Spinal Cord Stimulation for Practitioners; An Introduction

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Introduction

Spinal cord stimulation(SCS) is an adjustable, non-destructive, neuromodulatory procedure which delivers therapeutic doses of electrical current to the spinal cord for the management of neuropathic pain. The most common indications include post-laminectomy syndrome, complex regional pain syndrome (CRPS), ischemic limb pain, and angina. Scattered reports regarding the treatment of intractable pain due to other causes including visceral/abdominal pain, cervical neuritis pain, spinal cord injury pain, post-herpetic neuralgia, and neurogenic thoracic outlet syndrome have also appeared in the literature. The procedures are most commonly performed by neurosurgeons or anesthesiologists specializing in pain management but other specialties, such as rehabilitation medicine and orthopedic surgery, have also demonstrated interest in the procedure.

Relevant Anatomy

Understanding the somatotopy of the spinal cord is paramount to knowing the technical aspects of implantation. A basic tenet of SCS is to create an overlapping of paresthesia and pain region. In order to do this, correlation of the somatotopy and the level of the spinal cord is necessary. Barolat has published extensively on the mapping of the spinal structures in man. A database was created to suggest areas of sensory response to dorsal spinal cord stimulation.

High cervical regions such as C2 can cover the posterior occipital region, and occasionally the lower jaw. C2-4 stimulation will provide coverage of the shoulder while stimulation in the lower cervical region such as C5-6 will provide for the entire hand. To cover the anterior chest wall or the axilla, an electrode towards C7 will be necessary.

More commonly, an implanter will seek cover the lower extremities. Lateral placement at T11-12 will cover the anterior thigh, while placement at T11-L1 can cover the posterior thigh. Coverage off the foot as a whole can be achieved along these same areas but it becomes more difficult to cover the sole of the foot. Alternatively for coverage of the sole of the foot, a patient may require insertion on the lumbar L5 or S1 nerve roots. Low back pain is very difficult to cover because mid- thoracic stimulation can affect the chest and abdominal wall. The experience of the author had best localization with midline placement at T8-9. The studies performed by Dr. Barolat have been seminal in providing standardization to the field, but also opens the doors of many more future studies. The human spinal cord terminates at the conus between T12 to L1-2 level. As such, the T8-9 level is helpful as a landmark, but will vary from person to person.

Stimulation in these areas likely affects large afferent myelinated fibers that can include the dorsal columns, dorsal roots, dorsal root entry zone and the dorsal horn. It becomes increasingly difficult to distinguish stimulation patterns secondary to the overlap with simultaneous stimulation of more than one structure. Midline versus lateral placement would also affect desired outcome. Most patients prefer stimulation of the dorsal column from electrodes closer to the midline. Laterally, placed thoracic electrodes are more likely to stimulate the thoracic nerve roots and result in painful stimulation.

Indications

SCS has been used for a variety of pain conditions and is particularly indicated for pain of neuropathic origin, including post-laminectomy syndrome, complex regional pain syndrome, phantom limb pain, spinal cord injury pain, and interstitial cystitis. The indications have extended to include the treatment of intractable pain due to abdominal or visceral pain, and neurogenic thoracic outlet syndrome. SCS has been successfully utilized to treat severe pain due to ischemic disease of the lower extremities and more recently, intractable angina pain. Experience suggests that, in selected patients, SCS can produce at least 50% pain relief in 50-60% of the implanted patients. Interestingly, with the proper follow-up care, these results can be maintained over several years. The three most common indications are reviewed here.

Complex Regional Pain Syndrome (CRPS)

The implementation of SCS in individuals with CRPS type I can be difficult and one must forsee that the pain may spread to other body parts and this becomes challenging for coverage of all the affected areas with stimulation. In 1989, Barolat et al. reported reduction of pain in ten out of thirteen patients implanted. No patients in that series were made pain free but all ten reported a definitive difference when the stimulation was stopped. This was followed by several bodies of work by Kemler at al. starting in 1997 where eight of twelve patients reported near complete resolution of their symptoms and four also maintained good relief with permanently implanted leads.

In 2000, Kemler et al. published on a series of 54 patients who either underwent randomization to SCS with physical therapy or physical therapy alone. In the SCS group, 67% patients experienced significant pain relief which persisted at 6 months. In 2006, in a letter to the editor of NEJM, Kemler, recounted their five year follow-up on the patients with SCS. Their major conclusion was that the effects of SCS diminished over time for these patients. In this letter, they do not specify how reprogramming or modern devices might impact on the long term effects of SCS therapy.

Three additional prospective studies without matched controls have been reported and eight retrospective studies with reported success rates of 84% and a significant improvement in pain scores (VAS) and a >50% reduction in narcotic use by 44% of subjects. In 2011 a long term outcome analysis with paddle electrodes for the treatment of CRPS demonstrated that more than 50% of the patients reported greater than 50% pain relief at a mean follow up of 4.4 years and that 77.8% of the patients indicated they would undergo the procedure again for the same outcome.

Post-laminectomy syndrome (also called Failed back surgery syndrome – FBSS)

Post-laminectomy syndrome is vaguely defined. The term has included pain localized to the center of the lower lumbar area, pain in the buttocks, persistent radicular pain, or diffuse lower extremity(s) pain. Arachnoiditis, epidural fibrosis, radiculitis, microinstability, recurrent disk herniations, infections, have been perpetrated in the etiology of this syndrome. Most published series distinguish between back and leg pain, but the details of the pain syndromes are seldom defined. SCS is accepted in the treatment of leg pain, but its widespread use for relief of pain in the lower lumbar area still remains to be defined.

A great challenge, in the treatment of post-laminectomy syndrome, has been to obtain stimulation in the low back. Even with direct stimulation to the low back, the pattern of paresthesia is often replaced in time by an unpleasant segmental band of stimulation from the thoracic roots, which negates the benefits of the procedure. Previous pioneering work looked at the concept of the single and dual quadripolar electrodes in the midline to stimulate the axial low back. The advent of the tripole electrodes and the ability to steer current has made it more plausible to aim for low back paresthesia.

The longitudinal studies by North showed that in patients with post-surgical lumbar arachnoid or epidural fibrosis without surgically remediable lesions, SCS is superior to repeated surgical interventions on the lumbar spine (for back and leg pain) and to dorsal ganglionectomy (for leg pain). Systematic review of the literature was conducted by Turner in 1995. They reviewed a total of 41 articles from 1966 to 1994 that met their criteria. It was noted that approximately 50-60% of patients with post-laminectomy greater than 50% pain relief was attained from the use of SCS. In 1996, Burchiel et al conducted a prospective multi-center study with one year follow-up and also reported 55% successful stimulation. Medication usage and work status were not changed significantly.

North et al. also conducted a prospective study randomizing patients with FBSS to either repeat back surgery or SCS surgery. Patients were allowed to crossover after six months. Ten of fifteen patients crossed over from back surgery to SCS, while only two of twelve patients crossed over from SCS to back surgery. In 2011 a long term outcome analysis with paddle electrodes for the treatment of FBSS demonstrated that 30% of the patients reported greater than 50% pain relief at a mean follow up of 4.38 years and that 70.6% of the patients indicated they would undergo the procedure again for the same outcome.

Angina

The role of SCS in the management of refractory angina pectoris has become more grounded with well documented reports in the literature revealing uniformly good results in the relief of anginal pain. Further, the results have been maintained in long term follow-up and have been substantiated by a reduction in the intake of nitrates as well. Interestingly, other findings have supported the evidence that SCS has effects that go beyond pain relief. The observations that there is less ST segment depression and that the exercise capacity, the time to angina and the recovery time all improve with stimulation may suggest that there is a reduction in ischemia. In a positron emission tomography study, a redistribution of myocardial flow in favor of ischemic parts of the myocardium has been demonstrated as a long term effect of spinal cord stimulation, both at rest and after pharmacologic stress induction.

Hautvast et al. implanted SCS in patients with stable angina pectoris and randomized them. One group's remained inactivated while the other group was instructed to use the stimulator three times per day for one hour and with any angina attack. At 6 weeks, compared with controls, the treatment group had increased exercise duration and time to angina, and decreased anginal attacks and sublingual nitrate consumption. Also, observed was a decrease in ischemic episodes on EKG, as well as a decrease in observed ST segment depressions on exercise EKG. There was an increase in perceived quality of life and decrease in pain. It was shown that a placebo effect from surgery in the treatment group was unlikely because all patients had implantation surgery at baseline.

Mannheimer et al. randomized 104 patients accepted for CABG to receive either CABG (n=51) or SCS (n=53) in the ESBY study. This study demonstrated that patients randomized to SCS showed a greater than 30% improvement in NHP scores(Nottingham Health Profile) compared with baseline, which was significant and comparable to the improvement shown by patients randomized to CABG. These results were consistent on follow up after 4 years. It is important to know that the 5 year mortality of 27.9% in the ESBY study was similar between those receiving SCS and those who received CABG, with no difference in the percentage of cardiac deaths. The ESBY study showed that cardiac events were similar across the groups, but that there was significantly more cerebrovascular events obsevered in the CABG group.

The mechanisms of action of SCS are unclear. There may be homogenization of myocardial blood perfusion with SCS and that this reduces myocardial ischemia. Another study has demonstrated that SCS improved heart muscle lactate metabolism and oxygen demand and blood flow in the coronary sinus. The success of the procedure ultimately will be determined by the cardiologists and its widespread use. Similar to the indication for peripheral vascular disease, European physicians have demonstrated a substantially greater interest in the modality than US physicians. It would be interesting to see the companies and SCS community bring to the table some consensus statements from the cardiology community to explore the role of SCS in the treatment of intractable angina. It seems quite curious that angina could be such a popular indication in Europe, but the demographics of the United States does not permit this.

Conclusion

The treatment of chronic pain remains challenging. Spinal cord stimulation has been performed for over 30 years, and slow but steady progress with this technology has been made. As the equipment and stimulation parameters are improved, selection criteria has been better defined and is slowly being expanded. More importantly, experience in the technique and the equipment has made SCS a much more reliable and safe modality. Like all the modalities performed for chronic pain management, its results are favorable. It is important to remember that the goal of neurostimulation is to reduce pain, rather than to eliminate pain. It has been shown to have a 50% improvement in pain relief. Very few other invasive modalities can claim this success rate with a few years of follow-up.

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