Spinal cord stimulation for chronic pain

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Mechanism

Implantation: Electrodes are placed in the epidural space near the spinal cord and connected to a pulse generator implanted under the skin. Electrical Impulses: These impulses modulate pain signals, reducing the perception of pain.

Indications

Spinal cord stimulation (SCS) is a well-established treatment option in the multidisciplinary approach to chronic back and leg pain. Nevertheless, careful patient selection remains crucial to provide the most optimal treatment and prevent treatment failure.

The most common SCS application is for the relief of neuropathic leg pain.

Possible indications include:

1. diabetic neuropathy

2. refractory angina pectoris

3. postthoracotomy pain (intercostal neuralgia)

4. postherpetic neuralgia

5. painful limb ischemia from inoperable peripheral vascular disease

6. functional: spastic hemiparesis, dystonia, bladder dysfunction

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see Spinal cord stimulation for failed back surgery syndrome.

see Spinal cord stimulation for complex regional pain syndrome treatment

Benefits

Significant reduction in pain. Improved quality of life and functional ability. Reduction in the need for pain medications.

Procedure

Trial Period: A temporary system is implanted to test effectiveness. Permanent Implantation: If the trial is successful, a permanent device is implanted.

Risks and Considerations

Infection, bleeding, or nerve damage. Device malfunction or need for reprogramming. Not suitable for everyone, and effectiveness varies. Outcome:

Many patients experience substantial pain relief and improved function. Regular follow-up is necessary to ensure the device is working correctly and adjust settings if needed. Spinal Cord Stimulation is a valuable option for managing chronic pain, offering hope for those who have exhausted other treatments.

Spinal cord stimulation (SCS) is an established therapy for refractory neuropathic pain. To ascertain the balance between treatment benefits and risks, the French National Authority for Health requested a post-market registry for real-world evaluation of the long-term effectiveness and safety of the therapy.

402 patients undergoing implantation with a Medtronic SCS device as either a primo-implant (n=264) or replacement implant (n=138) were enrolled across 28 representative sites in France. Outcome measures at 2 years included pain intensity, satisfaction with treatment, improvement of pain relief and daily life activity, willingness to undergo the treatment again and use of pain treatments. A patient was considered a responder if, compared to baseline, predominant pain reduction was ≥50%.

At the 2-year follow-up visit, predominant pain intensity for primo-implant patients had decreased from baseline ($p<0.001$), with responder rates of 55%, 36% and 67% for the lower limbs, back and upper limbs, respectively. Most patients acknowledged an improvement in pain relief (89%) and daily

life activity (82%), were satisfied with treatment (91%) and willing to undergo the treatment again (93%). A significant decrease ($p<0.01$) in the proportion of patients receiving pain treatment was observed for all drug and non-drug treatments. Reported adverse events were in line with literature. Pain intensity at 2 years was comparable for patients in the replacement group, supporting the long-term stability and effectiveness of SCS.

Real world evaluation of the use of spinal cord stimulation under the recommendations of the French Health Authority shows that two years after the first implantation of an SCS device close to 60% of the patients retain a significant pain reduction and 74% show improvement in pain scores [of at least 30%] with significant decreases in drug and non-drug pain treatments [1].

Epidural electrical spinal cord stimulation (ESCS) is an established therapeutic option in various chronic pain conditions. In the last decade, proof-of-concept studies have demonstrated that ESCS in combination with task-oriented rehabilitative interventions can partially restore motor function and neurological recovery after spinal cord injury (SCI). In addition to the ESCS applications for improvement of upper and lower extremity function, ESCS has been investigated for treatment of autonomic dysfunction after SCI such as orthostatic hypotension [2].

High-frequency spinal cord stimulation

High-frequency spinal cord stimulation.

Experimental studies

Spinal cord stimulation (SCS) has demonstrated multiple benefits in treating chronic pain and other clinical disorders related to sensorimotor dysfunctions. However, the underlying mechanisms are still not fully understood, including how electrode placement in relation to the spinal cord neuroanatomy influences epidural spinal recordings (ESRs). To characterize this relationship, this study utilized stimulation applied at various anatomical sections of the spinal column, including at levels of the intervertebral disc and regions correlating to the dorsal root entry zone.

Method: Two electrode arrays were surgically implanted into the dorsal epidural space of the swine. The stimulation leads were positioned such that the caudal-most electrode contact was at the level of a thoracic intervertebral segment. Intraoperative cone beam computed tomography (CBCT) images were utilized to precisely determine the location of the epidural leads relative to the spinal column. High-resolution microCT imaging and 3D-model reconstructions of the explanted spinal cord illustrated precise positioning and dimensions of the epidural leads in relation to the surrounding neuroanatomy, including the spinal rootlets of the dorsal and ventral columns of the spinal cord. In a separate swine cohort, implanted epidural leads were used for SCS and recording evoked ESRs.

Results: Reconstructed 3D-models of the swine spinal cord with epidural lead implants demonstrated considerable distinctions in the dimensions of a single electrode contact on a standard industry epidural stimulation lead compared to dorsal rootlets at the dorsal root entry zone (DREZ). At the intervertebral segment, it was observed that a single electrode contact may cover 20-25% of the DREZ if positioned laterally. Electrode contacts were estimated to be ~0.75 mm from the margins of the DREZ when placed at the midline. Furthermore, ventral rootlets were observed to travel in

proximity and parallel to dorsal rootlets at this level prior to separation into their respective sides of the spinal cord. Cathodic stimulation at the level of the intervertebral disc, compared to an 'off-disc' stimulation (7 mm rostral), demonstrated considerable variations in the features of recorded ESRs, such as amplitude and shape, and evoked unintended motor activation at lower stimulation thresholds. This substantial change may be due to the influence of nearby ventral roots. To further illustrate the influence of rootlet activation vs. dorsal column activation, the stimulation lead was displaced laterally at ~2.88 mm from the midline, resulting in variances in both evoked compound action potential (ECAP) components and electromyography (EMG) components in ESRs at lower stimulation thresholds.

Conclusion: The results of this study suggest that the ECAP and EMG components of recorded ESRs can vary depending on small differences in the location of the stimulating electrodes within the spinal anatomy, such as at the level of the intervertebral segment. Furthermore, the effects of sub-centimeter lateral displacement of the stimulation lead from the midline, leading to significant changes in electrophysiological metrics. The results of this pilot study reveal the importance of the small displacement of the electrodes that can cause significant changes to evoked responses SCS. These results may provide further valuable insights into the underlying mechanisms and assist in optimizing future SCS-related applications [3].

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