwent permanent SCS implantation with percutaneous or paddle leads (CPT-4: 63650, 63655) followed by placement of internal pulse generator (IPG) (CPT-4: 63685), with the date of IPG implant serving as permanent implantation date and the date of first SCS implant serving as the index event. Patients were separated into two cohorts: 1) those that received SCS lead explant (CPT-4: 63661, 63662) with or without concomitant IPG explant (CPT-4: 63688) at any time following initial permanent implant, and 2) explant-free patients in implant-to-index event time. Patients were expected to not have any subsequent follow-up related to neuromodulation (e.g. SCS analysis/programming CPT-4: 95970–95973) following explant. Additional inclusion criteria were: 18 years of age, 1 year follow-up time prior to permanent implantation, and 1 year follow-up time after index event. For the purposes of multivariate regression analysis, patient cohort was further divided into high (>25), medium (9–24), and low (3–8) volume providers to delineate any relationship between provider volumes on explantation rates. Within the MarketScan Database, data coding prior to 2009 does not distinguish between revision and total explant. As such, events were coded as both IPG and SCS explant/revision for years <2009 (2007–2009) and as IPG explant or IPG and SCS explant for 2009 (2009–2012).

Data Collection

Data were collected on patient age, gender, comorbidities, employment status, insurance type, region, and year of index event; longitudinal analysis was used to identify comparable patients for each cohort. HCRU categories included pain encounters, pharmaceutical expenditures, inpatient admissions, pain procedures, and total costs pre- and post-SCS follow up. All-cause and pain-related expenditures and visits, as well as cumulative HCRU at 1-year after the index event, were calculated. Additional procedures performed within 3-years after the index event (e.g. back surgery, intrathecal pain pumps, other non-surgical medical management) were also counted.

Statistical Analysis

Descriptive statistics were reported and demarcated by explant versus non-explant status. Counts and percentages were reported for categorical variables. Means, standard deviations, medians, and quartiles were provided for continuous variables. Chi-square test was used for the group difference for categorical variables, and Kruskal Wallis test was used for group difference for continuous variables. Negative and extremely large values were removed by excluding the highest and lowest 1% of pay. A longitudinal model was used to project healthcare system savings with % reduction in explant rate. This analysis used a GEE linear model with log transformed cost for patients with up to 3-years of data after SCS lead implant. Each model included sex, age, employment status, year of SCS, insurance type, Charlson score, month of explant, explant status, follow-up months, and an interaction of follow-up month and explant. This analysis used a compound symmetry correlation structure for patients with multiple months of data (up to 3-years). For count outcomes, Poisson regression was used. Cohort comparison for percentage utilization of additional types of procedures was performed using Chi square or Fisher's exact tests. Kaplan-Meier curves and Cox proportional-hazards regression was used to compare occurrence of explant events. Adjusted Hazard ratios (HRs) with 95% confidence intervals (CIs) were reported for explant rates. All analyses were conducted with SAS version 9.4 (SAS Institute, Cary, NC, USA).

RESULTS

Patient cohort and demographics

We identified 8,727 unique patients that underwent SCS trials performed between 2007 and 2012. Overall, the patient cohort was 63.8% female with an average age of 52.1 ± 13.3 years and an average Charlson comorbidity score of 0.9 at implantation, as calculated from records 1-year prior to index event. The southern region comprised the largest geographic distribution (43.8%) of the patient cohort. 59.6% of patients were commercially insured and 24.3% were actively employed full-time. Descriptive statistics are provided in Table 1.

Healthcare resource utilization

Baseline healthcare-related expenditures were obtained for patients 1-year prior to the index event (Table 2). Explant cohort had significant higher total cost of treatment (median \$42,140.3 for explant patients, and \$27,821.7 for non-explant patients, $p < 0.0001$). Similarly, total number of pain encounters (median 103 vs. 180; $p < 0.0001$) and their associated costs (median \$9,227.9 vs. \$15,446.9; $p < 0.0001$) were significantly higher amongst the explanted group. Further, while the supply of all medications was similar across both groups, explanted patients had a significantly larger supply of pain prescriptions (median 180 vs. 258 days; $p = 0.0002$).

Multivariate regression analysis was performed to better understand the healthcare resource utilization differential between the two groups (Table 3). At the month of explant, explant patients were expected to have incurred 2.65 times the total cost compared to the non-explant cohort (CR 2.65, 95% CI [1.83, 3.84]; $p < 0.001$). Though statistically insignificant, in the month following explant, patients incurred a total cost that was 1.19 times that of non-explant patients (CR 1.19, 95% CI [0.82, 1.71]; $p = 0.363$). Holding other covariates at fixed

value, each unit increase of baseline Charlson score was associated with a 51% increase of total cost (CR 1.51, 95% CI [1.43, 1.59]; $p<0.001$). For each month following SCS lead implant, non-explant patients were expected to experience a 6% decrease in total costs; this rate of cost savings decreases after undergoing explant ($.94*1.02=.96$, which is 4% decrease in costs). Similar trends are reflected for pain prescription and total medication costs in the explanted cohort. Furthermore, by the month of explant, patients in the explant cohort had 3.62 times more inpatient admissions than non-explant patients (RR 3.62, 95% CI [1.42, 9.26]; $p=0.007$). In the month following explant, patients had inpatient admissions that were 4.33 times that of non-explanted patients (RR 4.33, 95% CI [2.28, 8.21]; $p<0.001$). Again, each unit increase of baseline Charlson score resulted in a 23% increase in total inpatient admissions, when holding all other covariates fixed.

Predictors of explantation

Multivariate regression analysis was performed to identify independent predictors of explantation at 1- and 3-years after initial SCS lead implantation (Table 4). Medium volume providers (9–24 cases/year) were associated with significantly reduced explantation rates at 1-year (HR 0.80, 95% CI [0.66, 0.96]; $p=0.019$) and 3-years (HR 0.77, 95% CI [0.65, 0.3]; $p=0.005$), in comparison to low volume providers. While high (>25 cases/year) volume providers were also associated with reduced explantation rates during these periods, these were not statistically significant. Age was another independent predictor of explantation at 1-year (HR 0.99, 95% CI [0.98, 1.00]; $p=0.010$) and 3-years (HR 0.99; 95% CI [0.99, 1.00]; $p=0.018$). Charlson index was also an independent predictor of explantation at 1-year (HR 1.07, 95% CI [1.01, 1.13]; $p=.022$) and 3-years (HR 1.07, 95% CI [1.02, 1.13]; $p=0.012$). Gender, insurance source, and employment status were not found to be independent predictors of explantation during the same periods.

Post-explant procedures

Overall, the explant cohort demonstrated increased use of procedures (median 19.0 vs. 9.0; $p<0.0001$) compared to non-explanted patients (Table 5). Injection use was significantly higher in the explanted group with an average of 1.7 injections (vs. 0.9 injections in non-explanted; $p<0.0001$). 3.8% of patients who were explanted subsequently underwent a repeat spinal cord stimulator trial (vs. 2.8% in non-explant; $p<0.0001$).

DISCUSSION

Cost-effectiveness remains an ever-growing focus of healthcare practice, within which the treatment of chronic pain is a sizable target. In 2014, personal health care expenditures saw a 5% increase from 2013, totaling \$2.6 trillion, with prescription drug expenditures totaling nearly \$300 billion²⁶. Chronic pain patients, in particular, represent a challenging cohort that requires long term, multimodal treatment. SCS has been shown to be an effective and cost-conscious treatment option, despite initial high costs associated with implantation¹⁰. Especially in the context of lumbar back pain, the most common cause of work-related disability in the otherwise healthy under-45 patient population¹¹, SCS has the additional unmeasured benefit of regained productivity. However, the variability of training and in practice across providers result in unstandardized methods in SCS utilization. Research is

especially limited in cases where SCS devices prove ineffective following permanent implantation. The provider and patient must then face the decision to explant the device, keep the device in place, or revise the device. The best practice and most economically efficient choice has yet to be determined.

In this study, we evaluated how healthcare utilization differs in patients who ultimately undergo explantation up to 3-years after an SCS trial and those who do not. SCS explant serves as a proxy for unsuccessful implant, whether from incomplete pain control or device malfunction. Thus, by delineating explant versus non-explant groups, we provide important insights into the cost of failed SCS treatment. Our analysis corroborated our hypothesis: the explant cohort was found to incur 2.65 times greater total cost compared to non-explant patients by the time they underwent explant. These patients also had a decrease in total costs that was lower than the controls (4% vs. 6%), as well as for pain prescriptions and total medications cost. Patients in the explant cohort also underwent significantly more procedures at 3-years after initial SCS implant (sum 24.7 vs. 15.7), which most notably included injections and sympathetic blocks. The impact of SCS explantation on healthcare costs and utilization is striking; if explanted patients experience lower SCS efficacy, it follows that they undergo significantly more alternative treatment methods as adjuncts.

Although the HCRU results followed logically with our assumptions about unsuccessful treatment of painful symptomatology as requisite for explant, we found that medium-volume providers were associated with the lowest explant rates at 1-year and 3-years post-SCS, compared to their low-volume colleagues, but also compared to the high-volume providers. One interpretation of these results is that medium-volume implanters simply experience more success with SCS implant, likely due to a combination of a lower-risk patient population compared to high-volume providers from existing referral patterns, and increased experience compared to low-volume providers. This does corroborate unpublished data from our group that demonstrated that medium-volume groups had overall superior HCRU in total, pain encounter, and pain prescription costs. It can be conjectured that high-volume providers are more often found in high-volume academic centers that tend to see sicker patients. As might be expected, each unit increase in Charlson comorbidity score was associated with an increase in total costs (51%). Thus, we infer that what we have chosen to define as SCS success in this study (i.e. low explant rate, lower HCRU) seen with medium-volume providers represents a ‘happy medium’ calibration beginning with a better baseline patient population that leads to improved postoperative outcome, decreased complications or need for subsequent troubleshooting, and ultimately lower explant rates and costs incurred.

Patient selection remains a critical aspect of SCS success and serves as an aspect of care that improves with experience^{18,19}. Additionally, providers with higher volume practices may have improved ancillary support staff and regular access to programming support services. It follows that the threshold for explantation increases if a provider has the capacity for continued calibration of device programming, a critical and oftentimes iterative step following device implantation. Further, although our data is complicated by coding differences before and after 2009 with regard to distinguishing between revision and explant, it is possible that medium- and high-volume providers tend to execute device revision(s) with higher thresholds for explant. Regardless, these results suggest that there are very real

effects on outcomes as a result of different training requirements. Delineating the differences will be useful to further guide and calibrate successful training regimens to optimize provider proficiency and outcomes.

Although Marketscan is able to identify unique patient cohorts (explant vs. non-explant), there is no data that allows identification of why these explants occurred. Baseline demographics are available, but time to SCS, pre-surgical pain quality, symptomatology, QOL, and work-related productivity—factors related to the efficacy of SCS implant—are not. In a systematic review of 25 studies, Celestin et al. found that psychological factors including somatization, depression, anxiety, older age, and poor coping were useful in helping to predict poor outcomes to SCS²⁷. Longer delay prior to SCS implant was also found to relate inversely to SCS success²⁸. Kumar et al. have reported an inverse correlation between long-term pain relief and implantation delay, with a critical time window of 2-years between pain syndrome onset and implantation. Within those 2-years, >50% pain relief can be attained in 85% of patients, which decreases to 9% if the implantation delay is >15-years; this averaged to effective pain control in 60% of patients²⁹. If the average wait time for SCS implantation is roughly 5-years, as reported from their single-institution study, this certainly decreases long-term success rates. Interestingly, they also noted that non-implanting neurosurgeons referred to an implant physician around 1.7 times earlier than orthopedic surgeons and anesthesiologists³⁰, highlighting provider practice variability. Our results do not delineate provider types (orthopedic surgery, neurosurgery, pain management, and PM&R) within volume groups or procedure setting (acute care centers, private hospitals, or large academic centers); however, differences undoubtedly exist across different providers based on training, standard practice, and institutional variability.

It is assumed here that SCS explant is the corollary to unsuccessful pain control or device malfunction. Hayek et al. reported a 34.6% complication rate for percutaneous SCS implants in a cohort of 234 patients with noncancer pain, 74.1% of which were hardware related, and which led to a 23.9% rate of revision and explant each²⁴. Explant was most commonly performed due to loss of therapeutic effect²⁴. Other studies have reported complication rates of 43% with SCS³¹, or 38% that were associated with hardware failures (e.g. lead migration, connection failure, breakage)²⁵. These are fairly high complication levels reported from data generated at academic institutions, and prior to the advent of more recent technologic advances in stimulator engineering and settings. Per general practice, SCS failure is loosely defined as unsuccessful pain control after 12- to 16-weeks of multimodal medical management with other pain treatment adjuncts. IPG explant does not always imply lead explant. In our practice, nonfunctioning IPGs and leads are both extracted at time of explantation. Barring extremely difficult extraction, there is little reason to only explant the lead or the IPG—retention of a foreign body is associated with its own set of complications, especially as a nidus for infection. However, the decision to explant is one jointly made by patient and provider, and we recognize that not all nonfunctioning SCS systems are explanted. It is possible that patients who failed SCS opted instead to discontinue its use rather than undergo a procedure for removal, which we were unable to capture here. Although we could not differentiate this possibility, it is important to consider the patient and provider populations who decide to undergo explant, from those who ‘could’ or ‘should’ and choose not to undergo explant.

There are several limitations to this study. First, this is a retrospective cohort analysis that uses unique instances of patients from a large, nationwide database. To address this, we performed multivariate analysis with regression covariates, and adjustment of appropriate patient and cost-related factors. Second, baseline clinical characteristics and other patient-related factors including pain intensity and quality of life could not be analyzed. Factors related to improved work-related productivity based on achieving pain relief through permanent implant were not accounted for in the cost analysis. Third, the database may not take into account the types of procedures or pain encounters that may contribute to varied healthcare resource utilization costs across the different providers. Lastly, the database does not account specifically for physician experience, patient selection, or customized spinal stimulator characteristics. This includes procedure details such as number of leads, lead placement, and dermatomal distribution of pain targets, all of which impact SCS success.

It should be noted that the explant group demonstrated higher costs prior to SCS implantation, an interesting association that we were unable to explore explicitly in this study. This potentially suggests that these eventual explant patients were from the outset less appropriate candidates for SCS. Perhaps they had undergone implantation as a ‘desperation’ measure after failing multiple therapeutic measures, and this in turn could be due to multiple intrinsic patient and pathology characteristics, such as higher levels of somatization. Despite the aforementioned limitations, this study provides us with useful insights into understanding costs associated with SCS explantation rates. This is the first large-scale study to take an essential step towards identification of a patient cohort in an SCS community that undergoes SCS explantation. Follow-up studies are necessary to delineate underlying factors resulting in explantation, as well as the effect of provider and volume-based differences on explant rates.

CONCLUSION

This longitudinal, retrospective analysis found that SCS explantation is associated with total increased healthcare resource utilization and quantified its impact. There is a high financial cost burden associated with failed SCS systems. The SCS explant cohort had significantly higher baseline costs (median \$42,140.3 vs. \$27,821.7 in non-explant groups; $p<0.0001$). At the month of explant, explant patients were expected to have incurred 2.65 times the total cost compared to the non-explant cohort (CR 2.65, 95% CI [1.83, 3.84]; $p<0.001$). Age of patient, medium provider volume, and Charlson index were found to be independent predictors of explantation. Medium- and high-volume SCS providers appear to experience fewer explantations. This has implications for clinician training, standardization of practice, and construction of meaningful national guidelines. Furthermore, the early identification of patient characteristics that may pose risk of increased explantation warrants further investigation of alternative treatment options for pain management.

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Table 1

Baseline characteristics of study cohort by explant status.

	Non-explant (N=7922)	Explant (N=805)	Total (N=8727)	<i>p</i>-value
Successful Trial, <i>N</i> (%)				
1	7922 (100.0%)	805 (100.0%)	8727 (100.0%)	
Inpatient, <i>N</i> (%)				0.7268
Inpatient	172 (2.2%)	19 (2.4%)	191 (2.2%)	
Outpatient	7750 (97.8%)	786 (97.6%)	8536 (97.8%)	
Charlson comorbidity score, <i>N</i> (%)				0.1133
N	7822	794	8616	
Mean (SD)	0.9 (1.3)	1.0 (1.3)	0.9 (1.3)	
Median	0.0	0.0	0.0	
Employment Status, <i>N</i> (%)				0.0516
Active Full Time	1931 (24.4%)	187 (23.2%)	2118 (24.3%)	
Retiree	1082 (13.6%)	97 (12.1%)	1179 (13.6%)	
Other	4909 (61.9%)	521 (64.7%)	5430 (62.3%)	
Gender, <i>N</i> (%)				0.1899
Male	2881 (36.4%)	274 (34.0%)	3155 (36.2%)	
Female	5041 (63.6%)	531 (66.0%)	5572 (63.8%)	
Age at SCS				0.0010
Mean (SD)	52.2 (13.3)	51.0 (12.8)	52.1 (13.3)	
Median	52.0	50.0	52.0	
Region, <i>N</i> (%)				0.0049
Northeast Region	403 (5.1%)	46 (5.7%)	449 (5.1%)	
North Central Region	1054 (13.3%)	89 (11.1%)	1143 (13.1%)	
South Region	3507 (44.3%)	319 (39.6%)	3826 (43.8%)	
West Region	784 (9.9%)	91 (11.3%)	875 (10.0%)	
Unknown Region	16 (0.2%)	0 (0.0%)	16 (0.2%)	
M	2158 (27.2%)	260 (32.3%)	2418 (27.7%)	
Insurance Source, <i>N</i> (%)				0.0091
CCAE	4754 (60.0%)	447 (55.5%)	5201 (59.6%)	
MAID	2158 (27.2%)	260 (32.3%)	2418 (27.7%)	
MDCR	1010 (12.7%)	98 (12.2%)	1108 (12.7%)	
Year, <i>N</i> (%)				<0.0001
2007	1210 (15.3%)	48 (6.0%)	1258 (14.4%)	
2008	1417 (17.9%)	101 (12.5%)	1518 (17.4%)	
2009	1572 (19.8%)	241 (29.9%)	1813 (20.8%)	
2010	1151 (14.5%)	192 (23.9%)	1343 (15.4%)	
2011	1315 (16.6%)	156 (19.4%)	1471 (16.9%)	
2012	1257 (15.9%)	67 (8.3%)	1324 (15.2%)	

MDCR, Medicare; MAID, Medicaid; CCAE, commercially available insurance
SD, standard deviation

Table 2

Healthcare resource utilization by explant status.

	Non-explant (N=7922)	Explant (N=805)	Total (N=8727)	p-value
Total Cost				<0.0001
N	7922	805	8727	
Mean (SD)	86740.5 (255259.1)	120449.9 (372441.5)	89849.9 (268369.5)	
Median	27821.7	42140.3	28825.6	
Pain encounters				<0.0001
N	7922	805	8727	
Mean (SD)	329.8 (1054.1)	452.1 (1110.0)	341.1 (1059.9)	
Median	103.0	180.0	110.0	
Total cost of pain encounters				<0.0001
N	7922	805	8727	
Mean (SD)	43764.8 (159662.2)	65441.8 (233042.7)	45764.3 (167879.7)	
Median	9227.9	15446.9	9726.7	
Inpatient admissions				0.0010
N	7922	805	8727	
Mean (SD)	2.3 (17.0)	3.1 (15.7)	2.4 (16.9)	
Median	0.0	0.0	0.0	
Cost of pain prescription				0.0905
N	7922	805	8727	
Mean (SD)	1024.3 (5327.3)	1063.8 (3242.1)	1027.9 (5170.1)	
Median	132.1	160.8	134.2	
Cost of all medication				0.0319
N	7922	805	8727	
Mean (SD)	3832.6 (7661.0)	3498.1 (7037.1)	3801.8 (7605.8)	
Median	1737.1	1292.1	1698.6	
Supply of pain prescription (days)				0.0002
N	7922	805	8727	
Mean (SD)	301.9 (385.0)	350.0 (365.6)	306.3 (383.5)	
Median	180.0	258.0	188.0	
Supply of all medication (days)				0.6295
N	7922	805	8727	
Mean (SD)	1456.0 (1425.4)	1486.9 (1399.6)	1458.9 (1422.9)	
Median	1130.5	1233.0	1137.0	
Pre-SCS follow-up (days)				0.0001
N	7922	805	8727	
Mean (SD)	677.8 (524.2)	736.4 (514.0)	683.2 (523.6)	
Median	561.5	664.0	569.0	
Post-SCS follow-up (days)				<0.0001
N	7922	805	8727	
Mean (SD)	721.4 (568.8)	868.2 (492.0)	735.0 (563.7)	

	Non-explant (N=7922)	Explant (N=805)	Total (N=8727)	<i>p</i>-value
Median	581.0	815.0	603.0	

SD, standard deviation

SCS, spinal cord stimulation

Table 3

Logistic regression of healthcare resource utilization.

	Total cost	Total meds cost	Pain enc. cost	Pain pscrip. cost	Pain enc. count	IP admission count	Pain pscrip. count
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age	1.00 (1.00, 1.01)	0.94 (0.93, 0.95) *	1.00 (0.99, 1.00)	0.96 (0.95, 0.97) *	0.99 (0.99, 1.00) #	1.00 (0.99, 1.01)	0.99 (0.99, 0.99) *
Gender of Patient							
Female	1.50 (1.32, 1.71) *	0.85 (0.71, 1.00)	0.97 (0.81, 1.16)	0.80 (0.67, 0.96) #	0.97 (0.84, 1.12)	1.04 (0.85, 1.28)	1.00 (0.96, 1.04)
Male	reference	reference	reference	reference	reference	reference	reference
Year							
2012	0.99 (0.79, 1.25)	1.80 (1.31, 2.48) *	2.66 (1.88, 3.75) *	1.22 (0.89, 1.68)	1.31 (0.99, 1.72)	0.76 (0.50, 1.16)	1.00 (0.93, 1.07)
2011	0.62 (0.49, 0.77) *	2.13 (1.57, 2.90) *	1.19 (0.87, 1.62)	1.34 (0.98, 1.83)	1.00 (0.77, 1.29)	0.63 (0.42, 0.93) #	0.94 (0.88, 1.01)
2010	0.88 (0.71, 1.10)	2.10 (1.54, 2.87) *	1.64 (1.21, 2.24) #	1.51 (1.10, 2.07) #	1.04 (0.79, 1.36)	0.53 (0.38, 0.72) *	0.99 (0.93, 1.06)
2009	0.92 (0.75, 1.13)	0.96 (0.71, 1.31)	1.35 (1.01, 1.80) #	0.90 (0.66, 1.21)	0.96 (0.75, 1.23)	0.61 (0.46, 0.81) *	0.95 (0.89, 1.01)
2008	0.94 (0.76, 1.17)	1.15 (0.83, 1.58)	1.37 (1.02, 1.84) #	1.12 (0.82, 1.54)	0.92 (0.74, 1.16)	0.82 (0.60, 1.13)	1.02 (0.95, 1.08)
2007	reference	reference	reference	reference	reference	reference	reference
Insurance source							
MDCR	0.74 (0.58, 0.94) #	8.93 (4.57, 17.46) *	0.31 (0.22, 0.43) *	0.84 (0.53, 1.33)	0.80 (0.65, 0.98) #	0.77 (0.57, 1.05)	0.87 (0.79, 0.96) #
MAID	0.49 (0.41, 0.58) *	0.02 (0.01, 0.03) *	0.12 (0.09, 0.15) *	0.01 (0.01, 0.01) *	0.48 (0.40, 0.58) *	0.49 (0.38, 0.64) *	0.57 (0.53, 0.61) *
CCAE	reference	reference	reference	reference	reference	reference	reference
Employment status							
MEDICAID		1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	reference	reference	reference
Other	0.93 (0.79, 1.09)	0.53 (0.28, 1.03)	1.03 (0.82, 1.31)	0.42 (0.28, 0.63) *	0.93 (0.79, 1.10)	0.81 (0.63, 1.04)	0.97 (0.92, 1.02)
Retiree/Medicare Eligible/Disabled	0.87 (0.71, 1.08)	6.61 (3.15, 13.87) *	0.64 (0.47, 0.88) #	1.84 (1.17, 2.91) #	0.87 (0.71, 1.06)	0.76 (0.57, 1.03)	1.05 (0.99, 1.13)
FT/PT	reference	reference	reference	reference	reference	reference	reference
Follow-up month after SCS lead	0.94 (0.94, 0.95) *	1.00 (1.00, 1.01) *	0.89 (0.88, 0.89) *	1.00 (0.99, 1.00)	0.95 (0.95, 0.96) *	0.97 (0.96, 0.98) *	1.00 (1.00, 1.00)
Charlson comorbidity score	1.51 (1.43, 1.59) *	1.06 (0.99, 1.14)	1.07 (1.00, 1.15)	0.93 (0.87, 1.00) #	1.03 (0.98, 1.07)	1.23 (1.18, 1.29) *	1.00 (0.99, 1.02)

	Total cost	Total meds cost	Pain enc. cost	Pain pscrip. cost	Pain enc. count	IP admission count	Pain pscrip. count
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Month after explant							
1	1.19 (0.82, 1.71)	3.88 (2.66, 5.66) *	0.69 (0.38, 1.24)	3.48 (2.38, 5.07) *	1.63 (1.16, 2.30))#	4.33 (2.28, 8.21) *	1.39 (1.27, 1.53) *
0	reference	reference	reference	reference	reference	reference	reference
Month of explant							
1	2.65 (1.83, 3.84) *	3.15 (2.20, 4.51) *	7.59 (4.23, 13.64) *	4.25 (2.97, 6.09) *	2.28 (1.50, 3.48) *	3.62 (1.42, 9.26))#	1.36 (1.24, 1.49) *
0	reference	reference	reference	reference	reference	reference	reference
Month*Explant							
	1.02 (1.00, 1.04))#	0.94 (0.93, 0.96) *	1.06 (1.03, 1.08) *	0.95 (0.94, 0.97) *	1.01 (0.99, 1.02)	0.97 (0.94, 1.01)	0.99 (0.98, 0.99) *

MDCR, Medicare; MAID, Medicaid; C/AE, commercially available insurance

OR, odds ratio; CI, confidence interval

meds, medication; enc, encounters; pscrip, prescription; IP, inpatient

* p<0.0001,

p < 0.05

Table 4

Predictors of explant rates at 1-year and 3-years after initial SCS implantation.

	At one year		At three years	
	OR (95% CI)	<i>p</i> -value	OR (95% CI)	<i>p</i> -value
Age	0.99 (0.98, 1.00)	0.010	0.99 (0.99, 1.00)	0.018
Gender of Patient				
Male	reference	.	reference	.
Female	1.12 (0.95, 1.31)	0.169	1.08 (0.93, 1.26)	0.314
Implant volume				
Low	reference	.	reference	.
Medium	0.80 (0.66, 0.96)	0.019	0.77 (0.65, 0.93)	0.005
High	0.92 (0.77, 1.11)	0.375	0.93 (0.78, 1.11)	0.419
Insurance source				
CCAE	reference	.	reference	.
MAID	1.02 (0.83, 1.26)	0.822	1.02 (0.84, 1.24)	0.852
MDCR	1.00 (0.73, 1.37)	0.993	1.00 (0.74, 1.34)	0.990
Charlson Comorbidity Score	1.07 (1.01, 1.13)	0.022	1.07 (1.02, 1.13)	0.012
Employment status				
FT/PT	reference	.	reference	.
Other	0.95 (0.77, 1.17)	0.640	0.97 (0.80, 1.19)	0.800
Retiree/Medicare Eligible/Disabled	0.87 (0.65, 1.16)	0.335	0.89 (0.67, 1.17)	0.394

MDCR, Medicare; MAID, Medicaid; CCAE, commercially available insurance

COBRA, Consolidated Omnibus Reconciliation Act of 1985

OR, odds ratio; CI, confidence interval

Table 5

Additional pain-related procedures post-SCS implant, by explant status.

	Non-Explant (N=7922)	Explant (N=805)	Total (N=8727)	<i>p</i> -value
Intrathecal pump implantation, <i>N</i> (%)				<0.0001
Mean (SD)	0.0 (0.2)	0.1 (0.3)	0.0 (0.2)	
Spine surgery, <i>N</i> (%)				<0.0001
Mean (SD)	0.1 (0.4)	0.2 (0.6)	0.1 (0.4)	
Injections, <i>N</i> (%)				<0.0001
Mean (SD)	0.9 (2.4)	1.7 (3.5)	1.0 (2.5)	
Sympathetic Blocks, <i>N</i> (%)				<0.0001
Mean (SD)	9.5 (15.6)	16.1 (16.0)	10.1 (15.8)	
Median	5.0	12.0	6.0	
Radiofrequency Ablations, <i>N</i> (%)				<0.0001
Mean (SD)	0.0 (0.4)	0.1 (0.5)	0.1 (0.4)	
Acupuncture, <i>N</i> (%)				0.4489
Mean (SD)	0.0 (0.8)	0.1 (1.7)	0.0 (0.9)	
Physical therapy, <i>N</i> (%)				0.0201
Mean (SD)	0.8 (5.4)	0.9 (4.6)	0.8 (5.4)	
Repeat SCS, <i>N</i> (%)				<0.0001
Mean (SD)	2.8 (2.0)	3.8 (2.0)	2.9 (2.0)	
Biofeedback, <i>N</i> (%)				0.0063
Mean (SD)	0.6 (3.9)	0.6 (4.4)	0.6 (3.9)	
Psychological counseling, <i>N</i> (%)				0.7499
Mean (SD)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
Chiropractor therapy, <i>N</i> (%)				0.8135
Mean (SD)	0.9 (6.6)	1.0 (8.1)	0.9 (6.8)	
Sum of additional procedures, <i>N</i> (%)				<0.0001
Mean (SD)	15.7 (21.2)	24.7 (23.5)	16.5 (21.6)	
Median	9.0	19.0	10.0	
Additional procedure, <i>N</i> (%)				<0.0001
No	210 (2.7%)	0 (0.0%)	210 (2.4%)	
Yes	7712 (97.3%)	805 (100.0%)	8517 (97.6%)	

SCS, spinal cord stimulator