differences for the biology of pain within the dorsal root ganglion in humans and implicates the immune system as a critical influence in these differences.

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Protocolized High-Dose (HD) and Low-Dose (LD) Spinal Cord Stimulation (SCS) Workflow Results in Meaningful Pain and Opiate Reduction

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INTRODUCTION: Various new waveforms for spinal cord stimulation (SCS) have emerged in recent years, with limited data supporting their utility in a real-world clinical setting. We report real-world results of a protocolized workflow algorithm that allows for high dose (HD) and low dose (LD) neurostimulation in patients with chronic pain undergoing SCS trial or permanent procedures.

METHODS: Prospective data was collected using the ManageMySurgery (MMS) mobile device platform in patients undergoing Medtronic SCS trial and permanent implant procedures. E-consent was obtained through the HIPAA compliant, mobile software platform. All data was de-identified, aggregated and analyzed.

RESULTS: In total, 104 patients (37 trial SCS and 67 permanent SCS) participated. For SCS trial and permanent procedures, the protocolized workflow algorithm resulted in a 91% trial success rate with >50% pain relief. At long-term follow-up (3 to 12 mo), 86% of permanent SCS patients reported they were getting the same or more relief as during their SCS trial. For permanent SCS patients, 79% reported >50% improvement in overall pain and 58% had >50% improvement in low back pain. The protocolized workflow algorithm resulted in a 37% "remitter rate," with these patients reporting themselves essentially pain free (VAS 0–3). Importantly, 52% of permanent implant patients stopped or reduced their 'as needed' pain medications by >50%. Additionally, 87% would recommend the same procedure to a friend or family member, 87% found device charging 'easy' or 'very easy' and 66% reported charging a few times a week or weekly.

CONCLUSION: A protocolized workflow algorithm that allows for HD and LD neurostimulation appears to have robust utility in providing meaningful pain relief and opiate reduction during both the SCS trial and permanent stages and at longer-term follow-up. Randomized controlled trials with extended follow-up are in progress.

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Internal Neurolysis With and Without Microvascular Decompression for Trigeminal Neuralgia

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INTRODUCTION: Trigeminal Neuralgia (TN) is a pain syndrome often resulting in debilitating, paroxysmal lancinating facial pain in various distributions. Microvascular decompression (MVD) is the mainstay surgical treatment when an offending vessel is identified. However, internal neurolysis (IN) or nerve-combing (NC) have become increasingly utilized as an adjunct or stand-alone therapy when low grade or no neurovascular compression (NVC) is identified intraoperatively, or as a salvage procedure in patients with TN unresponsive to MVD or other treatment modalities.

METHODS: A retrospective case series review was performed for patients with TN treated with IN, with or without MVD. An MVD was performed with IN when an offending vessel causing low grade compression was seen. If no NVC was identified, IN alone was performed. Twenty-three patients were identified with an average follow-up of 14.5 mo. The Barrow Neurologic Institute (BNI) Pain Scale and Hypesthesia Scale were used to determine outcomes. Additionally, a systematic review of the literature was performed for patients with TN treated with IN/NC with or without MVD.

RESULTS: The overall success of treatment with an average follow-up of 14.5 mo was 87%. There was no significant difference ($P = .235$) between rates of successful treatment for patients who had an MVD/IN versus IN alone, however there was a trend toward improved outcomes when MVD/IN were simultaneously performed; 93% MVD/IN versus 75% IN alone. The most common complication with IN was postoperative hypesthesia, however most patients (96%) had either no or mild non-bothersome hypesthesia at last follow-up.

CONCLUSION: IN with or without MVD represents a reasonable option for TN when low grade or no NVC is identified or as a salvage procedure when other modalities of treatment have failed.

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Earlier Radiosurgery Leads to Better Pain Relief and Less Medication Usage for Trigeminal Neuralgia Patients: An International, Multi-center Study

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INTRODUCTION: Trigeminal neuralgia (TN) is a chronic pain condition that is difficult to control with one or more medications. Disabling medication-related side effects are common, and benefit typically wanes over time. This study examined how stereotactic radiosurgery (SRS) affects outcomes and medication usage based on the time course between diagnosis and radiosurgery.

METHODS: We conducted a retrospective review of patients with Type I TN at 11 Gamma Knife treatment centers. SRS was the primary surgical intervention in all patients. Patient demographics, disease characteristics, treatment plans, medication histories, and outcomes were documented. Univariate and multivariate statistical analyses were used where appropriate; multivariate regressions were based on contributing variables where $P < .3$ in univariate analysis with covariates maintained if a significance level of $P < .05$ was achieved.

RESULTS: A total of 286 patients were included. Average follow-up was 27.4 mo. Patients who received SRS within 4 yr of initial diagnosis demonstrated a significantly shorter time to pain relief than those who received SRS later (median 21 d vs 27 d, $P = .030^*$). SRS significantly reduced the number of medications used both overall (mean 1.92 vs 0.96, $P \leq .0001^*$) and in each medication class by last follow-up. In multivariate analysis, higher maximum radiation dose was a robust predictor

of durable pain response (OR 1.13, $P = .001^*$) and, correspondingly, a negative predictor of treatment failure (OR 0.87, $P = .0005^*$). Overall adverse radiation effect rate was low (2.45%) and not associated with maximum dose.

CONCLUSION: Patients managed with SRS within 4 yr of diagnosis experienced a shorter interval to pain relief with low risk. SRS yielded significant decreases in adjunct medication utilization. Radiosurgery should be considered earlier in the course of patient care for TN.

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Effects of External Focused Ultrasound on Inflammatory Markers in Neuropathic Pain Caused by Common Peroneal Nerve Injury

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INTRODUCTION: Various rodent models have long been employed to study treatments for chronic pain. However, these studies have resulted in unsuccessful phase-I and II human trials that have failed to result in viable options for patients. Though limitations of animal models are no doubt one issue, lack of objective markers corresponding with pain relief play a role. Our lab has shown significant pain relief in a common peroneal nerve injury (CPNI) rat model following administration of external pulsed low-intensity focused ultrasound (liFUS), thus, establishing external liFUS as a promising technique for treatment of neuropathic pain. Current knowledge of liFUS effects are limited to observable behavioral changes, and little is known of the mechanism of action. To successfully translate this device into the clinic, we examine molecular changes in the inflammatory cascade.

METHODS: Male rats underwent CPNI to induce neuropathic pain. External liFUS treatment was performed on the L5 dorsal root ganglion (DRG) in the neuropathic model, which was determined from responses to Von Frey fibers (VFF). 24 h post liFUS treatment, L5 DRGs were obtained from 4 distinct cohorts: rats that underwent CPNI with liFUS, CPNI with sham liFUS, sham CPNI with liFUS, and sham CPNI sham liFUS (n = 4 for each group). Using a membrane-based sandwich immunoassay (Proteome Profiler Rat Cytokine Array Kit from R&D System), we assessed relative abundances of 6 anti-inflammatory cytokines and 16 pro-inflammatory cytokines.

RESULTS: CPNI resulted in an 82.5% decrease of tumor necrosis factor alpha (TNFa) and a 61.8% increase of macrophage inflammatory protein 1-alpha (MIP-1a). liFUS led to a 60% decrease in MIP-1a and a 40% increase in TNFa. Other changes in cytokines were not affected by CPNI or liFUS.

CONCLUSION: liFUS resulted in similar changes in TNFa and MIP-1a, as compared to spinal cord stimulation and other medical treatments for pain syndromes. Further work will examine inflammatory responses over time and in female rats.

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Defining the Therapeutic Window (TW) for Spinal Cord Stimulation (SCS) Using Evoked Compound Action Potential (ECAP) Recordings: Results From the Evoke Study

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INTRODUCTION: Spinal cord stimulation (SCS) is an established treatment for chronic pain; however, long-term success remains suboptimal. Current SCS therapies are fixed-output and do not account for large variation in electrical field strength due to changes in distance between the electrode and spinal cord (SC).

METHODS: In Avalon, 50 subjects were implanted and programmed in closed-loop; in Evoke, 134 subjects were randomized into open-loop (OL-SCS) or closed-loop (CL-SCS). ECAPs, a measure of SC activation, are recorded following each stimulation pulse in both groups. Each subject's therapeutic window (TW) is determined individually as the ECAP amplitude range between sensation perception threshold and discomfort. Without a measure of SC activation (eg, ECAPs), TW can only be based on perception of intensity; however, stimulation can produce variable SC activation (ECAP amplitude) as the electrode to SC distance varies with movement.

RESULTS: In the Evoke Study, each subjects' TW was determined in the clinic, along with the clinician prescribed level. There was no statistical difference between the 2 groups' TWs; however, CL-SCS subjects spent significantly more time in the TW despite having equivalent therapeutic ranges. Long-term data showed a similar percentage of stimuli in the TW (83%-97%).

CONCLUSION: TW can be individually defined by ECAP amplitudes (measure of SC activation), removing the need to rely on subjective reports of intensity, which can vary over time and with movement.

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Healthcare Resource Utilization Among Patients With Non-Surgical Refractory Low Back Pain in the United States: A Retrospective Analysis of Health Insurance Claims Data

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INTRODUCTION: The economic burden of low back pain (LBP) in the US is estimated between $84.1 and $624.8 billion. Some patients with LBP that persists despite conventional medical management are ineligible for spine surgery and are considered to have non-surgical refractory back pain (NSRBP). We investigated the healthcare resource utilization (HCRU) of patients with NSRBP.

METHODS: The IBM MarketScan® Research databases were queried for adult patients with a diagnosis of LBP, excluding instability (eg, spondylolisthesis) and non-mechanical etiologies, and negative history of failed back surgery syndrome or spine surgery within the study period (2009-2016). For a patient to qualify as refractory, we required utilization for >30 d of pain medications (prescribed within 2 wk of diagnosis) or non-pharmacologic therapies within the 3 to 24 mo following initial diagnosis. Annual total costs, including inpatient and outpatient service costs and outpatient medication costs, were calculated for 2 yr.

RESULTS: Among 50 801 patients, median total cost was $3,755 (IQR $1,299, $9,108) at 1 yr pre-diagnosis, reached $6,622 (IQR