Spinal cord stimulation for chronic pain management: mini-review

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Spinal cord stimulation (SCS) has been used extensively for the management of refractory chronic pain, including complex regional pain syndrome and failed back surgery syndrome. The progressive improvements in the selection criteria of patients, implantation devices, and techniques in implantation can lead to satisfactory results for the treatment of a range of chronic pain. In addition, despite its high initial cost, it provides an improvement of the function and quality of life of patients cost-effectively, compared to alternative therapy strategies. This article reviews the equipment and technology, indications, and complications of SCS.

Keywords: Complex regional pain syndromes; Failed back surgery syndrome; Spinal cord stimulation

INTRODUCTION

Shealy et al. [1] introduced the concept of dorsal column stimulation by implanting an electrode lead into the epidural space. In 1967, he implanted a dorsal column stimulator into the epidural space in patients suffering from cancer pain. Recently, it was demonstrated that many spinal neural structures (dorsal columns, dorsal roots, dorsal root entry zone and the dorsal horn) were stimulated by the electrical stimulation of the lead in the epidural space [2]. The mechanism of the analgesic action of spinal cord stimulation (SCS) was based initially on the gate control theory of pain proposed by Melzack and Wall [3]. On the other hand, it has been suggested that the SCS has multiple analgesic actions

by acting on any abnormal activity in the A- β neurons that receive pain, restoring the normal gamma amino butyric acid levels in the dorsal horn, and releasing adenosine in the central nervous system [4,5]. In the spinal cord, pain modulating neurotransmitters, such as substance-P, and serotonin, are released by SCS [6]. In addition, SCS interferes with the direct transmission of pain signals traveling along the spinal cord to the brain [7]. At low levels of stimulation, the activity of the sympathetic nerve system was attenuated significantly, resulting in a reduction of pain and an increase in blood flow [7,8].

In 2017, Farber et al. [9] included 5,328 patients who underwent SCS implantation for the treatment of failed back surgery syndrome (FBSS) and found that SCS provided long

term cost effectiveness despite the high initial cost compared to conventional medical management (CMM). In a previous study, the health-related quality of life (HRQoL) and the cost implications of SCS combined with CMM was compared with CMM alone in 100 patients with FBSS. The SCS required additional healthcare cost but greatly improved the HRQoL [10].

THE EQUIPMENT AND TECHNOLOGY

The SCS system includes the electrode leads, a cable, a pulse generator, and a programmer. The unipolar electrodes were initially introduced, which can produce a limited field of paresthesia and allow the application of leads. Electrode leads with four to ten electrodes were subsequently developed to stimulate multiple dermatomes of pain. The percutaneous electrode can be implanted into the epidural space via Tuohy needles without a laminectomy (Fig. 1). The percutaneous technique can be ideal because it allows the placement of SCS without a surgical incision [11]. In addition, a percutaneous technique allows the testing of several spinal cord levels. By placing multiple parallel electrodes into the epidural space, various configuration matrices can be constructed to stimulate painful dermatomes. On the other hand, a paddle electrode lead can be placed in the epidural space via open surgery (laminotomy or partial laminectomy), which provides greater stability and less predisposition to migrate [11,12].

The implanted leads are connected to the pulse generator via an extension cable. The pulse generator contains a

lithium battery, which is activated and managed by adjusting the amplitude, pulse width, and frequency using outside telemetry [13]. Patients alone can turn the stimulator on and off, and control the stimulation amplitude, frequency, and pulse width. The lifespan of the battery varies mainly with the use and the level of utilized parameters (voltage, rate, pulse width, etc.). With the average use, most patients implanted with non-rechargeable pulse generators can expect a battery life of 2.5 and 4.5 years [13]. On the other hand, a new SCS system with a rechargeable pulse generator can last for up to 10 years [13]. In addition, it is suitable for patients requiring higher amplitudes of stimulation. Recently, the rechargeable pulse generator has been used widely because of its small size and ease of maintenance [14,15].

INDICATIONS

Neuropathic pain is sometimes refractory to current pharmacological treatments and nerve blocks. Spinal neuromodulation is one of the most exciting developments in the pain management. SCS is effective in the treatment of intractable neuropathic pain disorders (Table 1).

Failed back surgery syndrome

FBSS is defined as a condition of persistent pain after back surgery. SCS is effective in the treatment of pain in the upper and lower extremities while the effectiveness of SCS in axial pain is controversial [16,17]. A meta-analysis conducted by Taylor et al. [18] showed that SCS not only reduces pain, but also improves the quality of life by decreasing the consumption of analgesics over time. In this study, the level of evidence for the efficacy of SCS in FBSS was “moderate.” In 1991, North et al. [19] examined the effects of SCS in 50 patients with FBSS (averaging 3.1 previous operations). They recorded at least 50% sustained pain reduction in 53% of patients at 2.2 years and in 47% of patients at 5.0 years after the implantation of SCS. In addition, most patients reported significant improvements in their activities of daily living, and

Fig. 1. Implantation of the percutaneous spinal cord stimulator.

Table 1. Indications for spinal cord stimulation

Failed back surgery syndrome
Complex regional pain syndrome (type 1 and 2)
Neuropathic pain secondary to peripheral nerve injury
Post herpetic neuralgia
Post amputation phantom limb pain

10 out of 40 patients who were disabled prior to SCS returned to work. In 2005, North et al. [20] compared the efficacy of SCS and re-operation for the management of refractory FBSS with radicular neuropathic pain (with or without low back pain). SCS was more successful with greater than 50% pain reduction than reoperation after a 3 year follow up. In addition, the amount of opiate analgesics decreased significantly in SCS compared to re-operation [20]. Kumar et al. [21] reported that SCS was superior to CMM in patients with FBSS after a 24 month follow-up. They also showed that SCS improved significantly the leg pain relief, HRQoL, and functional capacity [21].

Complex regional pain syndrome

Complex regional pain syndrome (CRPS), formerly known as reflex sympathetic dystrophy, is a chronic pain syndrome that often progresses with time. This pain is a type of neuropathic pain with a variety of symptoms, including spontaneous pain, allodynia, hyperalgesia, dystrophic changes in the skin, osteoporosis, and loss of motor functions [22]. Broseta et al. [23] reported that the pain associated with nerve injuries or amputation was decreased significantly in all patients who received SCS. In 2004, Kemler et al. [24] examined the effects of SCS with physiotherapy compared to physical therapy alone in patients with CRPS type I. They reported that at the 6 month follow-up, the mean decrease in pain score was 2.4 with SCS compared to 0.4 with physical therapy using the visual analog scale (VAS) from 0 (no pain) to 10 (worst possible pain). In addition, patients with SCS showed significant improvement in the pain-rating index, McGill Pain Questionnaire, and the HRQoL [24]. On the other hand, Kemler et al. [25] reported that the pain-alleviating effects of SCS in patients with CRPS-I decreased over time, and produced results similar to those of physical treatment. Despite this, the global perceived effect of SCS was higher in that of physical treatment, and 95% of patients with SCS would repeat the SCS treatment [25]. Some studies suggested that SCS should be included in the guidelines for the management of CRPS [26-28]. If patients do not respond to conventional treatments within 12 to 16 weeks, a trial of SCS is recommended for patients diagnosed with CRPS that is refractory to treatment, such as medication and nerve block within 3 months [28].

Post herpetic neuralgia

The effectiveness of SCS for the treatment of post herpetic neuralgia (PHN) is controversial. Recently, it was reported that SCS resulted in excellent pain reduction in 23 out of 28 patients (82%) with intractable PHN [29]. In addition, it was found that SCS may be considered as an effective option for patients with refractory pain during the acute and sub-acute phases of herpes zoster [30]. Further studies will be needed to evaluate the efficacy of SCS for the prevention or treatment of PHN.

COMPLICATIONS

Patients reported several complications related to SCS, which resulted in an increase in medical cost and a decrease in the effect of SCS (Table 2). The rate of complications associated with SCS was reported to be 20% to 40% [11,31]. The complications were generally minor with the proper expertise. The most common complication was electrode migration (11% to 45%). The incidence of migration of the electrode lead was reported to be higher in a percutaneous lead than paddle leads. The migration of the lead generally occurred within 1 week after the implantation of SCS. The neurological complications due to a spinal nerve injury, epidural hematoma, and infection can be fatal [32]. Strict sterilization and prophylactic antibiotic therapy should be considered during the procedure [16]. Local pain at the implant site should be investigated for an indolent infection of the implanted equipment. When infection occurs, antibiotics and the removal of the infected hardware are required [32]. Persistent pain at the insertion of a battery can sometimes require repositioning of the battery. The incidental leakage of cerebral spinal fluid during the procedure can cause a postdural puncture headache, which requires conservative management or epidural blood patch [14].

Table 2. Complications related to spinal cord stimulation

Electrode migration
Infection
Postdural puncture headache
Local pain
Hardware malfunction

CONCLUSION

Chronic and intractable pain should be considered as a disease entity. SCS has been well established as an effective treatment for several pain conditions. SCS has been proven to be effective in the long term for chronic intractable pain conditions. In addition, SCS improve the functional ability and quality of life. To increase the effectiveness of SCS, suitable patients should be selected, and the physician should be aware of the anatomy and physiology of the spinal cord and master the technique for the implantation of SCS.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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