# SPINAL CORD STIMULATION

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**C M Schade, MD, PhD, PE**

TPS 10.25.2014

# DISCLOSURES

- I am a speaker for Medtronic Neurological
- This presentation is free of commercial bias
- Some of these slides were prepared by Medtronic, Boston Scientific, St.Jude and Nevro

  I have independently verified the scientific information
- Nevro is not approved in the United States
- Nevro is not for sale in the United States
- I am not promoting or recommending any of these products

# Disclaimer

This presentation contains information on products that are undergoing clinical evaluation and are not FDA approved. The presentation is not meant to make any claims that these products have been found safe or effective by FDA.

The Prodigy™ system received CE Mark in March 2014

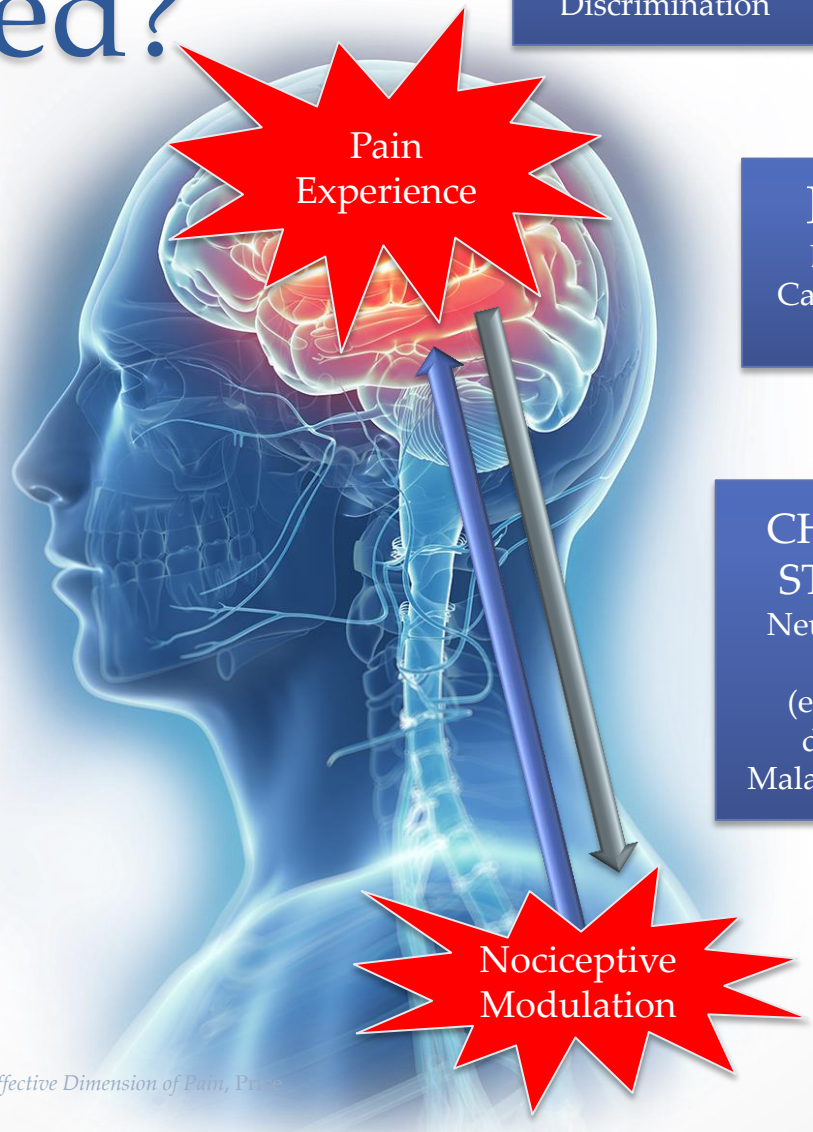
# Outline

- Chronic Pain Overview
  - How is pain perceived? – Central mechanisms & psychology of pain
- "State of The Art"
  - Tonic Stimulation
- Unmet needs in SCS for chronic pain management
  - Non-response / inadequate response at trial
  - Patient intolerance of paresthesia, further compounded by patient positionality
  - Evolving pain patterns post-implant of permanent SCS system
  - Address patients' pre-occupation with pain
- Burst and High Frequency Stimulation
  - How well does it target unmet needs – Clinical evidence review
  - How do they work – mechanisms of action
  - Open questions and evidence generation

# How is pain perceived?

**SENSORY**
Intensity,
Localization,
Discrimination

**CONTEXT**
Pain Beliefs,
Expectation,
Placebo




**MOOD**
Depression,
Catastrophising,
Anxiety

**COGNITIVE**
Hypervigilance,
Attention,
Distraction,

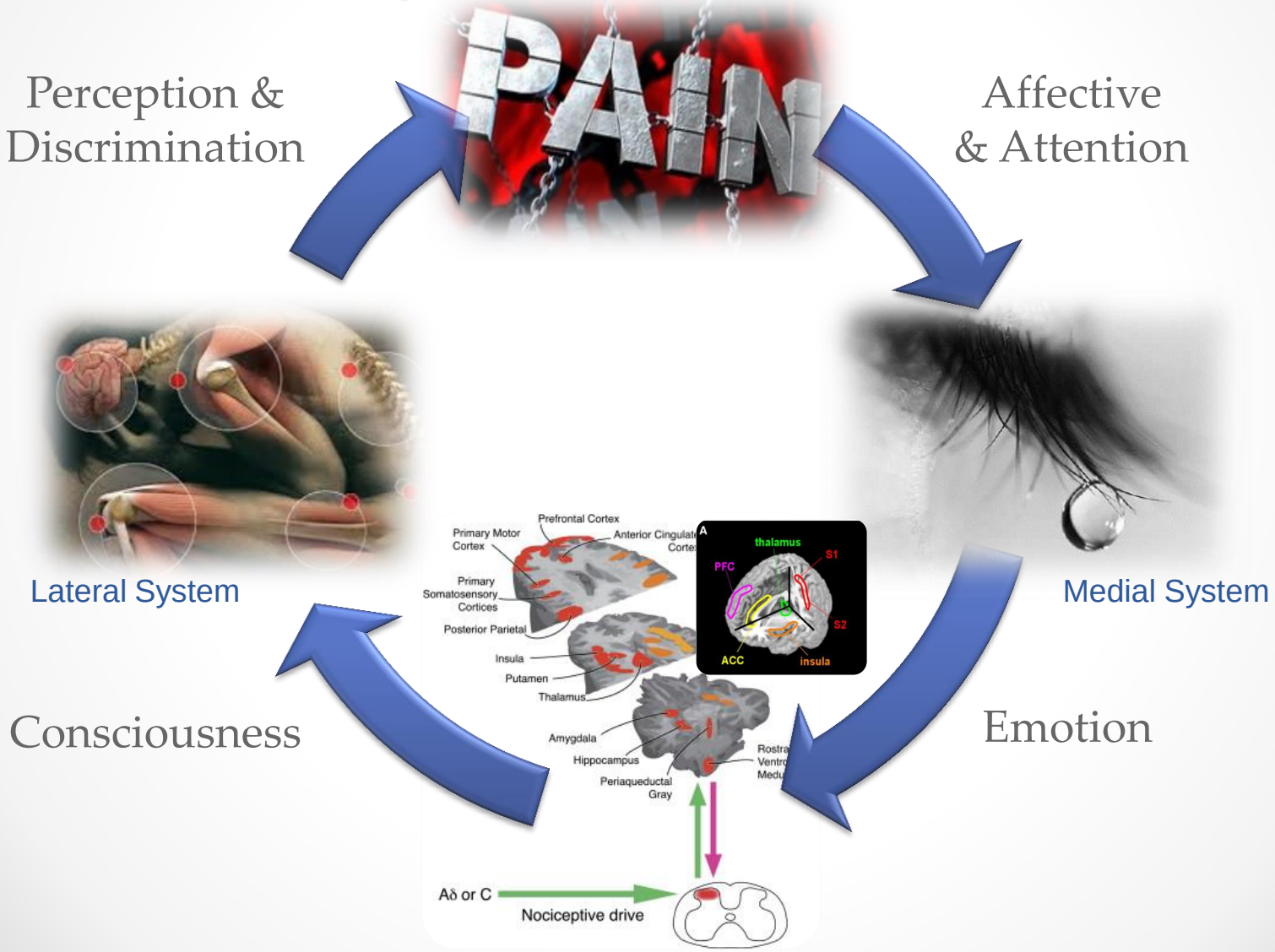
**CHEMICAL & STRUCTURE**
Neurodegeneration
Metabolic
(e.g. opioidergic,
dopaminergic)
Maladaptive Plasticity

Aδ or C
Nociceptive
input

* *Psychological and Neural Mechanisms of the Affective Dimension of Pain*, Price et al, Science, 00368075, Vol.288, Issue 5472

# Somatosensory System

(Price 2000, Craig 2002, Fields 2004, Rainville 1999)



# Concept of SCS

## Neuropathic pain

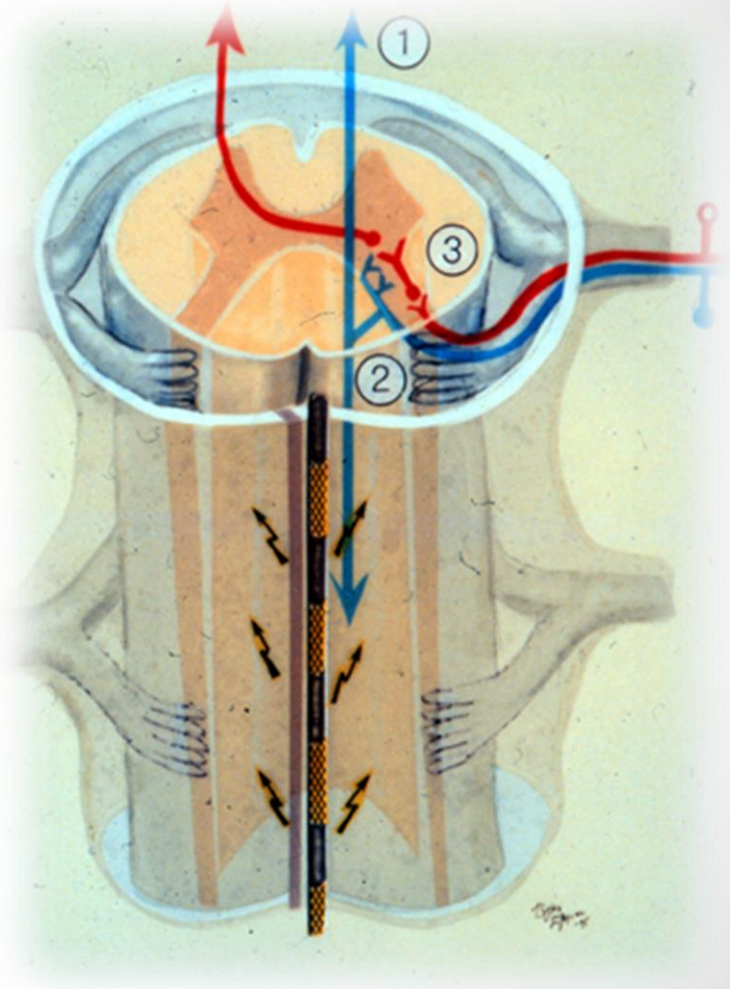
Ectopic or spontaneous discharges in C fibres
(Wu 2002)

## Paresthesia and dysesthesia

Ectopic discharges in Aβ fibres
(Ochoa 1980, Nordin 1984)

## Spinal cord stimulation

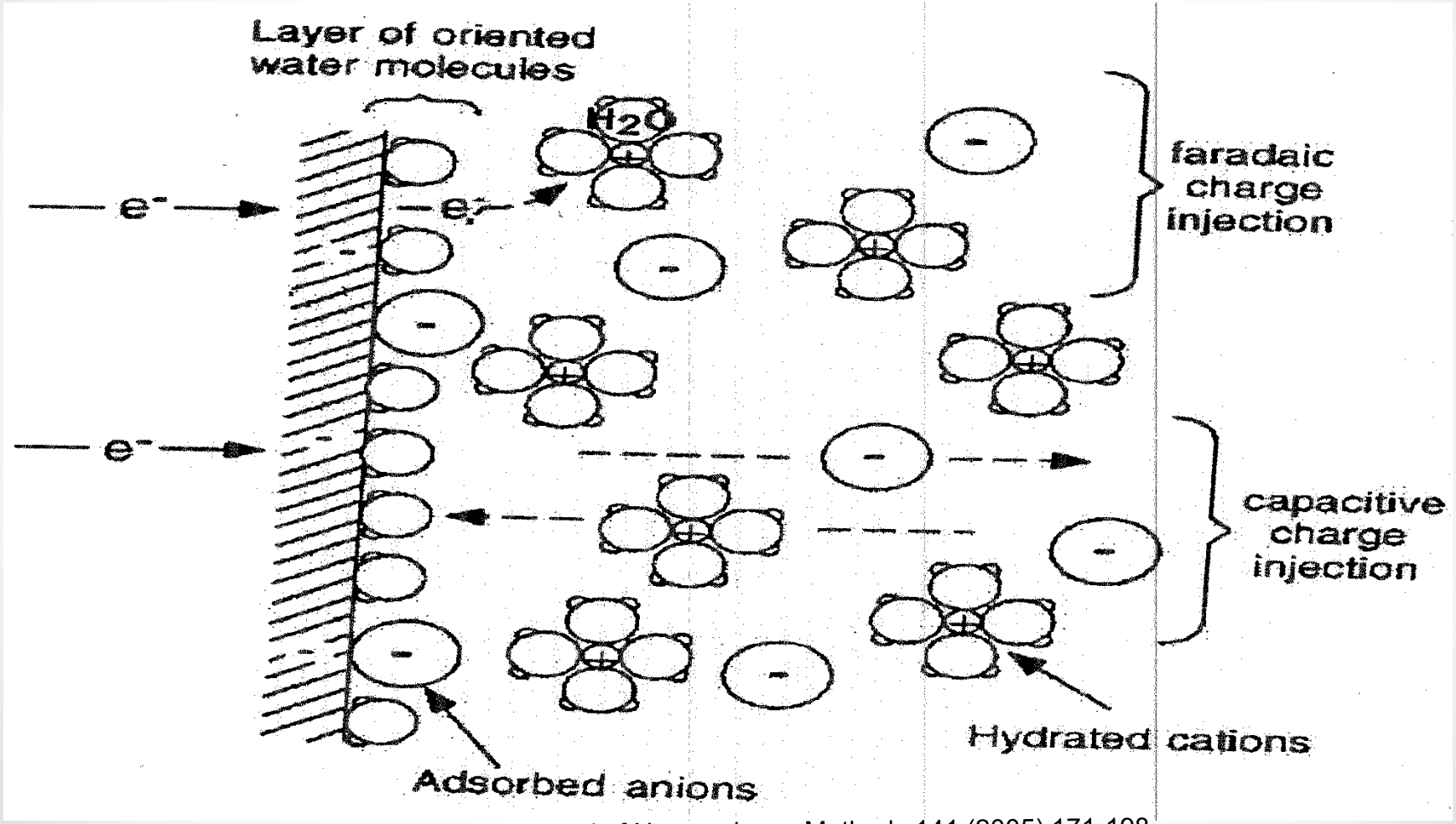
Activates Aβ to suppress C and Aδ fibers
Via inhibitory interneurons (Melzack & Wall 1965)





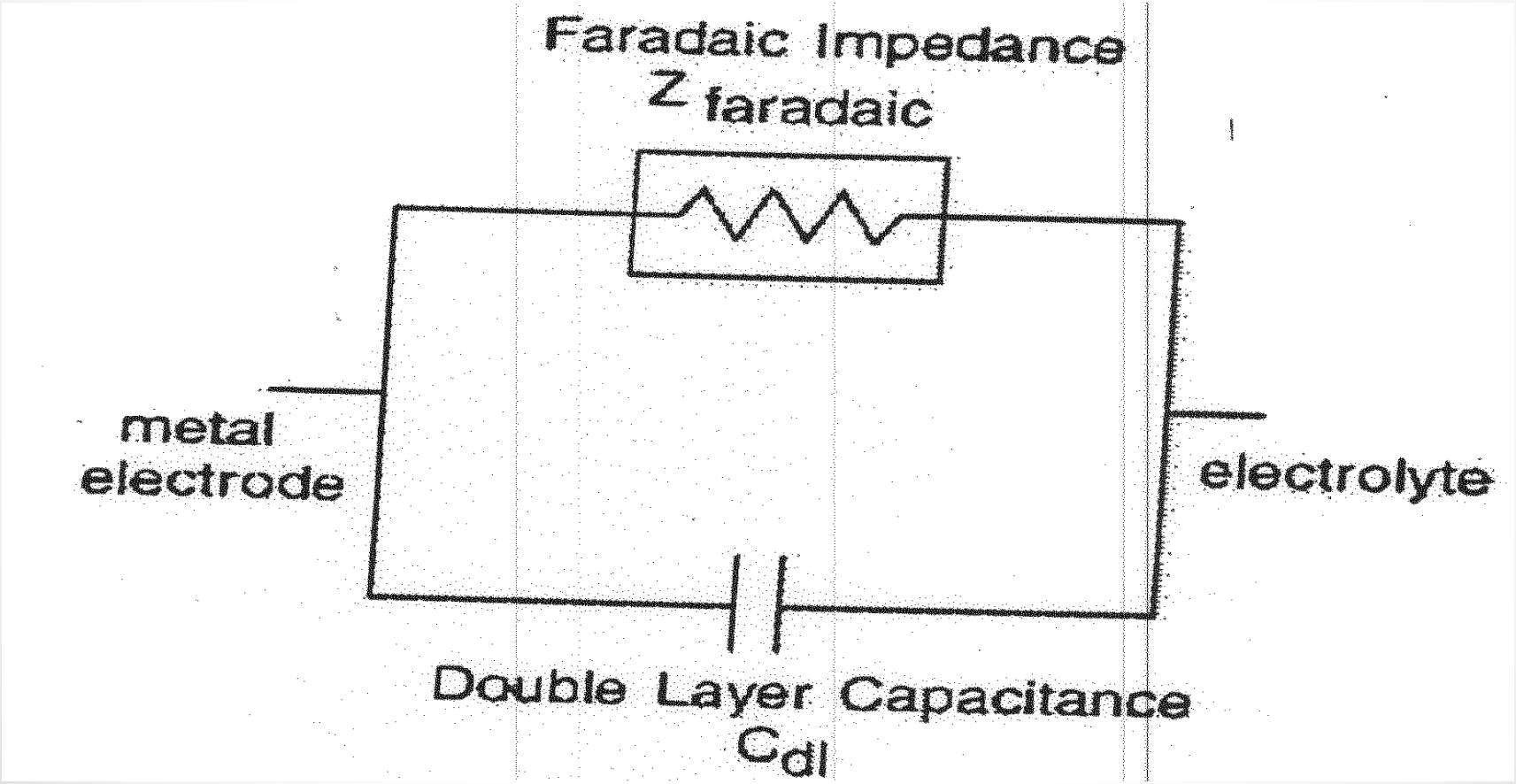

1. Cui et al., Neuroscience Letters, 1998.

# THE ELECTRODE/ELECTROLYTE INTERFACE



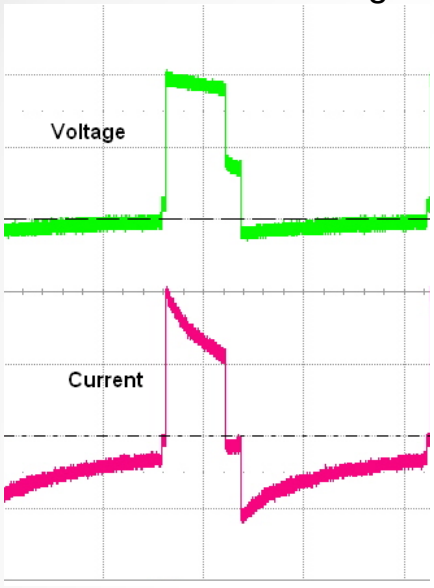

D.R. Merrill et al/ Journal of Neuroscience Methods 141 (2005) 171-198

# THE ELECTRODE/ELECTROLYTE INTERFACE

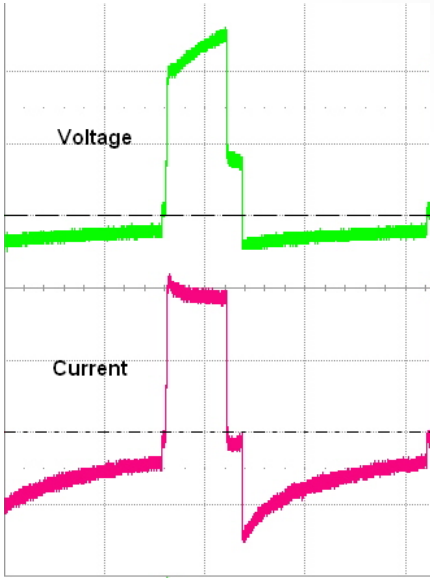



D.R. Merrill et al/ Journal of Neuroscience Methods 141 (2005) 171-198

Voltage Mode
green trace - voltage during the pulse
red trace - current during the pulse




Current Mode
green trace - voltage during the pulse
red trace - current during the pulse




Some questions that may arise from these plots:
Q: Why isn't the voltage constant in voltage mode?
A: The voltage is regulated to a constant level prior to being delivered through a 10 uF series capacitor to the electrode. As the 10 uF capacitor builds up a slight voltage during the pulse the voltage during the pulse slightly decreases.

Q:Why does the current drop so much on the voltage mode pulse?
A: The impedance of the electrode-tissue interface increases during the pulse, so the current decreases during the pulse faster than the voltage. (This is the same reason why the voltage increases during a constant current pulse…it needs to increase in order to keep the current constant while the electrode-tissue interface impedance increases during the pulse

Q: Why does the voltage not return to zero between the therapy pulse and the recharge pulse?
A: The electroe-tissue interface builds up a small potential during the therapy puse which will go to zero after the recharge pulse is delivered. You can see from the current trace that current is not being delivered during this time even though there is a potential between the two electrodes.

*traces are taken in a saline load. the impedance is in the 1K ohm range

Voltage Mode

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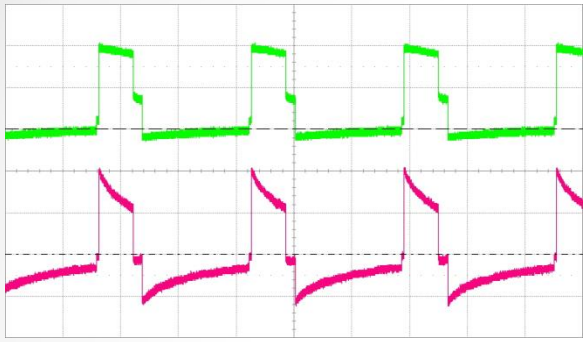

Current Mode

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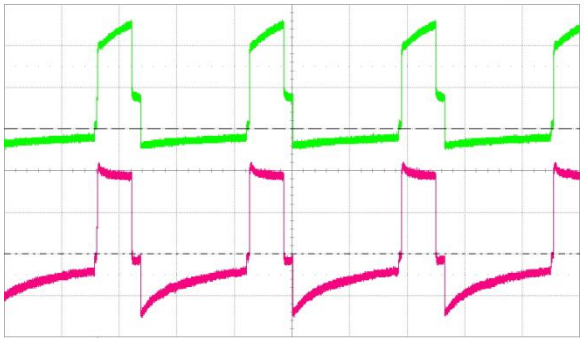
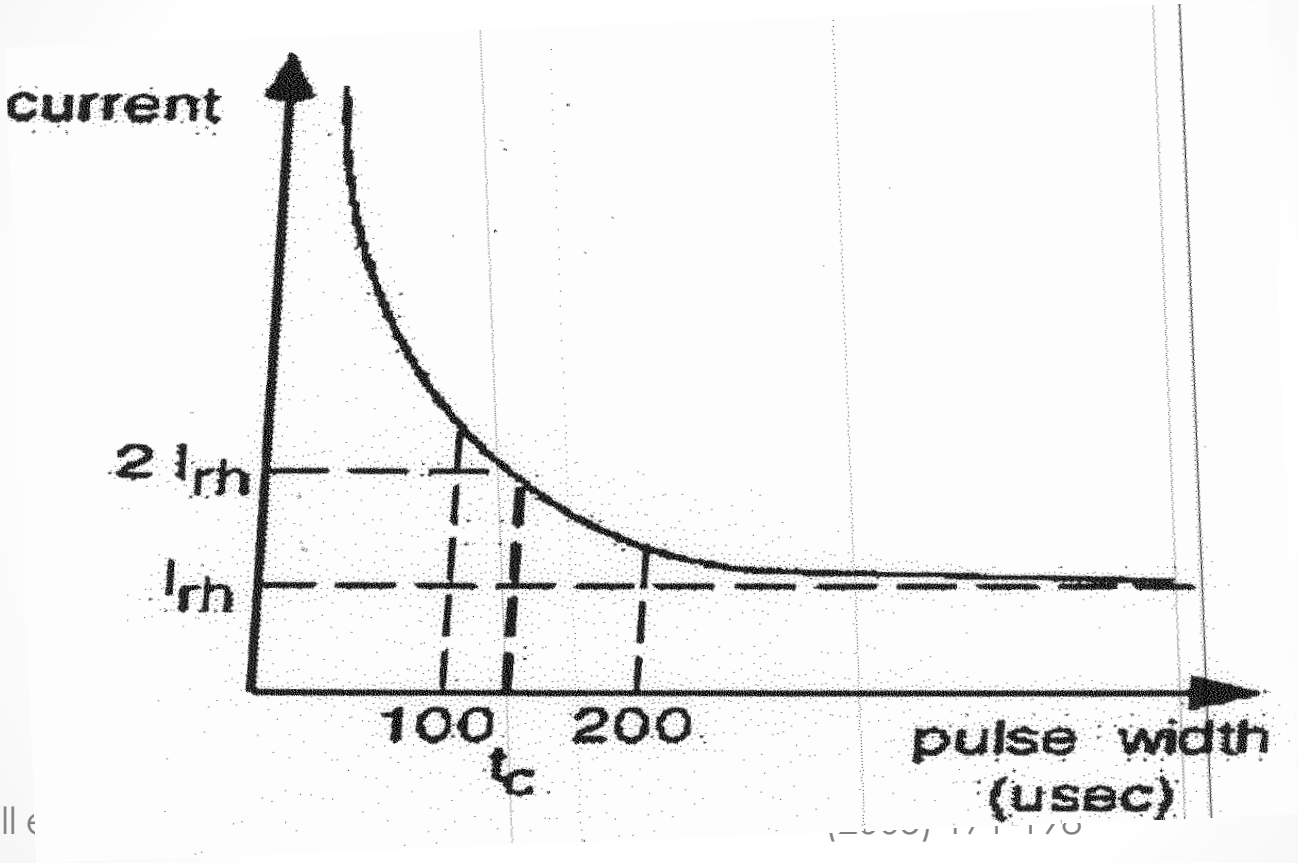
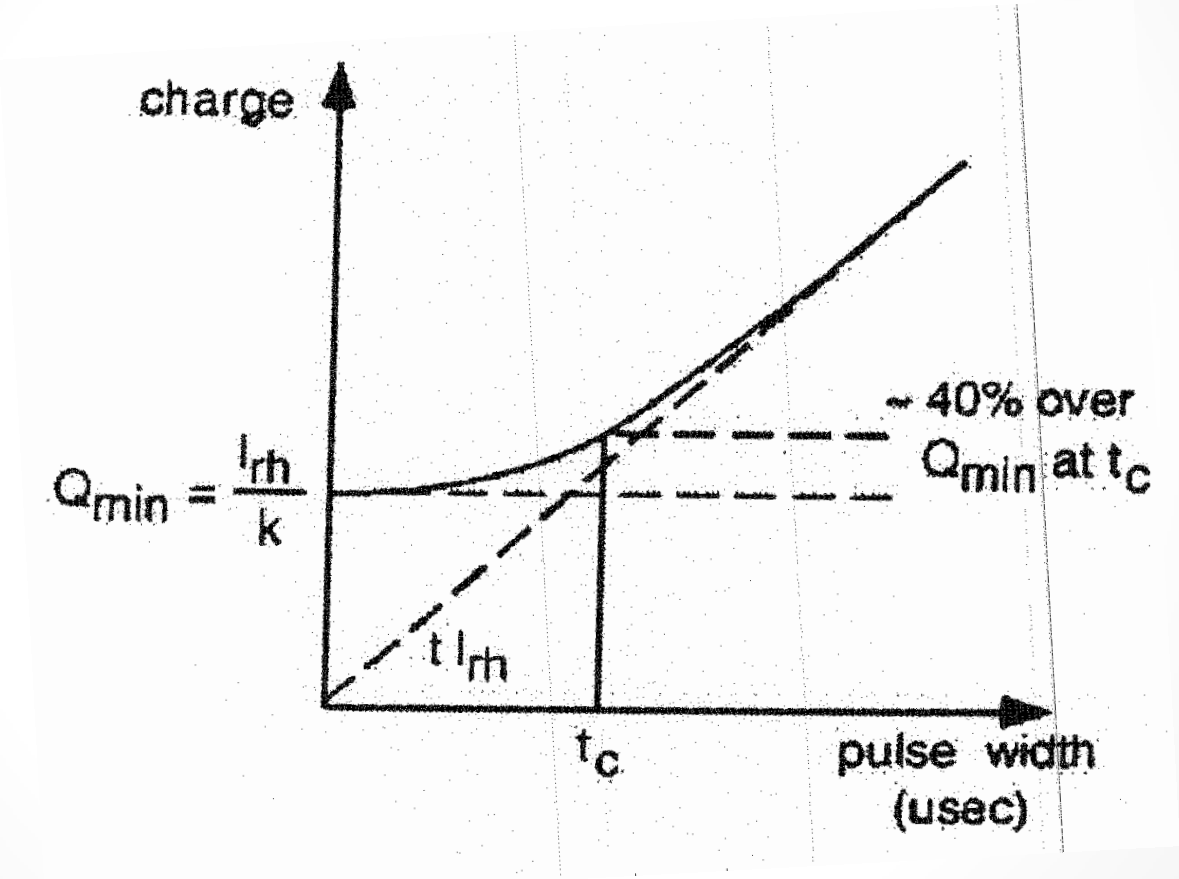


# STRENGTH-DURATION CURVE FOR INITIATION OF AN ACTION POTENTIAL




D.R. Merrill e

# CHARGE – DURATION CURVES FOR INITIATION OF AN ACTION POTENTIAL




D.R. Merrill et al/ Journal of Neuroscience Methods 141 (2005) 171-198

# "STATE OF THE ART" Tonic Stimulation

- BOSTON SCIENTIFIC
- MEDTRONIC NEUROLOGICAL
- ST. JUDE

PRECISION SPECTRA™
Spinal Cord Stimulator System

# Precision Spectra™ SCS System

## Innovation Focused On Pain Relief™


NM-269603-AB_OCT2014

# History of Innovation Focused On Pain Relief

PRECISION SPECTRA™
Spinal Cord Stimulator System

# Innovation Focused on Pain Relief™

PRECISION SPECTRA™
Spinal Cord Stimulator System


## Not enough coverage

32 dedicated power sources provides unprecedented coverage of the cord

## Untreated Pain Areas

4 Ports providing flexibility to treat pain both now and in the future

## Stimulation Side Effects

Precision Spectra's Illumina 3D™ advanced programming algorithm creates a customized stimulation field designed to improve pain targeting.

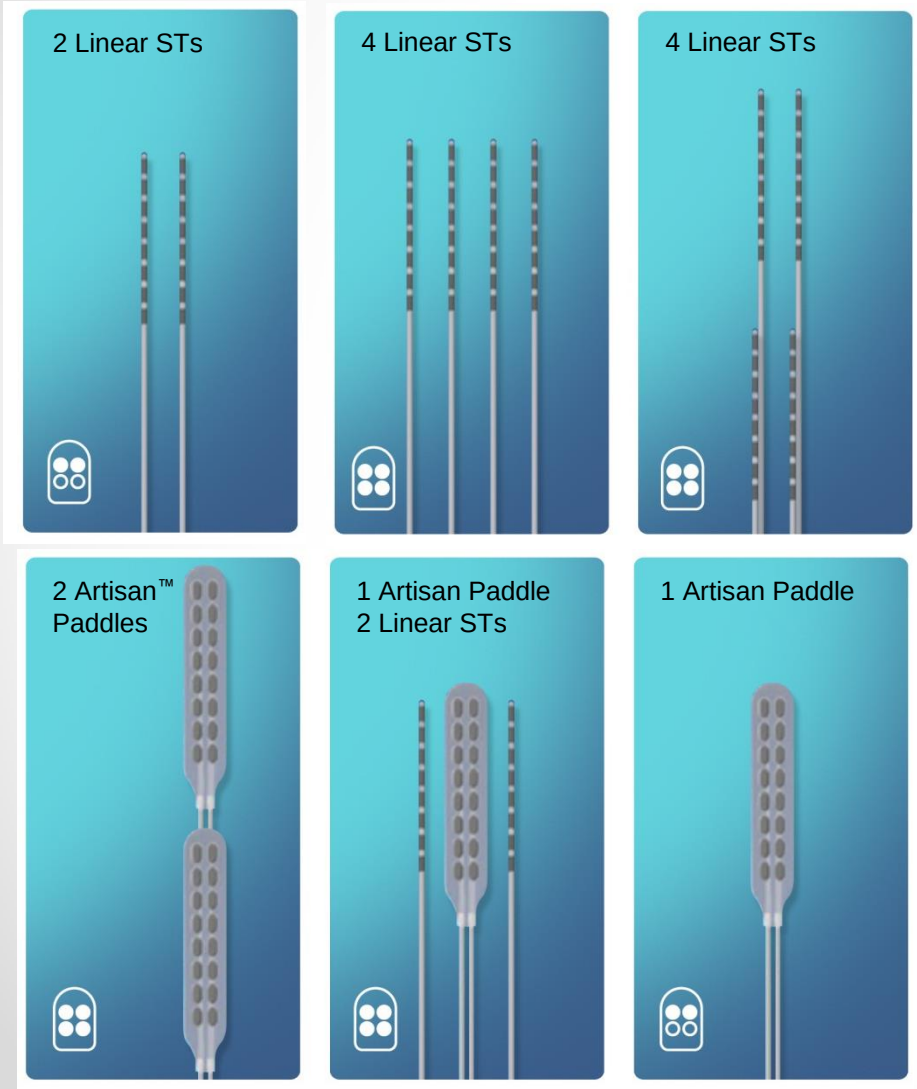
# Precision Spectra™

## ImageReady™ MRI Technology

PRECISION SPECTRA™
Spinal Cord Stimulator System


**ImageReady MRI Technology makes MR Conditional head scans possible.**

# ImageReady™ Lead Configurations





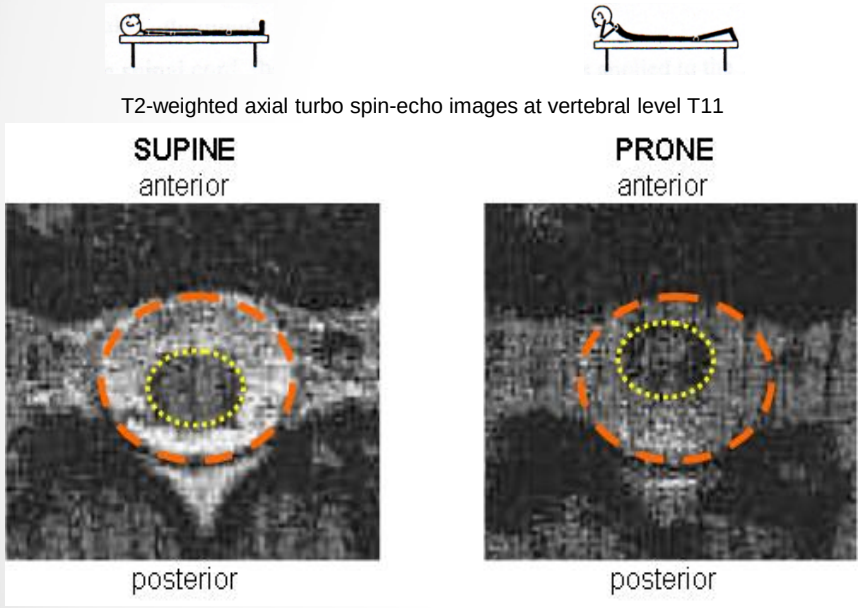
With more lead configuration options to come…

# MEDTRONIC

## Technology that goes beyond …
## AdaptiveStim

# A Dynamic Problem

- The spinal cord moves in the anterior-posterior direction with changes in posture at the low thoracic level

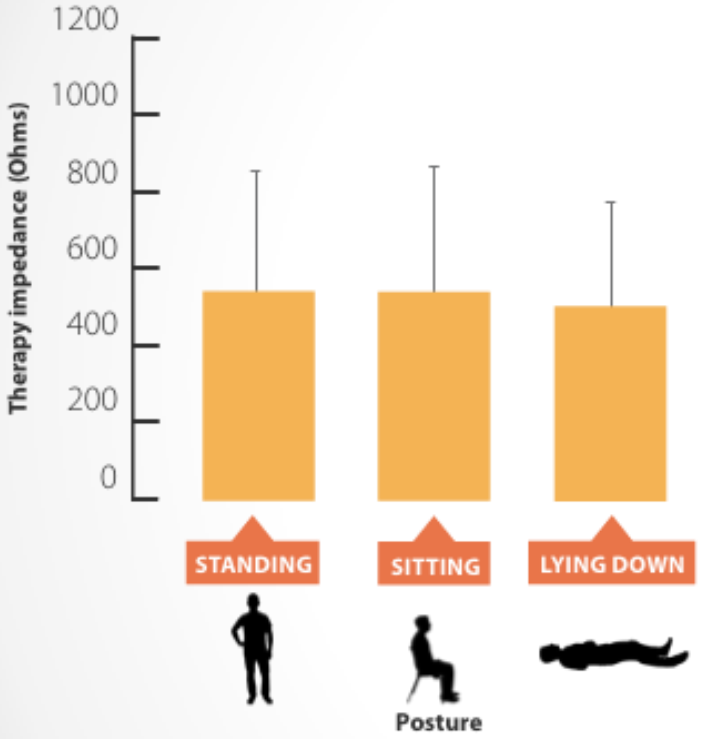



- On average, the spinal cord moves 2.2 mm between supine and prone postures at T11 and 3.4 mm at T12
- Positional changes can result in spinal cord movement as much as 3 mm
- 2-3 mm can be a significant issue with stimulation and pain relief

Holsheimer J, den Boer JA, Struijk, JJ, Rozeboom AR. MR Assessment of the Normal Position of the Spinal Cord in the Spinal Canal. *AJNR Am J Neuroradiol*. May 1994;15:951-959..

# Impedance: Two Studies Confirm

Abejon D, Feler CA. Pain Physician, 2007

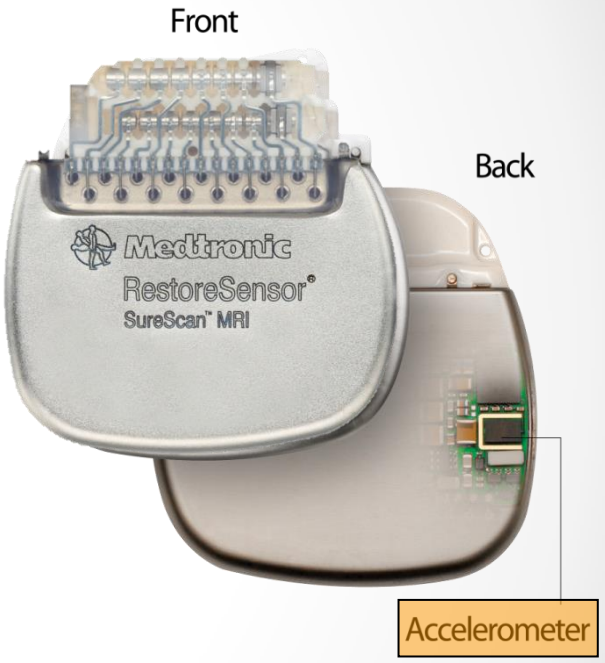



Schade CM, Schultz D, et al. Abstract. NANS 2009


- No statistically significant differences in posture related impedance have been found

# AdaptiveStim® with RestoreSensor® Neurostimulator
# A Solution for a Dynamic Problem

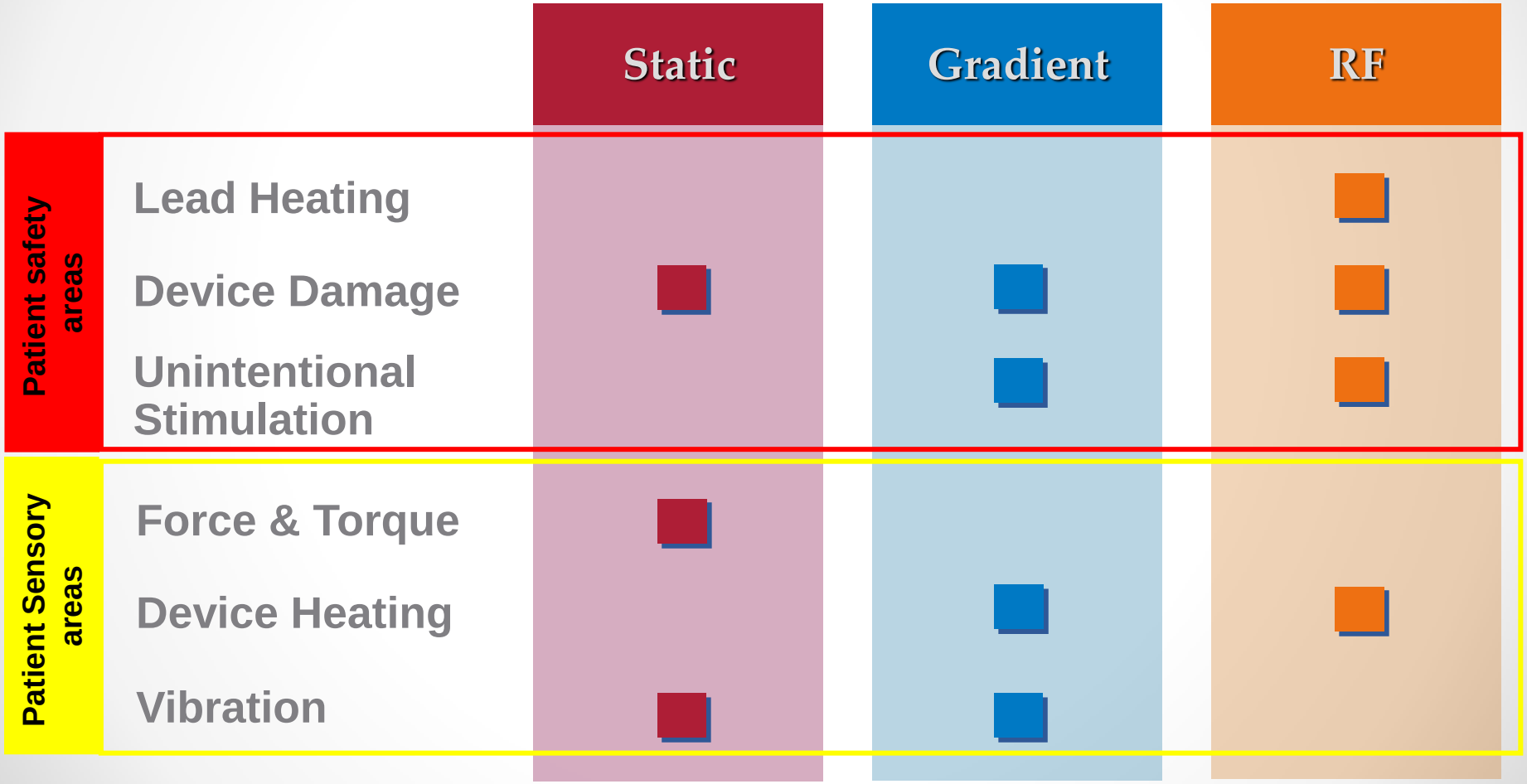
- Automatically adapts to a patient's changing postural therapy needs to ensure continuous therapy optimization
- Records patient activity level
- Includes SureScan® MRI Technology that gives patient safe access to MRI scans on any part of the body*



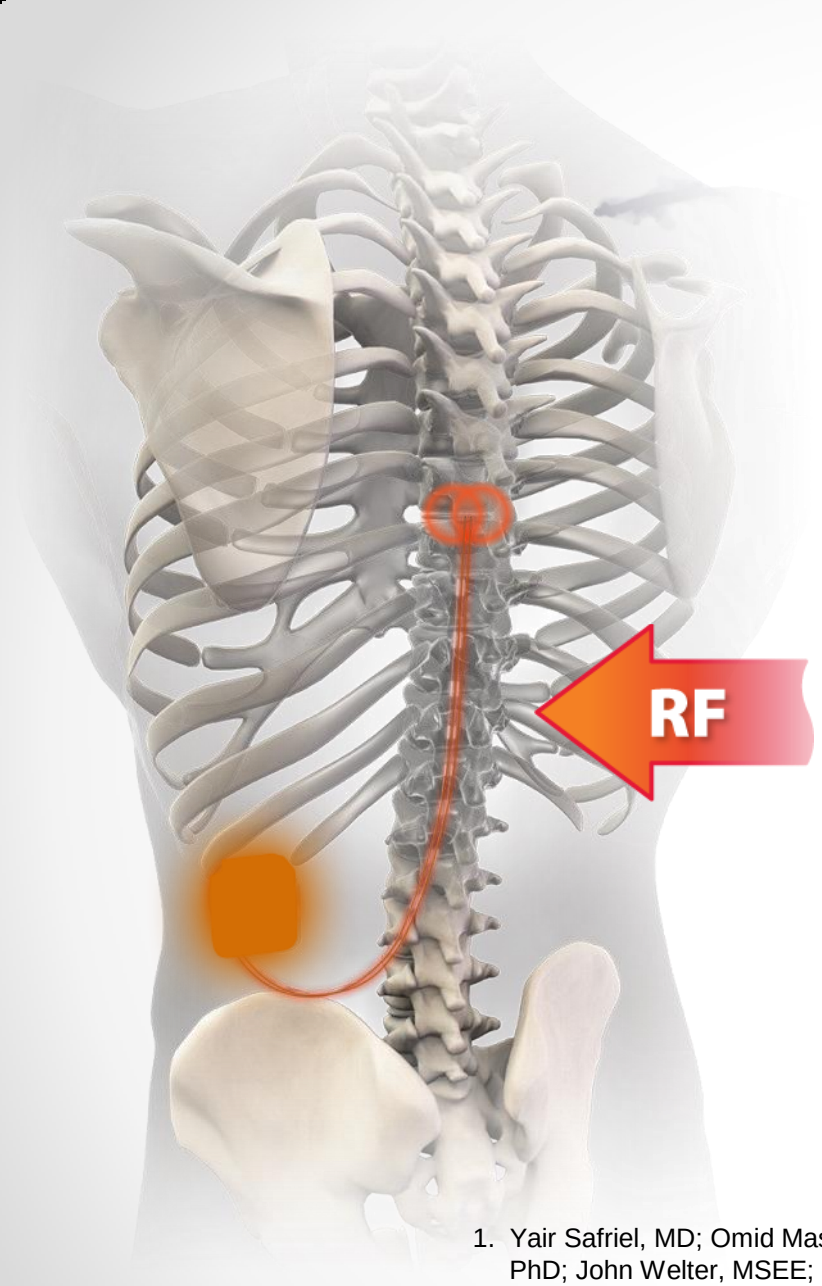

MR Conditional

* Under specific conditions and requires SureScan implantable neurostimulator and Vectris leads. Refer to approved labeling for full list of conditions

# Multiple Potential Interactions with Medical Devices




ISO 10974:2012




# Risk of Lead Heating

**The most significant patient risk is lead heating[1]**

- Radio frequency (RF) energy can collect in the lead wires and dissipate at the lead tip electrodes, causing thermal injury of the spinal cord[1]
- Can cause Irreversible neurological damage[2]


1. Yair Safriel, MD; Omid Mashhadi, BSEE; Maria Breitenfeldt, PhD; Heather Orser, PhD; John Welter, MSEE; Steve Manker, BSME. Understanding the Potential Effects of MRI on Patients with Spinal Cord Stimulation Systems. NANS 2012.
2. Eric R. Cosman, Jr., MEng, PhD,* and Eric R. Cosman, Sr., PhD, Prof. Electric and Thermal Field Effects in Tissue Around Radiofrequency Electrodes. *Pain Medicine*, 2005.

# Medtronic SureScan® MRI System for SCS*


SureScan MRI versions:
RestoreSensor®
RestoreUltra®
RestoreAdvanced®
PrimeAdvanced®

New
Shielded
Vectris® Lead


Updated
MyStim®
Patient
Programmer

Injex®
Anchors

**MR Conditional**

Under specific conditions and requires SureScan implantable neurostimulator and Vectris leads. Refer to approved labeling for full list of conditions

# Defining MR Safety


**MR Safe:** An item that poses no known hazards in **all** MR environments. A nonconducting or a nonmagnetic item, such as a plastic Petri dish, poses no known hazards in all MR environments.


**MR Conditional:** An item that has been demonstrated to pose no known hazards in a **specified** MR environment with specified conditions of use.


**MR Unsafe:** An item that is known to pose hazards in all MR environments.

1. Expert Panel on MR Safety:, Kanal, E., et al. ACR guidance document on MR safe practices: 2013. *J Magn Reson Imaging*. 2013;37: 501-530.
*2. Designation F2503-05; MR task group of American Society for Testing and Materials (ASTM) International*

# St Jude Protégé, the First and Only Upgradeable SCS System

**Upgradeability**
- Only upgradeable SCS system
- Can be updated without surgical replacement

**Warranty**
- 7 years
- Coverage up to $1,250


**Access to New Features**
- Upgradeable system provides easy access to new technologies once approved

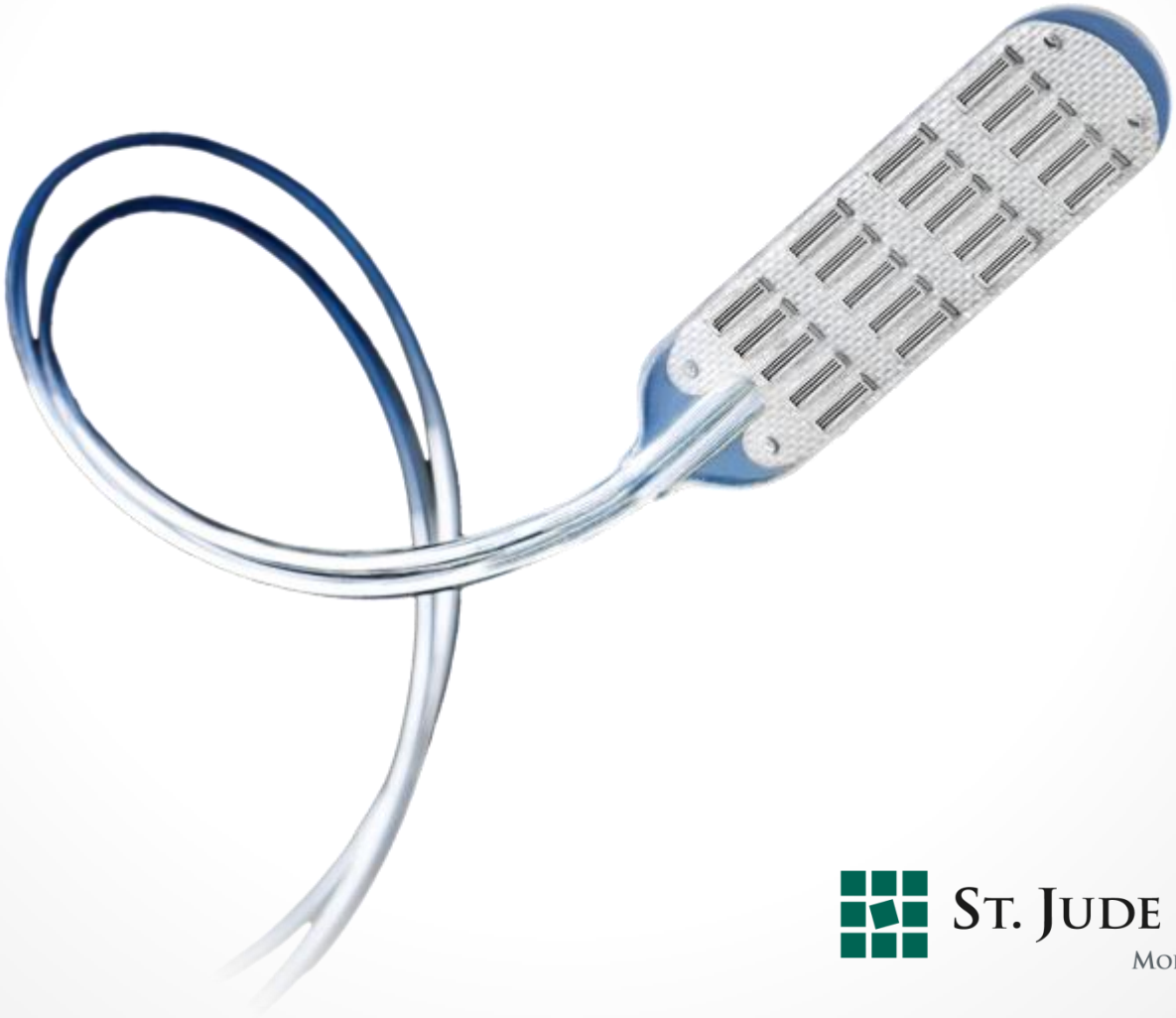
**FDA Approved Potential Battery Life**
- 10 years (high settings) of practical recharge
- No end-of-life shut-off

**Compatibility**
- Compatible with broad portfolio of leads

St. Jude Protégé Implantable Pulse Generator Competitive Sell Sheet. US-2000501 A EN (3/14). Data on file.

# Penta Lead Technology

The world's first and only five-column paddle lead...

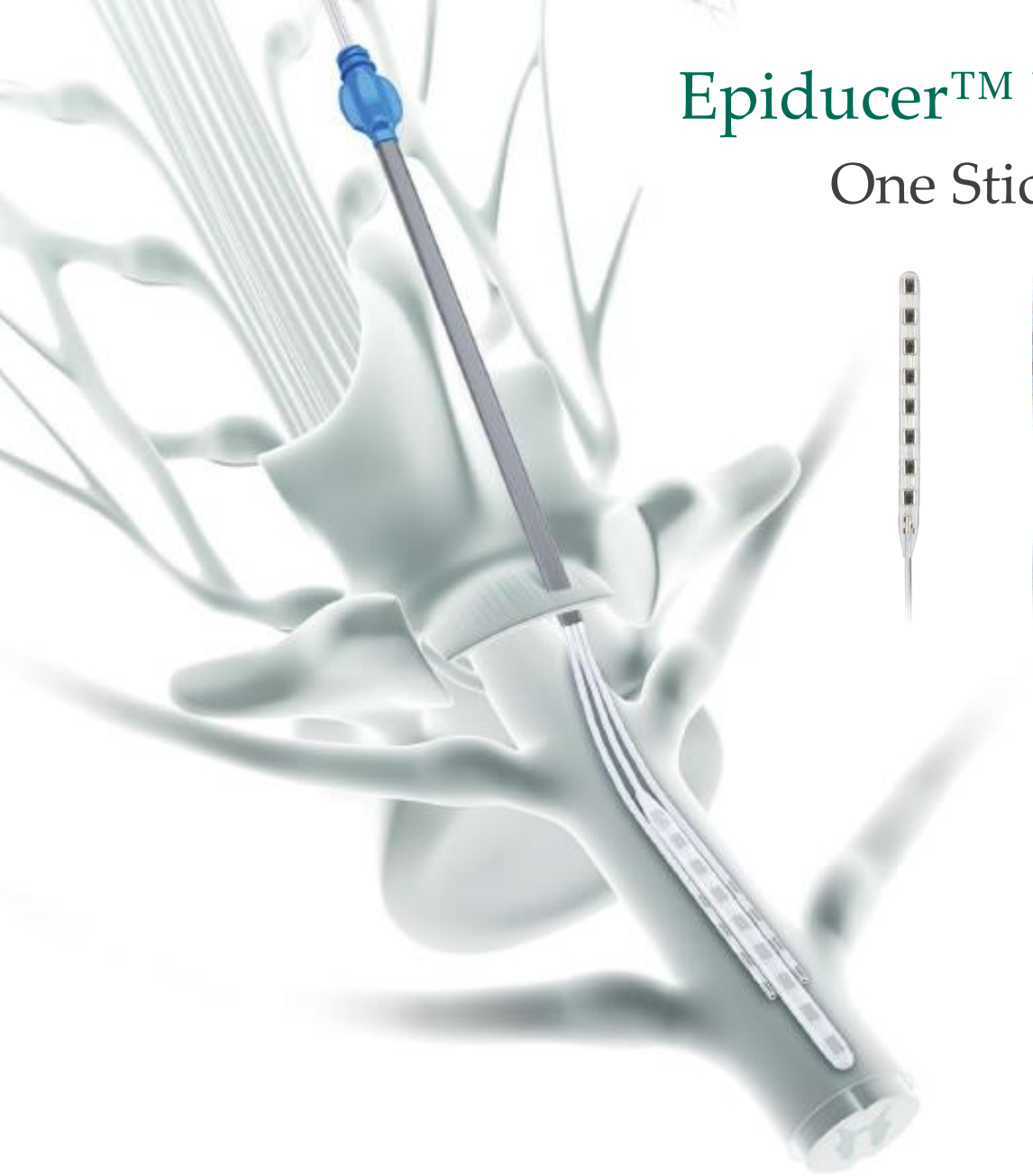


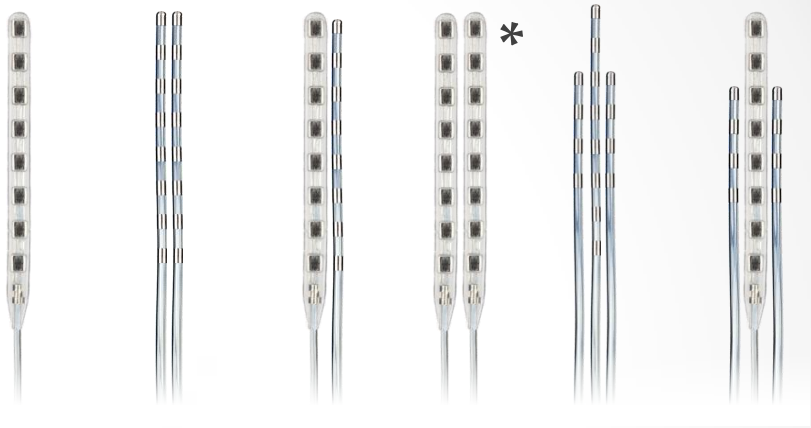
ST. JUDE MEDICAL™

MORE CONTROL. LESS RISK.

# Epiducer™ Lead Delivery System

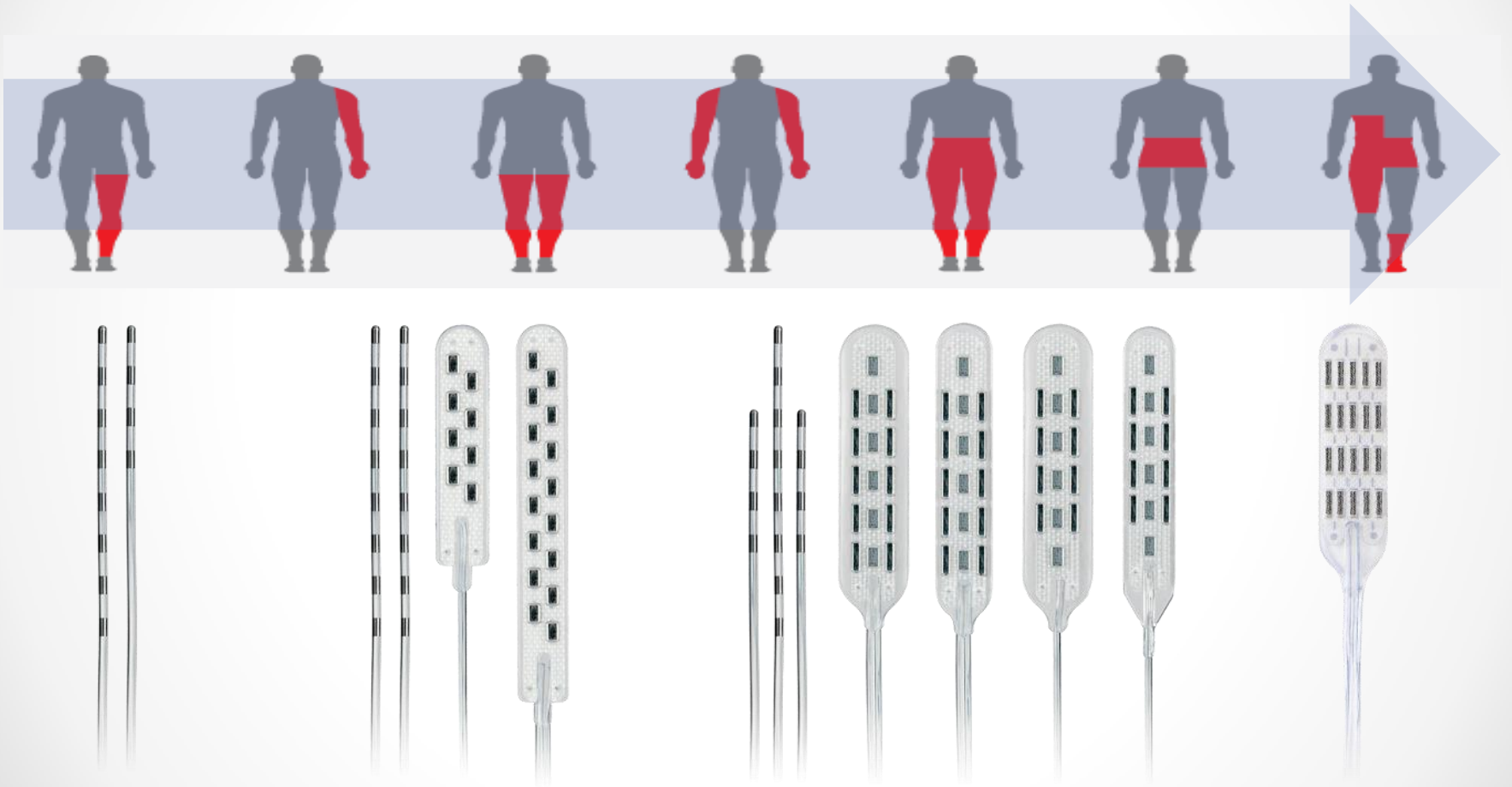
## One Stick. Multiple Options.






*The placement of two S-Series leads will require separate introduction of each lead.

# Lead Options to Cover Pain Patterns



This diagram is a guide only. It is not intended to be a substitute for medical advice.

# Inadequate pain control with tonic SCS trials

- SCS for neuropathic pain is an accepted standard of care in the treatment of chronic pain. However, current solutions may not fully address patients' pre-occupation with pain or other associated psychological factors
- With increasing awareness and quantification, studies now show 20-30% of patients are non-responders*[1,2], with some studies showing even higher rates of failed trials[3].
- Pain control in patients with nociceptive pain remains ineffective[4,5]

*Non-Responders defined as:

i) All failed trials
ii) Permanent cases w/ insufficient pain coverage over time
iii) Complex back pain (severe intensity) inadequately addressed with tonic stimulation


1. Vancamp T, et al. INS 2013
2. Truin M, Janssen SP, van Kelef M, Joosten EA. Eur J Pain. 2011
3. Lad et al, A National Survey of Spinal Cord Stimulation Trial to Permanent Conversion Rates , NANS 2013 poster
4. Raphael et al, Spinal Cord Stimulation and its Anesthetic Implications, Continuing Education in Anesthesia, Critical Care and Pain (CEACCP), Volume 9, No.3, 2009
5. Krames E, Implantable devices for pain control: spinal cord stimulation and intrathecal therapies, Best Pract Res Clin Anaesthesiology 2002 Dec;16(4):619-49.

# Paresthesia is a challenging component of tonic SCS therapy[1]

- Tonic SCS (above perception threshold) relies on the presence of paresthesia in treated limbs to:
  - Deliver pain reduction using Gate theory
  - Validate appropriate lead positioning
- This aspect of the modality has some limitations:
  - Obtaining paresthesia in the lower back can be challenging (despite numerous technical improvements).
  - Changes in body position can significantly modify intensity of paresthesia – requiring frequent adjustments.
  - Substantial minority of patients do not tolerate paresthesia, or prefer not to feel sensation at all.
- **Painful or undesirable paresthesia is a reported reason for failed SCS trials.**

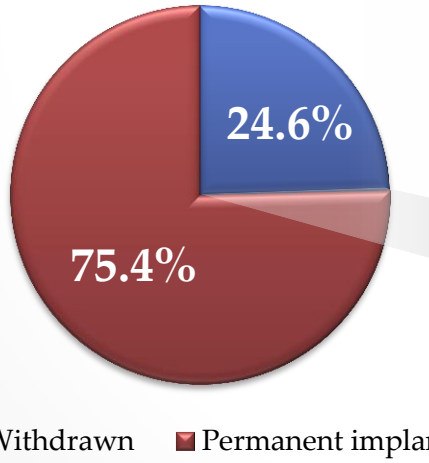


1. Oakley JC, Spinal Cord Stimulation in Axial Low Back Pain: Solving the Dilemma, Pain Medicine, Vol 7, No. S1, 2006

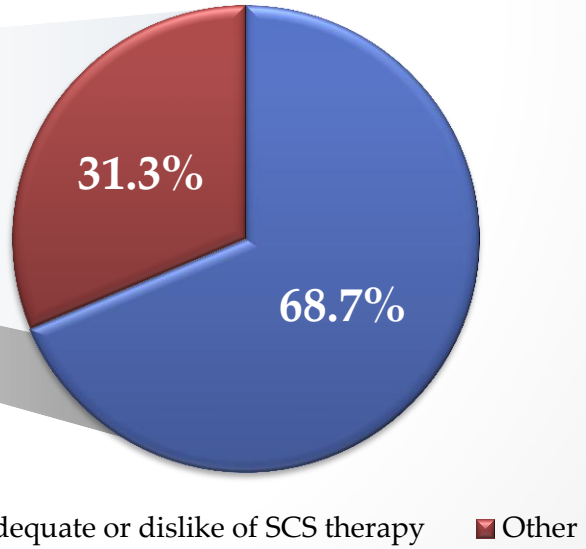
# Inadequate pain control or dislike for SCS therapy are most common reasons for withdrawal after trial period

- Approximately 25% of patients withdraw after the SCS implant trial period[1]
- Approximately 69% of withdrawing patients cited inadequate or dislike for SCS therapy[1]
- In some studies, approximately 15% of patients underwent explantation of SCS systems[2]

**Approximately 25% of patients refuse permanent SCS implants[1]**




**Reasons for refusing permanent SCS implant[1]**




1. Oakley JC, et al. A new spinal cord stimulation system effectively relieves chronic, intractable pain: a multicenter prospective clinical study. Neuromodulation 2007; 10(3): 262-278..
2. Mekhail et al, *Cost Benefit of Neurostimulation for Chronic Pain, Clin f Pain* • Volume 20, Number 6, November/December 2004

# NEUROMODULATION

- A primary goal of neuromodulation and neurostimulation devices is to achieve control over the nervous system in order to alleviate the effects of disease.
- The response of the nerve and muscle to trains of high-frequency AC waveforms was first characterized by Wedensky.
- Known as: Kilohertz frequency alternating current (KHFAC)
- “Wedensky inhibition” : The rapid failure of neuromuscular junction transmission following stimulation at frequencies in excess of 100 Hz

# KHFAC

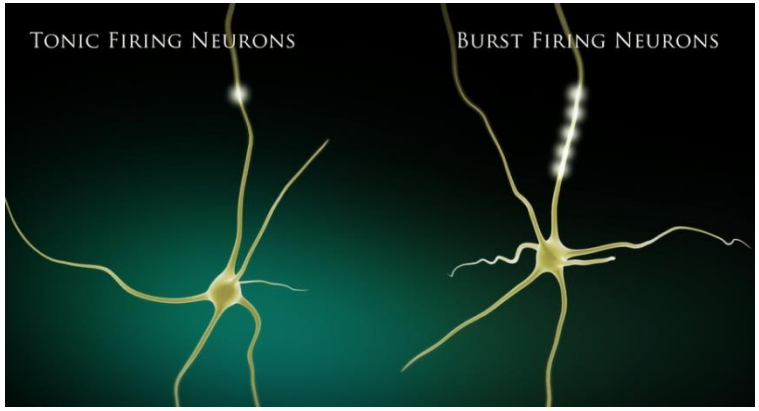
- (i.e., zero net charge delivery) because this method has been shown to produce an extremely rapid block of nerve conduction that is quickly reversible.
- "high-frequency alternating current," is ambiguous and has resulted in some confusion in the literature
- Frequencies as low as 130 Hz have been termed high frequency
- It is important to properly distinguish the specific parameters used for KHFAC block because the characteristic effects on the nerve vary considerably as a function of frequency, amplitude, and electrode design (and possibly other factors as well)
- Highly unlikely to work through skin as surface stimulation

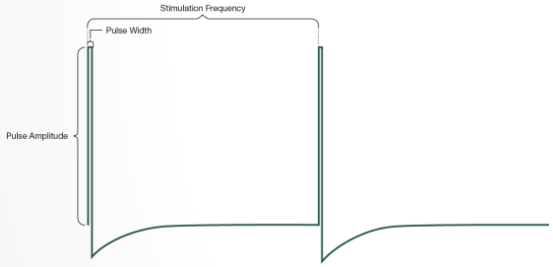
# KHFAC

- The use of the term KHFAC to refer to the use of continuous charge-balanced AC in the frequency range of ~1 to 100 kHz.
- This particular range of frequencies has received the most study in the past few years.
- KHFAC block also should not be confused with the use of brief bursts of electrical stimulation in the kHz frequency range. These bursts, typically delivered at 50 Hz or lower, are used in an attempt to activate tissue more effectively and are not a method of nerve block.

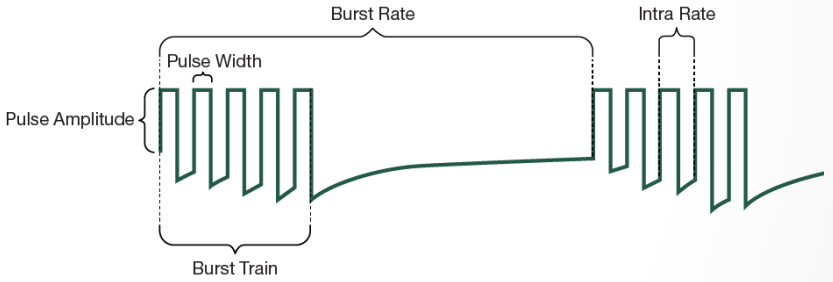
# Understanding BURST stimulation

# Understanding Neuron Types: Tonic




Some neurons fire in a tonic or continuous manner




Other neurons fire in groups of action potentials (bursts) followed by periods of dormancy

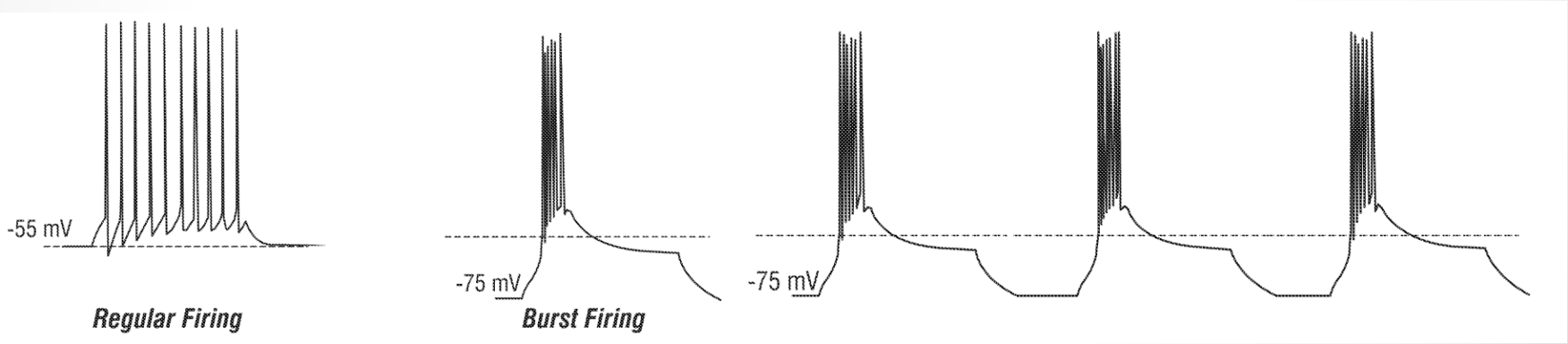
- Both burst & tonic firing neurons may be parallel firing modes within the same sensory system[1]
- Composition of burst & tonic firing neurons varies in the pain pathway thereby creating a need for tailored therapy



1. Oswald AM, et al. J Neurosci. 2004.

# Origins of Burst Stimulation

- Burst is a naturally occurring signaling modality in human physiology and is interpreted differently by the nervous system[1,2,3].
  - e.g. Thalamic cells can fire in tonic and burst modes[1].
- Thalamic burst firing considered a more potent activator of the cortex[2,3]. Ascending action potentials more likely to be routed to the cortex when thalamic cells firing in bursts.





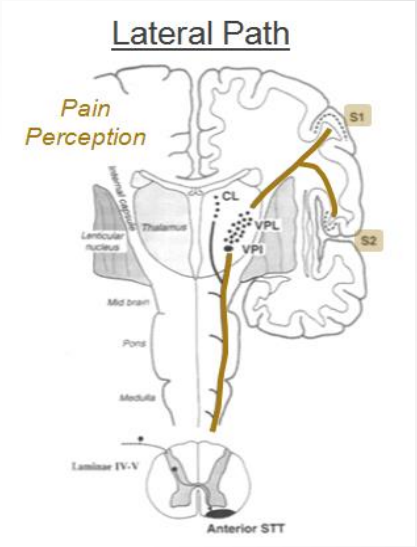
1. Jahnsen H, Llinás R. : Voltage-dependent burst-to-tonic switching of thalamic cell activity: an in vitro study. Arch Ital Biol. 1984 Mar;122(1):73-82.
2. Harvey A. Swadlow & Alexander G. Gusev : The impact of 'bursting' thalamic impulses at a neocortical synapse. Nature Neuroscience 4, 402 - 408 (2001).
3. Sherman SM : A wake-up call from the thalamus. Nature neuroscience, 2001

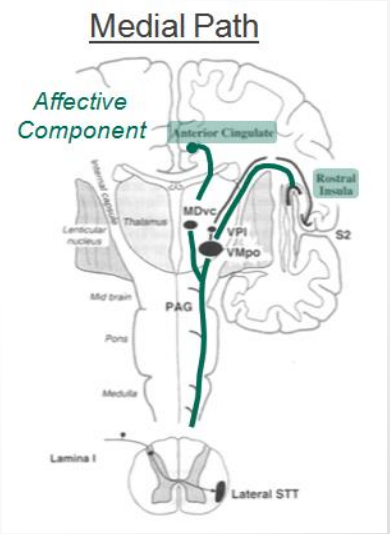
## Current Working Hypothesis:

Burst stimulation may exert its main effect through an ability to modulate

both lateral & medial pathways

- Pain stimuli are likely processed in parallel by two pathways:
- Lateral discriminatory pathway – helps identify the location, type and intensity of pain
  - Hybrid pathway consisting of
    - WDR neurons firing in tonic → PH (lam. 1, 4-6) → Thalamus (VPL, VPM) → 1 & 2 SSC. Predominant triggering neurons in the lateral pathway
    - Low-threshold neurons firing in burst can also be found in the lateral pathway
- Medial affective/attentional pathway – helps drive attention & salience to the pain
  - Nociceptive specific neurons firing in bursts → PH (lam. 1) → Thalamus (MDvc, VMpo) → Anterior Cingulate, Anterior Insula, Amygdala.
  - Fires in bursts[2].

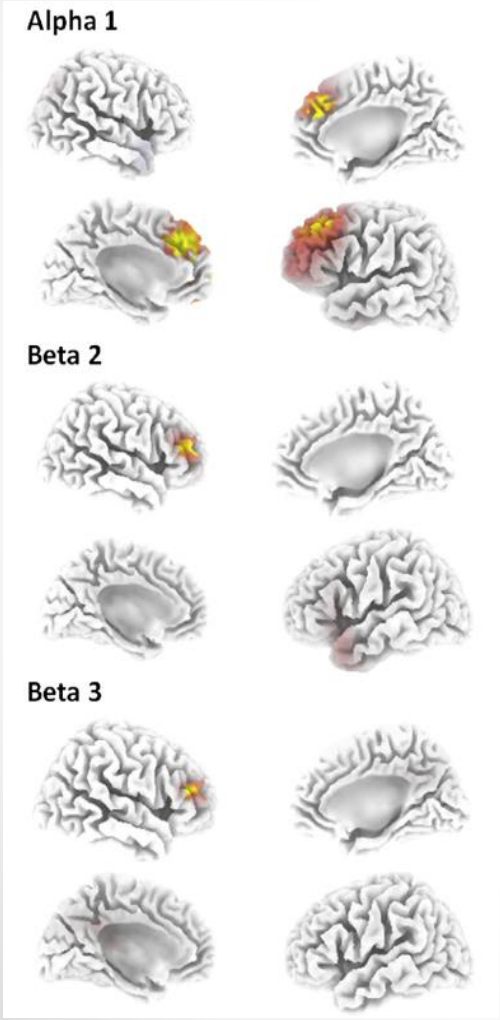




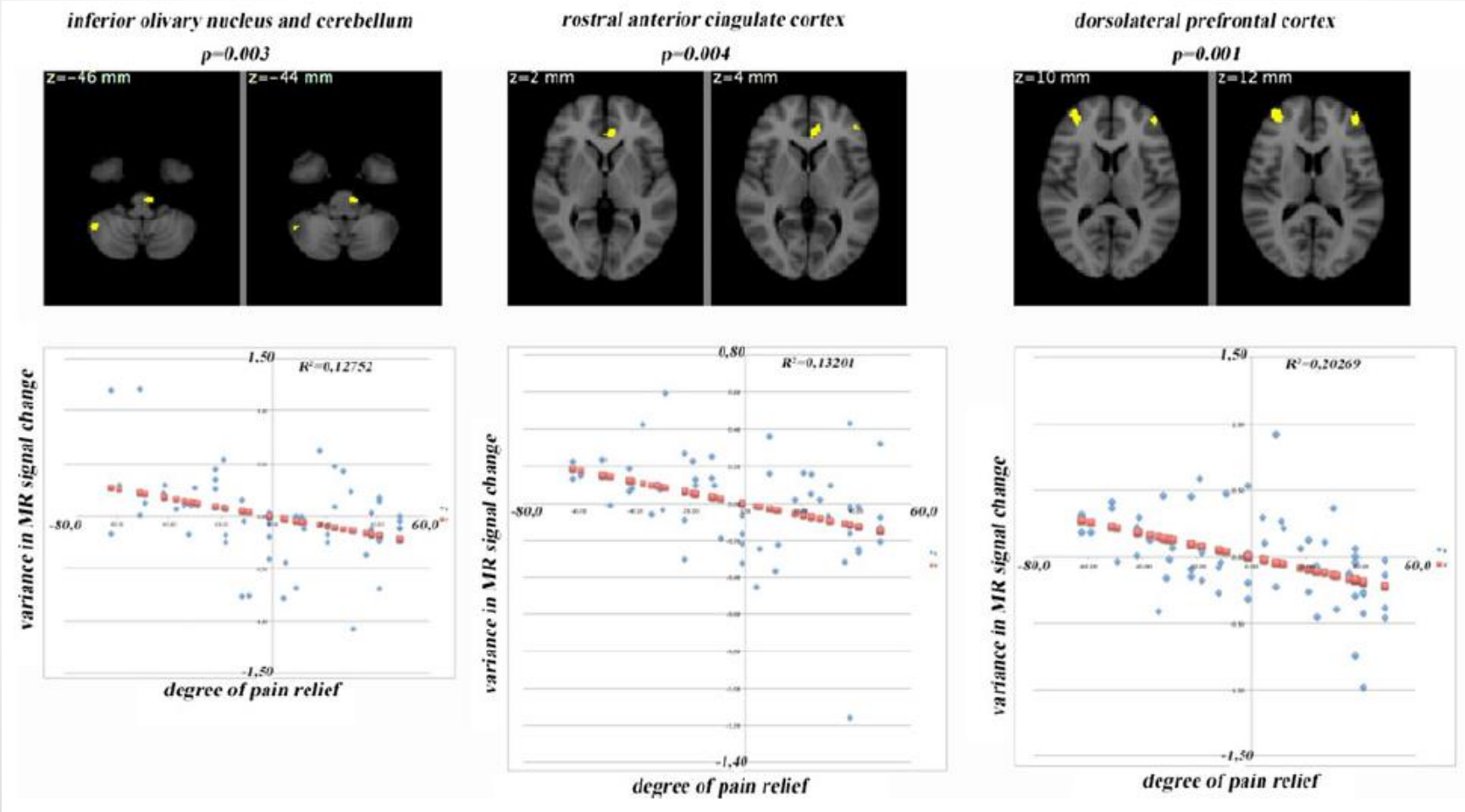
1. De Ridder D, et al. World Neurosurgery 2013.
2. Lopez-Garcia JA, and AE King. Eur J Neuroscience 1994.
3. Larry R. Squire, Darwin Berg, Floyd E. Bloom, Sascha du Lac, Anirvan Ghosh, Nicolas C. Spitzer. Fundamental Neuroscience. 3rd Edition, Chapter 25: Somatosensory System, Academic Press (Elsevier), p. 599,2008.

# Source-localized EEG supports significantly more alpha activity in medial pathway




In a subgroup of 5 patients in De Ridder's study, burst stimulation showed more alpha activity in the dorsal anterior cingulate in comparison with tonic, placebo, and baseline.

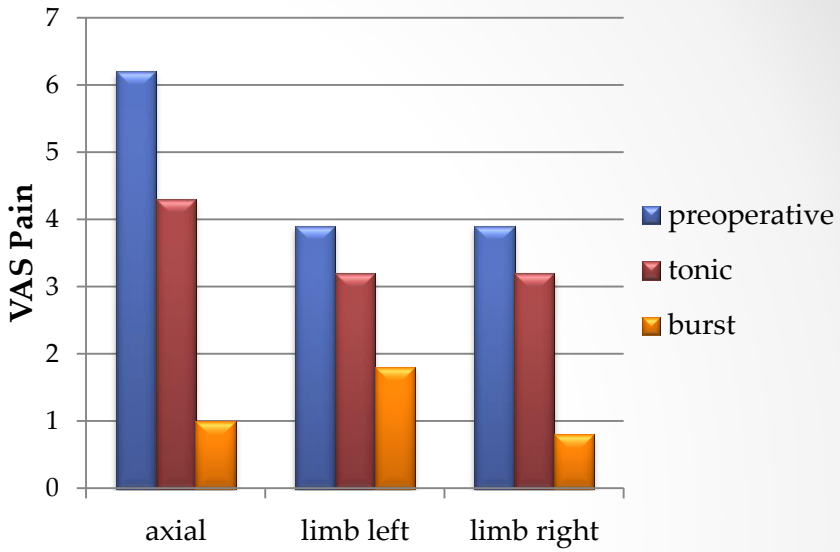
# fMRI study suggests thalamus and ACC are responsive to SCS stimulation and modulating pain perception

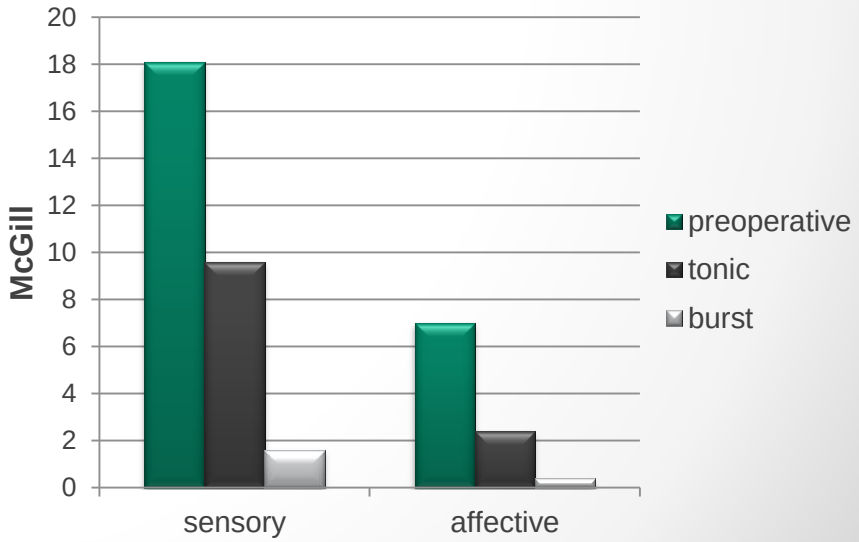



Moens M, et al. Neuroradiology 2012.

# Burst Stimulation suppressed pain with no paresthesia reported in 83% of tested patients

- First study to report on Burst Stimulation for suppression of neuropathic pain (n=12).
  - All patients underwent implantation of SJM Lamitrode™ paddle lead and Eon™ IPG
  - Average follow-up time of 20.5 months
- Key takeaways:
  - 17% of patients experienced parasthesia following burst stimulation vs. 92% of patients following tonic stimulation
  - Burst stimulation resulted in a significant improvement of 7.29 VAS points post-operatively for limb pain ($p < 0.001$)
  - Burst stimulation also resulted in significant improvement on the McGill Short Form, 16.73 points from pre-operative experience ($p<0.001$)
  - No complications or adverse events reported



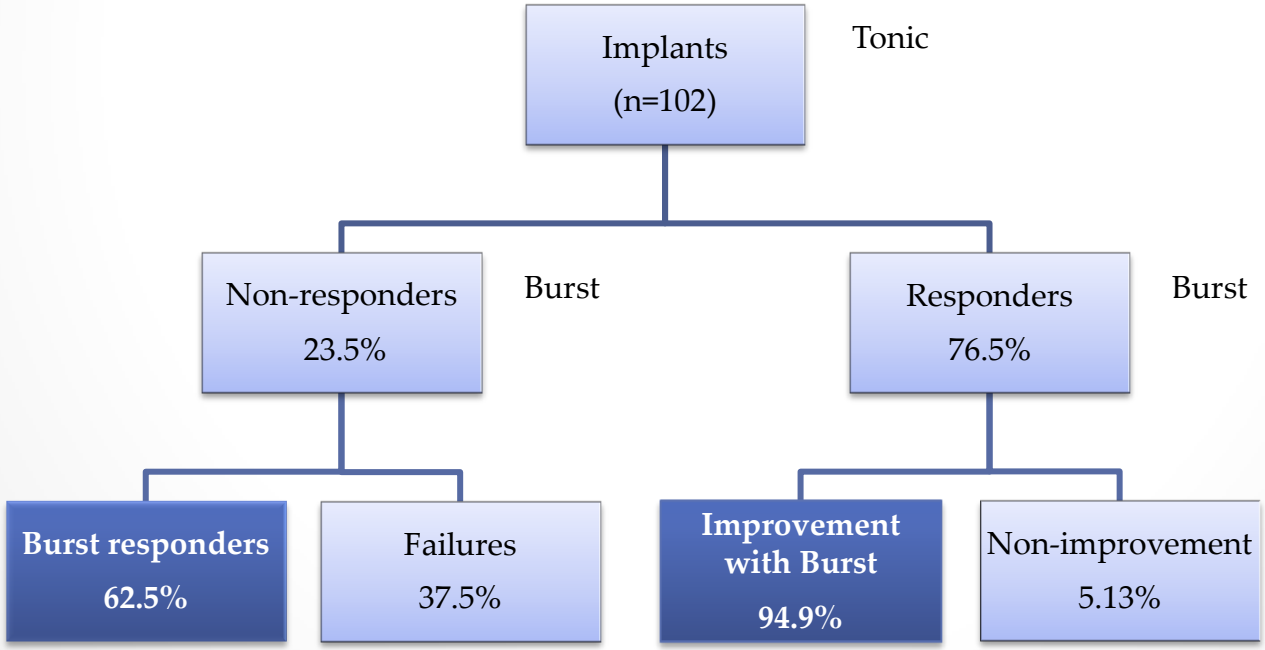






De Ridder D et al. Neurosurgery 2010.

# Burst stimulation may salvage non-responders and improve response in tonic SCS responders

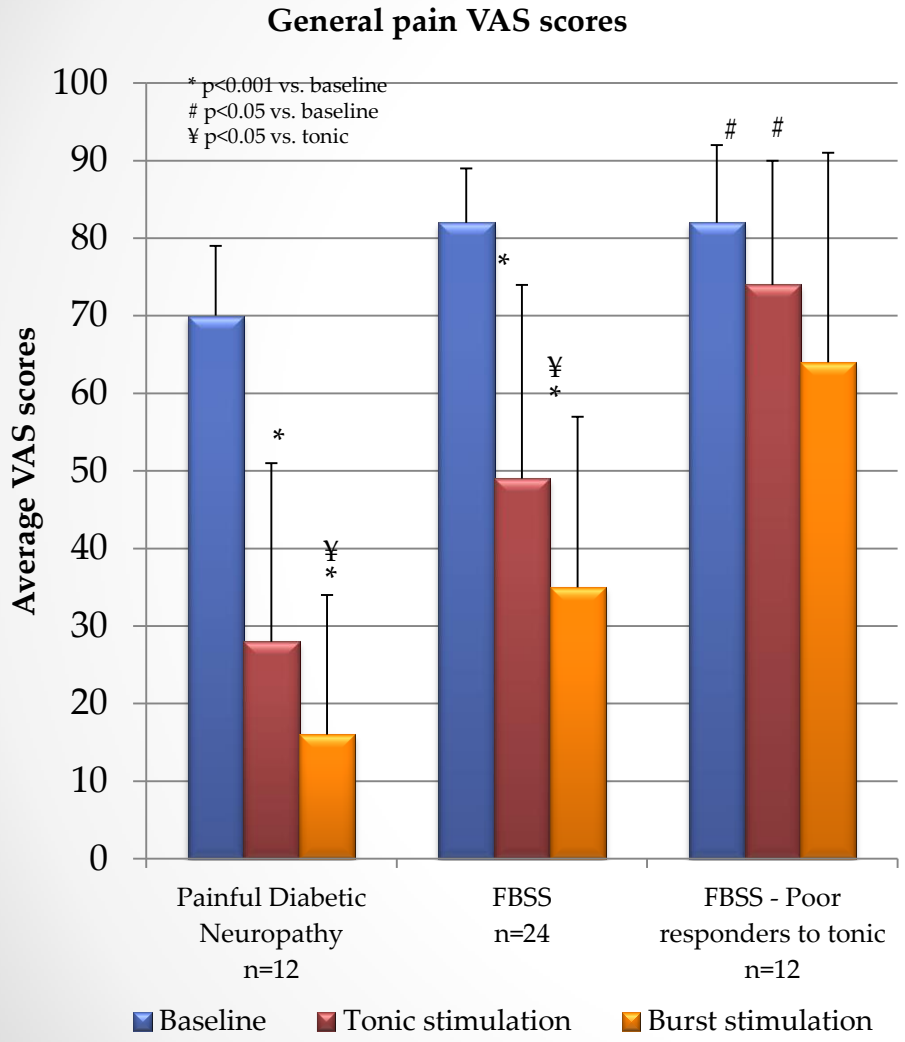
- 102 patients at 2 centers
- 23.5% of patients did not respond to tonic SCS therapy
- 62.5% of chronic non-responders to tonic SCS responded to Burst stimulation
- 94.9% of chronic responders to tonic SCS had further improvement to response rate with Burst stimulation






1. Vancamp T, et al. INS 2013

# Burst stimulation provides further pain relief in patients first treated with tonic stimulation

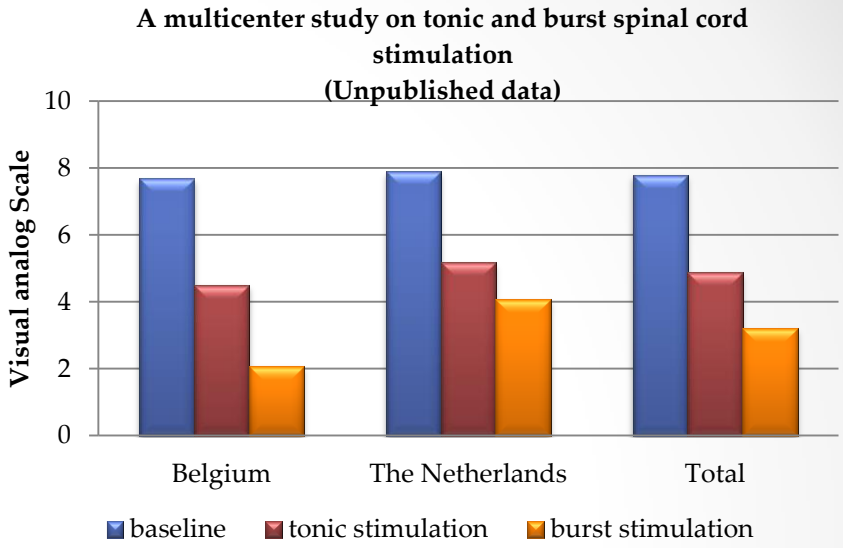


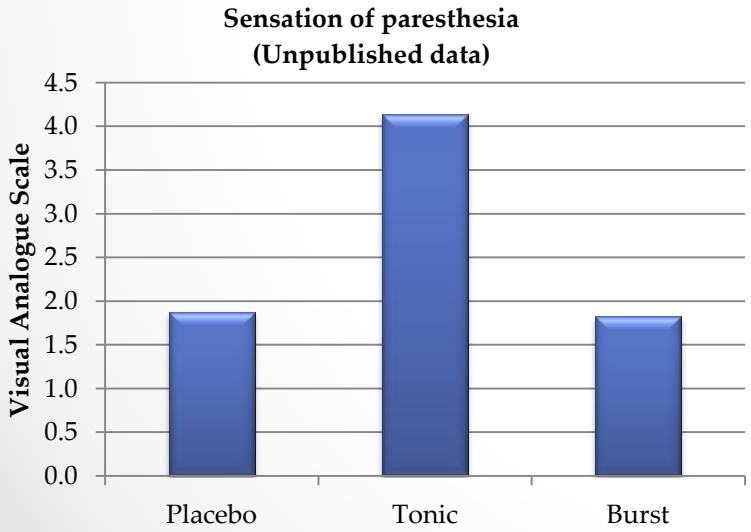

- Compared to baseline, burst stimulation resulted in:
  - 77% reduction in VAS scores in diabetic neuropathy patients
  - 57% reduction in VAS scores in failed back syndrome (FBSS) patients
  - 23% reduction in VAS scores in FBSS patients who were poor responders over time to tonic stimulation
- In comparison to tonic stimulation, about 60% of patients experienced further pain reduction when burst stimulation was applied

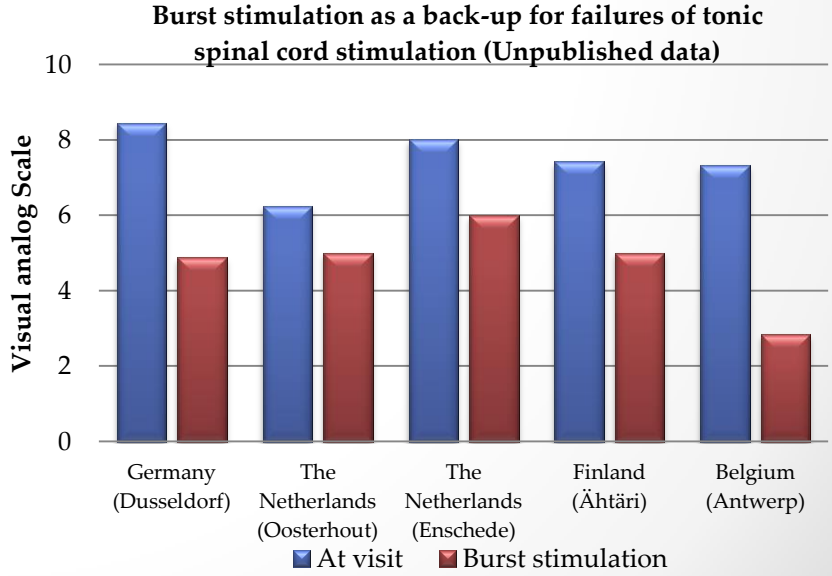
de Vos CC, et al. Neuromodulation 2013.

# Ongoing Clinical Experience[1]

- 200+ patients at 9 centers utilizing modified SJM Eon Mini™ rechargeable IPG
- Burst Stimulation compares favorably to tonic and may even rescue some tonic failures
  - 95% of Tonic responders have greater pain relief with Burst Stimulation™
  - 60%-80% of Tonic non-responders respond to Burst Stimulation™ thereby reducing therapy failures.
- Paresthesia is minimized with burst stimulation.



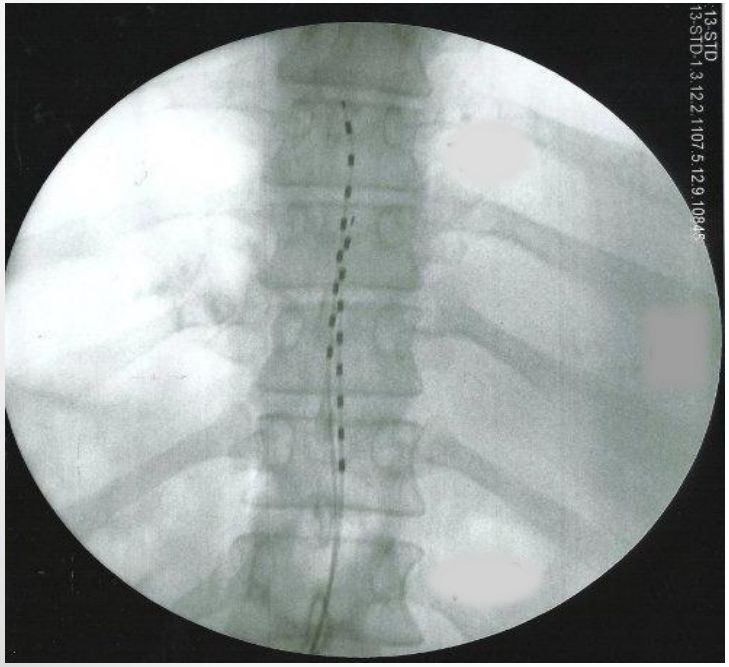






1 – Data on file

# Lack of Paresthesia Simplifies Procedure

- Conventional SCS requires intraoperative paresthesia mapping
  - Potentially uncomfortable for patient, frequent adjustments
  - Can lead to wide range in procedure times



HF-10 SCS Lead Positioning:

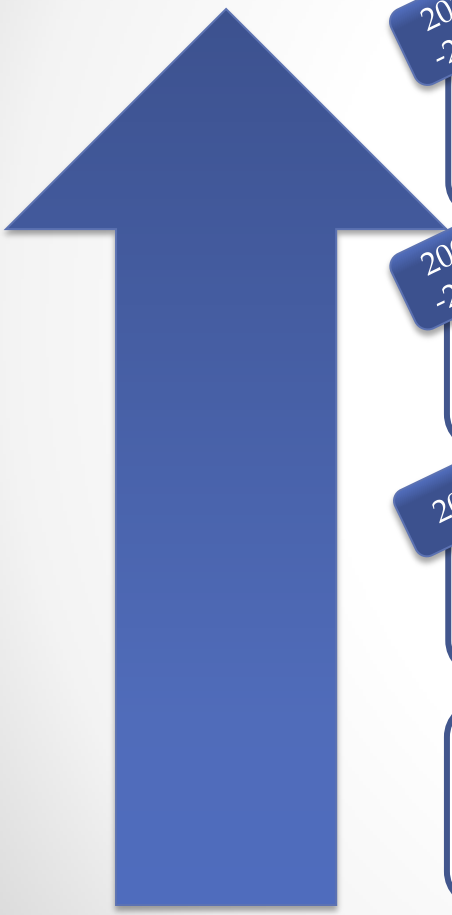
- No paresthesia mapping
- Anatomically positioned
- Overlapping leads along midline

→ Shorter, predictable procedure times

# HF10 SCS

- HF10™ SCS: 10 kHz High-Frequency SCS Therapy
- Commercial Availability: Europe & Australia
- Device: Senza® SCS system
  - Pulse rate up to 10 kHz
  - Rechargeable: 10 year battery life labeling
  - Daily recharge of ~45 min
  - Charger, patient controller, programmer similar to traditional SCS
- Patients treated: >2,500

# Evidence Building Strategy



2012 -2014

**US RCT**

- Multicenter, prospective, randomized study
- Comparison of HF10 SCS to traditional SCS
- Enrollment completed in March 2013 (241 patients)

2009 -2013

**EU Multicenter Study**

- Single arm, open label study
- 2 centers, 83 patients
- Demonstrated long-term safety and efficacy

2008

**US Pilot Study**

- 5 centers, 24 patients, acute follow-up
- Evidenced safety and efficacy in humans

**Pre-Clinical**

- Multiple animal models
- Evidenced proof of concept & safety

# Peer-Reviewed Publications

Neuromodulation: Technology at the Neural Interface

Received: July 23, 2012 Revised: October 24, 2012 Accepted: November 6, 2012

(onlinelibrary.wiley.com) DOI: 10.1111/ner.12015

## Effect of High-Frequency Alternating Current on Spinal Afferent Nociceptive Transmission

Jason M. Cuellar, MD, PhD*, Konstantinos Alataris, PhD†, Andre Walker, MSEE†, David C. Yeomans, PhD‡, Joseph F. Antognini, MD§

Neuromodulation: Technology at the Neural Interface

Received: April 27, 2012 Revised: October 20, 2012 Accepted: January 3, 2013

(onlinelibrary.wiley.com) DOI: 10.1111/ner.12032

## Novel Spinal Cord Stimulation Parameters in Patients with Predominant Back Pain

Jeffrey Tiede, MD*; Lora Brown, MD†; Gennady Gekht, MD†; Ricardo Vallejo, MD‡; Thomas Yearwood, MD, PhD§; Donna Morgan, MD¶

Neuromodulation: Technology at the Neural Interface

Received: May 16, 2012 Revised: July 30, 2012 Accepted: October 11, 2012

(onlinelibrary.wiley.com) DOI: 10.1111/ner.12006

## High-Frequency Spinal Cord Stimulation for the Treatment of Chronic Back Pain Patients: Results of a Prospective Multicenter European Clinical Study

Jean-Pierre Van Buyten, MD†*, Adnan Al-Kaisy, MD††, Iris Smet, MD*, Stefano Palmisani, MD†, Thomas Smith, MD†

**Objective:** The objective of this prospective, open-label, multicenter European clinical trial was to quantify the efficacy and safety of a spinal cord stimulation (SCS) system that utilizes high-frequency (up to 10 kHz) waveforms, which do not produce paresthesia, for the treatment of chronic, intractable pain of the back and/or limbs.

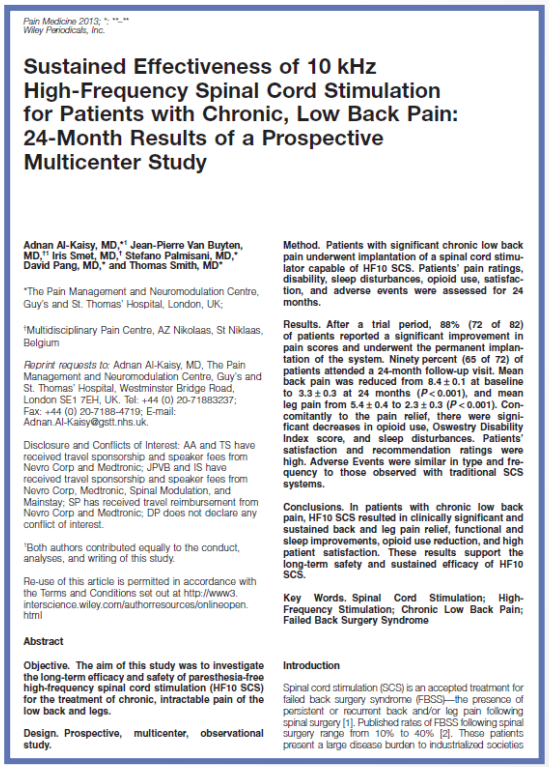
**Material and Methods:** Eighty-three patients, with significant back pain, were recruited for a trial of high-frequency stimulation through two percutaneous eight-contact epidural leads. Patients' pain ratings, disability, sleep disturbances, and satisfaction, as well as complication rates, were assessed for up to six months.

**Results:** After a trial period, 88% (72 out of 82) of patients reported a significant improvement in visual analog scale (VAS) scores and underwent permanent implantation of the high-frequency SCS system. Mean back pain VAS of 8.4 was reduced to 2.7 at six months ($p < 0.001$). Mean leg pain VAS of 5.4 was reduced to 1.4 at six months ($p < 0.001$). Seventy-four percent of patients had greater than 50% back pain relief at six months. There were significant improvements in Oswestry disability score and sleep, and reductions in pain medication use. Adverse events observed were those seen with conventional SCS therapy—lead migration, wound infection, and pain around implant site.

**Conclusions:** In a cohort of patients with difficult-to-treat chronic back pain, high-frequency SCS provided significant and sustained low back pain and leg pain relief to more than 70% of treated subjects. Notably, this was achieved without paresthesia. Patients also experienced significant improvement in disability and sleep. Overall, the results confirm a favorable safety and efficacy profile of the high-frequency SCS system.

**Keywords:** axial back pain, failed back surgery syndrome, high-frequency stimulation, low back pain, spinal cord stimulation

**Conflict of Interest:** Drs. Van Buyten, Al-Kaisy, and Smet received fees related to the presentation of study results at scientific congresses from Nevro Corp. The other authors reported no conflicts of interest.



*Pain Medicine 2013; *: **–***
*Wiley Periodicals, Inc.*

## 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

**Adnan Al-Kaisy, MD,*† Jean-Pierre Van Buyten, MD,†‡ Iris Smet, MD,† Stefano Palmisani, MD,* David Pang, MD,* and Thomas Smith, MD***

*The Pain Management and Neuromodulation Centre, Guy's and St. Thomas' Hospital, London, UK;

†Multidisciplinary Pain Centre, AZ Nikolaas, St Niklaas, Belgium

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Disclosure and Conflicts of Interest: AA and TS have received travel sponsorship and speaker fees from Nevro Corp and Medtronic, JPVB and IS have received travel sponsorship and speaker fees from Nevro Corp, Medtronic, Spinal Modulation, and Mainstay; SP has received travel reimbursement from Nevro Corp and Medtronic; DP does not declare any conflict of interest.

†Both authors contributed equally to the conduct, analyses, and writing of this study.



**Abstract**

**Objective. The aim of this study was to investigate the long-term efficacy and safety of paresthesia-free high-frequency spinal cord stimulation (HF10 SCS) for the treatment of chronic, intractable pain of the low back and legs.**

**Design. Prospective, multicenter, observational study.**

**Method. Patients with significant chronic low back pain underwent implantation of a spinal cord stimulator capable of HF10 SCS. Patients' pain ratings, disability, sleep disturbances, opioid use, satisfaction, and adverse events were assessed for 24 months.**

**Results. After a trial period, 88% (72 of 82) of patients reported a significant improvement in pain scores and underwent the permanent implantation of the system. Ninety percent (65 of 72) of patients attended a 24-month follow-up visit. Mean back pain was reduced from 8.4 ± 0.1 at baseline to 3.3 ± 0.3 at 24 months ($P < 0.001$), and mean leg pain from 5.4 ± 0.4 to 2.3 ± 0.3 ($P < 0.001$). Concomitantly to the pain relief, there were significant decreases in opioid use, Oswestry Disability Index score, and sleep disturbances. Patients' satisfaction and recommendation ratings were high. Adverse Events were similar in type and frequency to those observed with traditional SCS systems.**

**Conclusions. In patients with chronic low back pain, HF10 SCS resulted in clinically significant and sustained back and leg pain relief, functional and sleep improvements, opioid use reduction, and high patient satisfaction. These results support the long-term safety and sustained efficacy of HF10 SCS.**

**Key Words. Spinal Cord Stimulation; High-Frequency Stimulation; Chronic Low Back Pain; Failed Back Surgery Syndrome**

**Introduction**

Spinal cord stimulation (SCS) is an accepted treatment for failed back surgery syndrome (FBSS)—the presence of persistent or recurrent back and/or leg pain following spinal surgery [1]. Published rates of FBSS following spinal surgery range from 10% to 40% [2]. These patients present a large disease burden to industrialized societies

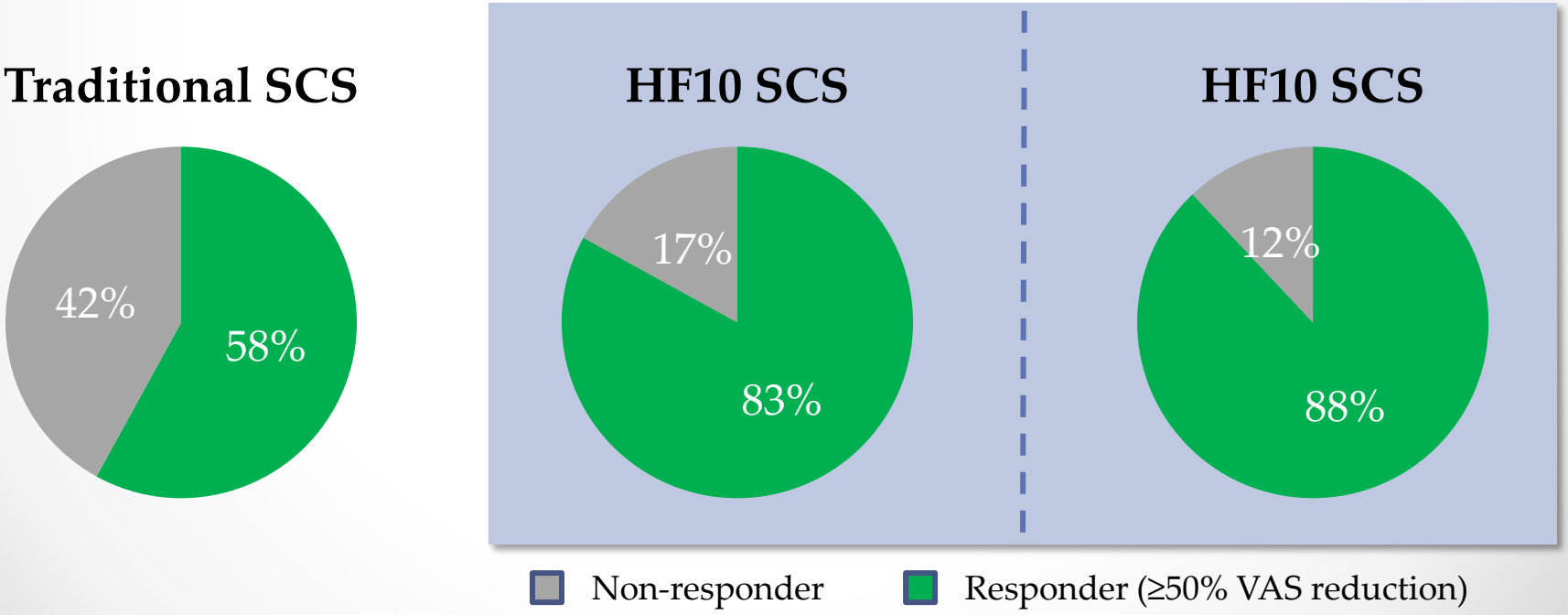
# High Trial Success Rate

**24-Patient Study**
**[Tiede et al. 2013]**

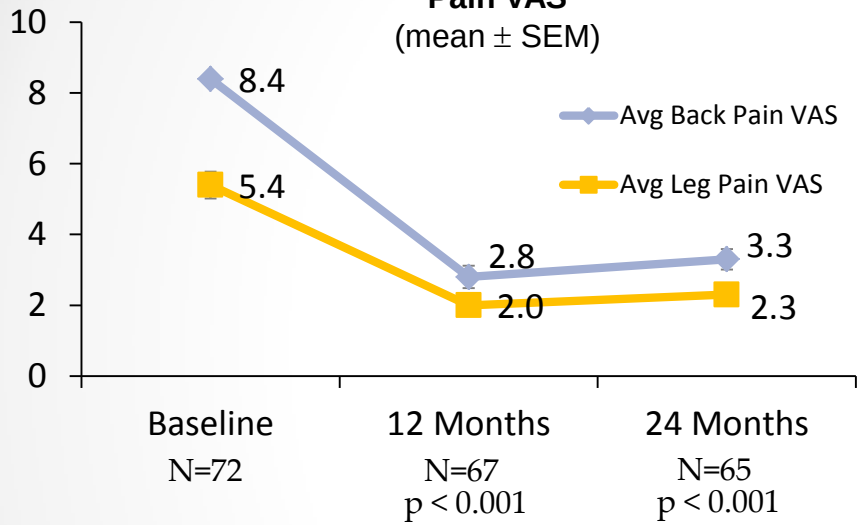
- Serial trial phases: Traditional SCS, then HF10 SCS
- Baseline Back VAS: 8.1

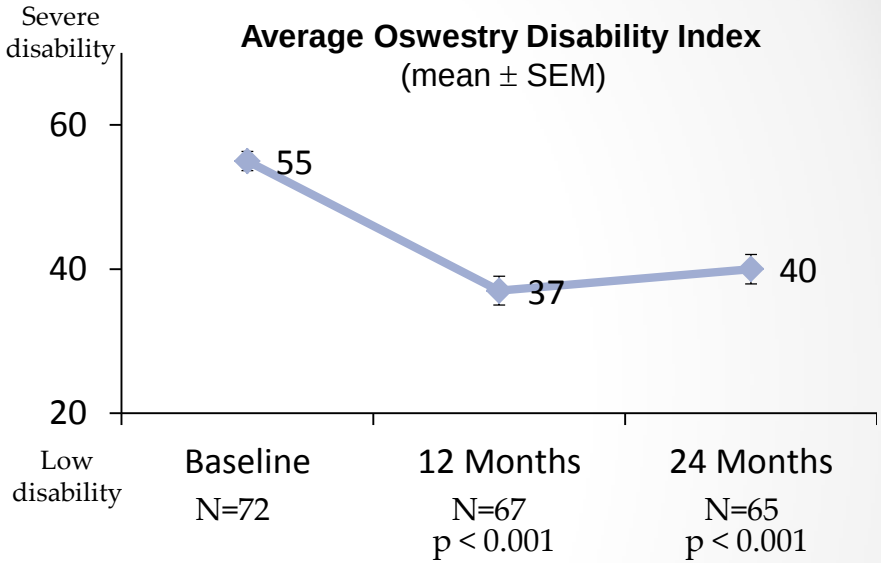
**82-Patient Study**
**[Van Buyten et al., 2013]**

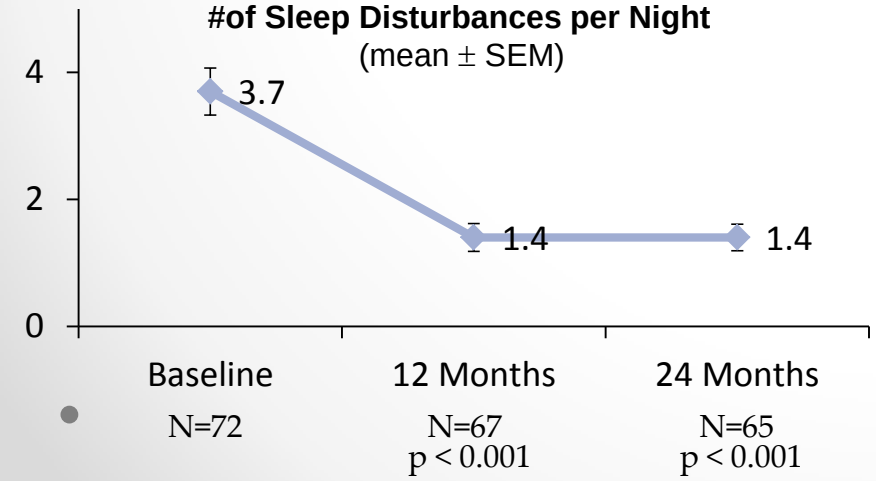
- Long-term f/u study
- Baseline Back VAS : 8.4

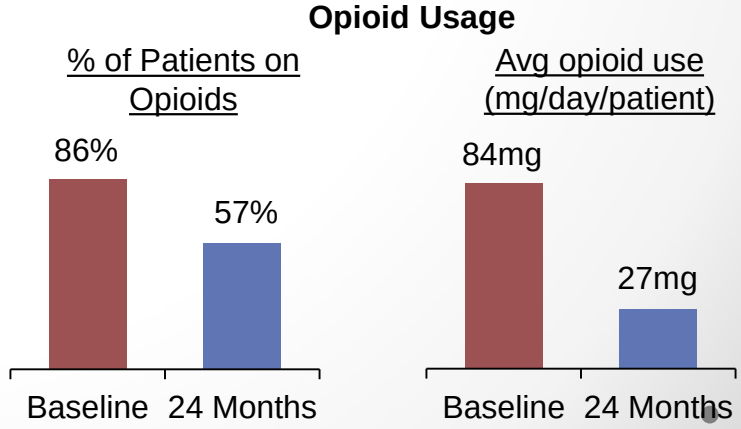


# Significant & Sustained Results



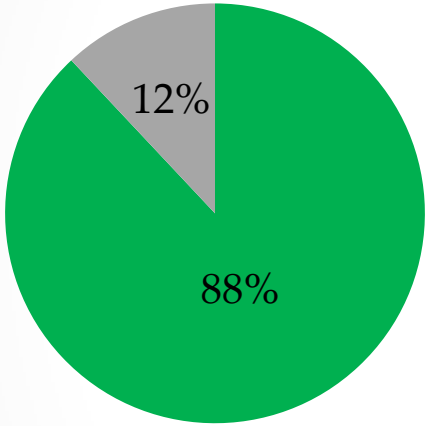



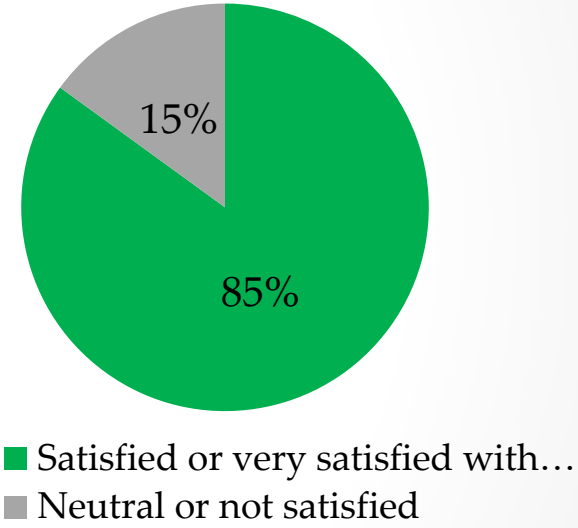

[1]Al-Kaisy, Van Buyten, Smet et al. Pain Medicine 2013

# High Level of Patient Preference & Satisfaction

*24-patient study* [1]




*82-patient study* [2]

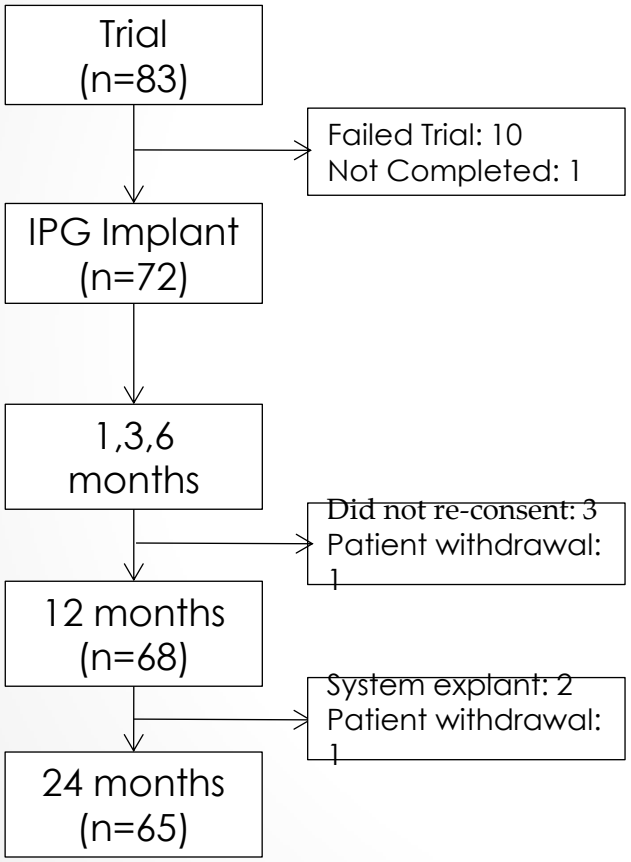



**Primary factors likely driving these results**

- Significant back and leg pain relief
- Paresthesia-free therapy → no posture-dependent uncomfortable stim

[1] *Tiede et al. 2013,* [2] *Van Buyten et al. 2013*

# European Prospective Multicenter Study




Key Inclusion Criterion:

VAS back pain score $\geq$ 5 out of 10

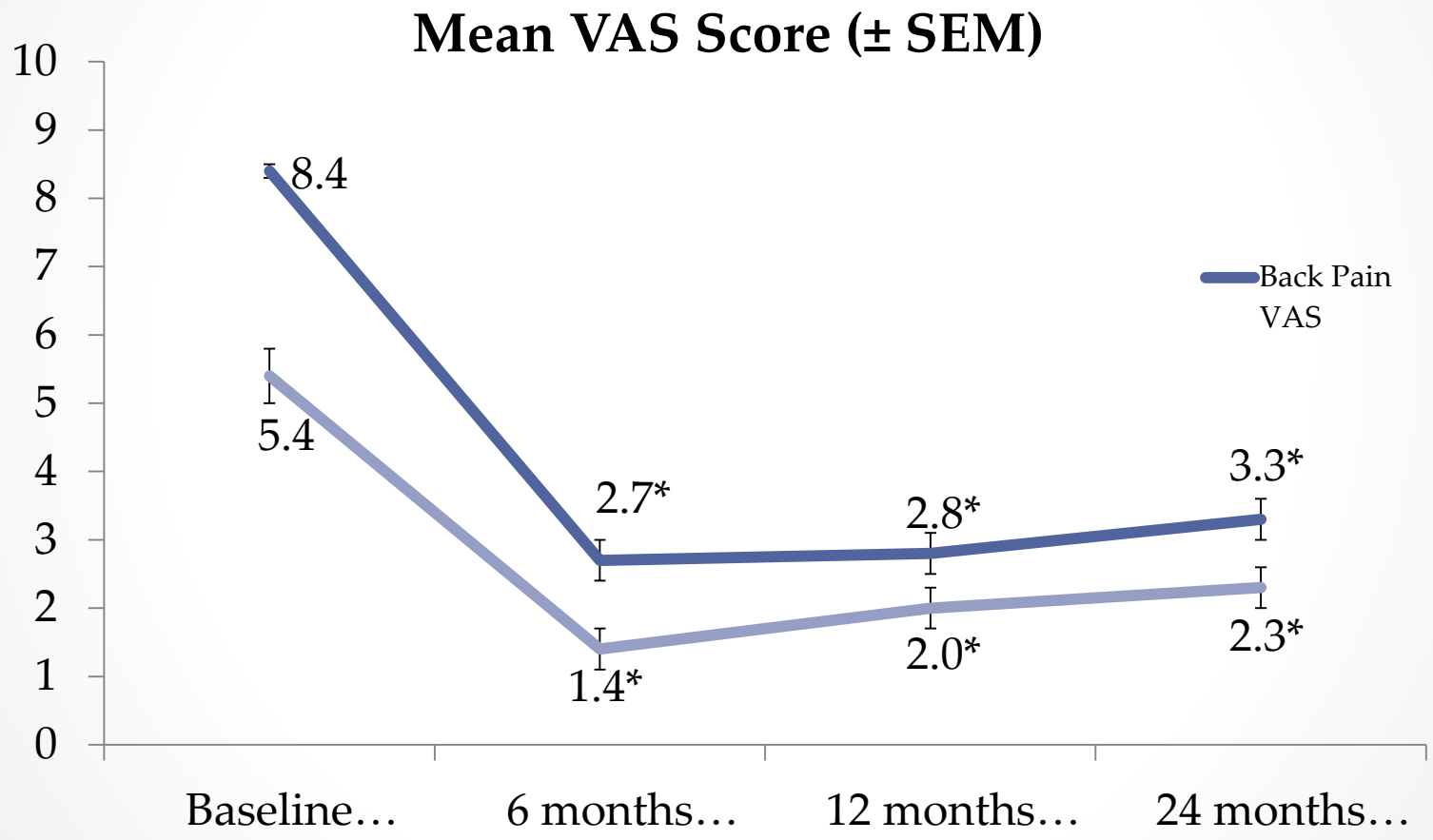
Key Exclusion Criterion:

Standard SCS contra-indications

Key Measured Outcomes:

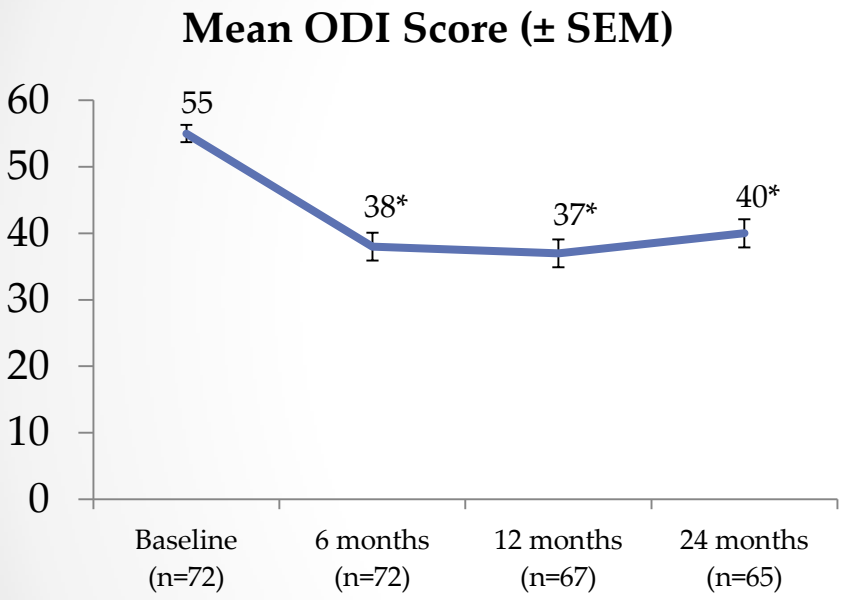
- Pain relief using Visual Analog Scale (VAS)
- Improvements in functional capacity (Oswestry Disability Index - ODI)
- Improvement in sleep quality using the number of sleep disturbances per night
- Reduction in opioid intake
- Device-related Serious Adverse Events

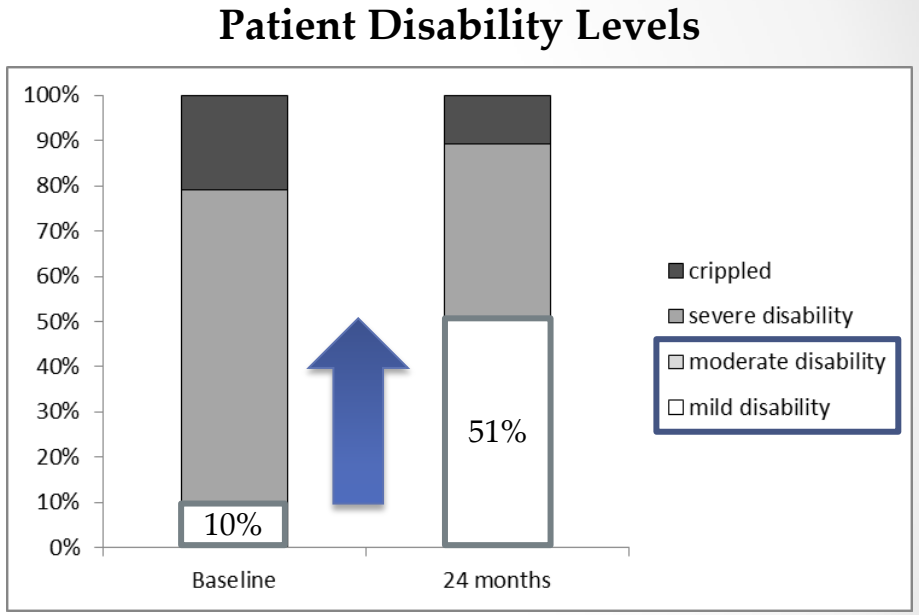
# Significant and Durable Pain Relief




* p-value < 0.001 compared to baseline

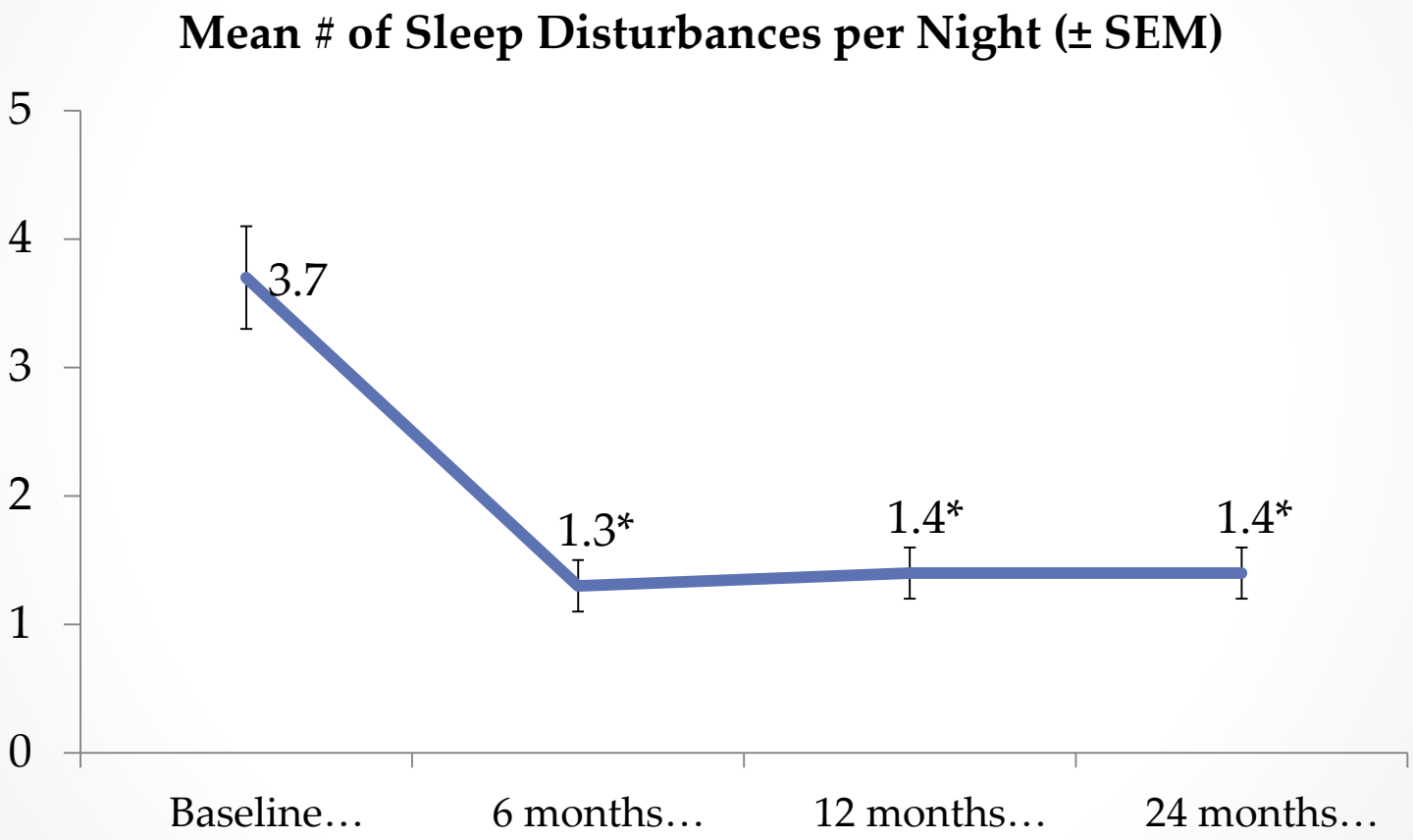
# Improved Function



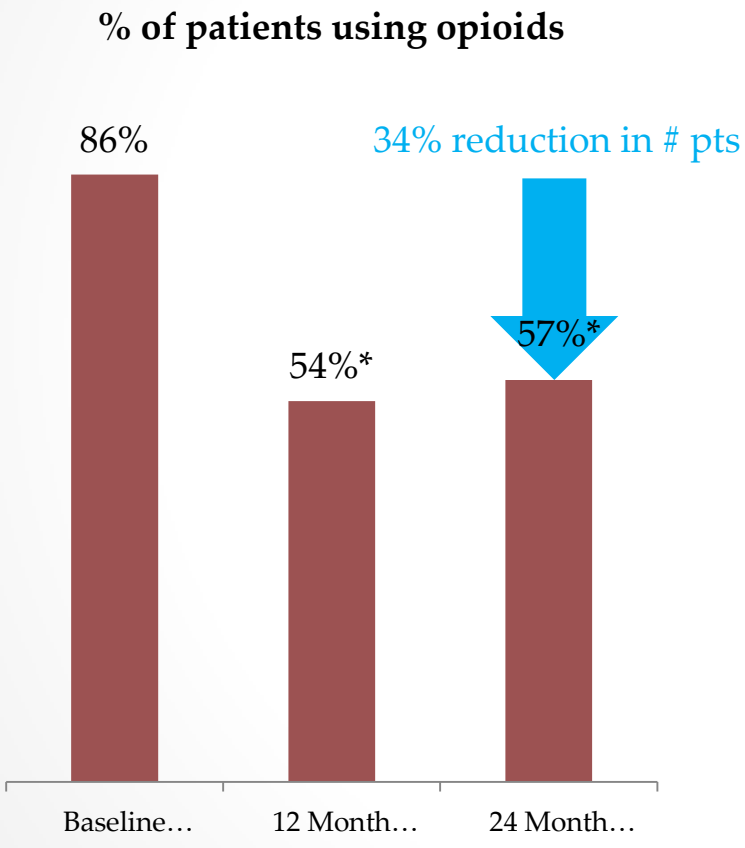

* p-value < 0.001 compared to baseline

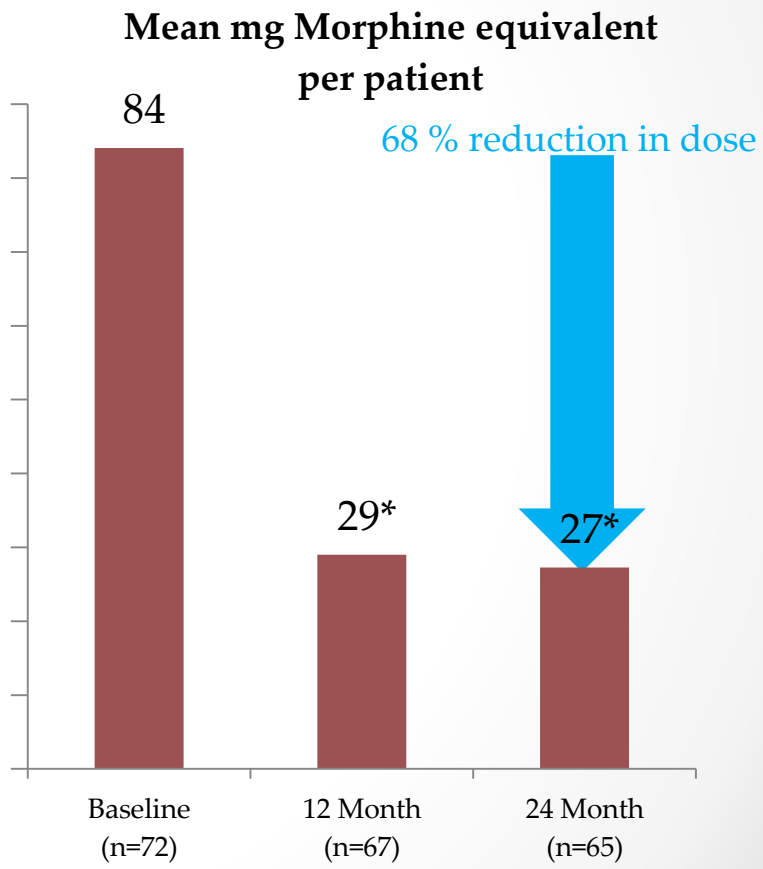
# Improved Sleep Quality




* p-value < 0.001 compared to baseline

# Decreased Opioid Use




* p-value < 0.001 compared to baseline

# US Pivotal Study on HF10 Therapy

Comparison of Senza to Commercial Spinal Cord Stimulation for the Treatment of Chronic Pain (SENZA-RCT):

- Multicenter, prospective, randomized, controlled trial comparing HF10 SCS with traditional SCS system
- Patients with intractable pain of the trunk and/or limbs

Status :

- 241 patients enrolled in 7 months at 11 US centers
- Follow-up ongoing

# CONCLUSION

- "The fact remains that this (Van Buyten et al) is a remarkable trial, which has already had stimulating effects in the field of spinal cord stimulation. . .Yet the superiority of the therapy remains to be demonstrated and the reader should remember that uncontrolled studies unavoidably embellish the results."
- - Eric Buchser, MD
- Lousanne, Switzerland