

SPINAL CORD STIMULATION AND IMPROVED HAND FUNCTION IN A TRAUMATIC UPPER LIMB REPLANTATION: A CASE REPORT

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Background: Spinal cord stimulation (SCS) is commonly used to treat chronic pain that is refractory to conservative management. SCS has demonstrated efficacy in reducing paresthesia and pain, but functional motor improvements after this type of intervention are reported less often.

Case Report: A 70-year-old man sustained a traumatic left forearm amputation in 2015, which was followed by surgical reattachment and persistent neuropathic pain. The patient tried several interventions, including nonsteroidal antiinflammatory drugs, muscle relaxants, gabapentin, pregabalin, opioids, duloxetine, and nerve blocks. Ultimately, in 2017, he underwent the implantation of an SCS device. The SCS provided a maximum 90% reduction in pain and eliminated the paresthesias. The pain reduction notably helped double his range of motion when compared to pre-implantation interventions. He demonstrated improved range of motion, reduced muscle atrophy, and increased strength.

Conclusion: SCS provided both substantial pain relief and unanticipated functional recovery in this patient, whose upper limb had been amputated. This case serves to highlight a novel therapeutic benefit of SCS beyond pain relief.

Key words: Spinal cord stimulator, neuromodulation, amputee, replantation, motor function, strength, pain

BACKGROUND

Since its introduction in 1967, spinal cord stimulation (SCS) has been employed to manage chronic pain conditions, offering meaningful relief in cases that are often resistant to other treatments. While the effects of SCS were first attributed entirely to the gate control theory of pain, more recent research indicates that additional mechanisms are involved (1). These mechanisms include modulation of the noradrenergic and serotonergic pathways associated with pain. Additionally, according to a newer theory, SCS may directly reduce hyperexcitability in the wide dynamic range neurons of the dorsal horn and activate small-diameter fibers (2). Compared to the systemic pharmacological intervention, SCS neu-

romodulation can target the pain more locally, with a reduced side effect profile (3). Each SCS lead contains 8 to 16 electrodes arranged in a ladderlike pattern, allowing for selective stimulation of specific portions of the lead. The leads are positioned in the epidural space and advanced to the targeted spinal cord level.

SCS has also made several technological advancements over the years. Most SCS devices currently have 4 optimization parameters that the patient and/or physician can alter: electrode location, frequency (Hz), pulse width (μ sec), and amplitude (mA) (4). Although SCS was created primarily for chronic pain control, there is emerging evidence that neuromodulation may also

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influence motor function (5-7), and clinical trials continue to increase as clinicians attempt to broaden the application of these devices (8). Much of the expansion of research into SCS has come from studies exploring its use in the recovery of locomotion after spinal cord injuries (9). Reports have highlighted improved hand strength and muscle control in patients who receive SCS (10).

The authors present a unique case of a patient who suffered a traumatic upper-limb amputation but then achieved adequate pain relief with an SCS device in addition to experiencing progressive restoration of his hand's range of motion and strength. After 2 years of rigorous physical therapy, his hand strength was noted to have recovered to only a 2/5 rating, at which point he proceeded with an SCS implantation procedure to help further control the pain. Seven years after the placement of the SCS device, his current hand strength is 4/5. This development highlights a novel therapeutic potential for this technology: to not only relieve pain but potentially increase function in amputees after successful replantation.

CASE

A man who was 70 years old during the present case study sustained a traumatic injury to his left upper extremity in 2015 while working with an electric saw. The trauma resulted in autoamputation of that left upper extremity, a few centimeters proximal to the wrist. He underwent emergent surgical reattachment of the limb and subsequent reconstructive procedures. The initial injury is seen in Fig. 1.

Despite extensive postoperative rehabilitation and physical therapy, the patient continued to experience severe pain in his left hand and forearm. The patient tried various forms of conservative and pharmacological management, including at-home exercises, nonsteroidal antiinflammatory drug, muscle relaxants, gabapentin, pregabalin, duloxetine, and opioids. The patient also received only mild pain relief from localized nerve blocks. Of the pharmacological treatments, gabapentin helped the most with pain, and the patient took 600 mg of that medication 2-4 times daily. After 2 years of trialing these therapies, he presented to the clinic in 2017 to discuss other options for pain control.

At the time of his presentation, he was alert and oriented in all domains. Motor strength testing showed right-hand flexion and extension at 5/5 and left-hand flexion and extension at 2/5. The patient was hypersensi-

tive to palpation at the surgical scar site. He described the hand pain as constant, burning, tingling, and sharp. The pain, which worsened upon touch, movement, and sitting, was described as a 4-5/10 on the numeric rating scale. Hand and finger range of motion was severely restricted. There also was no light or deep sensation remaining in the left hand, except for hot and cold awareness along with the paresthesia and pain.

SCS was discussed as the next possible treatment option for the pain, and the risks and benefits of the procedure were detailed at length. The expectation was that if successful, the spinal cord stimulator could help reduce the patient's pain and paresthesia significantly. Once the device was surgically placed, settings were kept at a constant high frequency (10 kHz), and the tips of the 2 leads were placed at the superior edges of C3 and C4 vertebrae, respectively. Initial programming delivered 0.6 mA at a 30- μ sec pulse width. As adjustments were made, the patient received the greatest benefit at a lower current (0.3A). The patient initially experienced the most pain relief from the electrodes at the C5-C6 disc space (Program 1). Currently, in 2025, he is utilizing the electrodes at the superior border of the C4 vertebrae (Program 2). The only parameter controlled by the patient is the level of current in 0.3 mA intervals. Placement of the leads can be seen in Fig. 2.

Following the implantation, the patient reported a pain reduction of up to 80-90% from baseline. The paresthesia sensations largely resolved. Importantly, the pain reduction gave him a greater ability to move his hand, which led to an approximate twofold increase in the range of motion in his left hand and fingers from their pre-implantation status. His physical exam in 2025 showed a 5/5 strength in right-hand flexion and extension and a 4/5 strength in left-hand flexion and extension. Compared to the results of the previous exam in 2017, improved muscle tone was noted in the left hand, which also showed less atrophy after the implantation. The patient was able to regain sufficient hand function and ultimately returned to work, improving his quality of life substantially. Figs. 3 and 4 demonstrate the current condition of the replantation and the timeline of the treatment, respectively.

DISCUSSION

Spinal cord stimulation has long been a safe and effective method for treating difficult, resistant pain (11-13). Traditionally, the theory of how SCS worked was related to the gate control theory of pain developed by Melzack

and Wall. More recent data, however, suggest that the full mechanism of action is not completely understood (1,2,14,15). Functional recovery of muscle function in SCS patients is reported less often in the literature. Muscle atrophy and weakness are common sequelae of spinal cord and peripheral nerve injuries and arise when adequate neural input to the muscle cells is not received. In the absence of these signals, the myocytes degenerate: they accumulate fat, undergo protein degradation, and ultimately progress to apoptosis (16).

While the precise process by which SCS mitigates atrophy has yet to be defined, researchers have demonstrated that the technique can increase muscle volume and prevent muscle loss (17,18). Preclinical animal models have suggested that SCS promotes neuroplasticity and axonal regeneration in neuronal injury (6,7,19). In human clinical studies, SCS has been associated with rapid and sustained recovery of hand and arm function in patients with motor deficits caused by spinal cord injury (20). Some researchers hypothesize that tonic epidural spinal cord stimulation can modulate spinal circuitry that enables sensory input to serve as a source of neural control (21).

Electrophysiological studies demonstrate that SCS preferentially recruits large-to-medium-diameter afferent fibers within the dorsal roots, which provide excitatory synaptic input to motoneurons and interneuronal pathways, thereby enhancing motor output (22,23). Clinically, several reports have documented measurable functional improvements, including increased grip strength, force generation, and muscle activation (5,10,20). In addition to cases of upper-extremity recovery, SCS has also facilitated restoration of walking in select patients with paralysis (24). Collectively, these findings highlight neuromodulation through SCS as an emerging therapeutic strategy with the potential to improve quality of life for patients with chronic pain, spinal cord injury, and even limb paralysis. The limitations of this study are due to the single-patient design.

One case cannot prove a causal role, nor will the findings always be generalizable to other patients.

CONCLUSION

In this case, SCS provided not only substantial pain relief but also unexpected functional recovery for a patient with an upper-limb amputation who underwent surgical replantation. This rare presentation underscores the potential of SCS to offer benefits beyond its established role in pain management. SCS



Fig. 1. Initial photograph of the traumatic accident in 2015.



Fig. 2. Anterior/posterior and lateral fluoroscopic images of lead placements at tops of C3 and C4 vertebrae.



Fig. 3. Photographs of the injured hand in 2025.

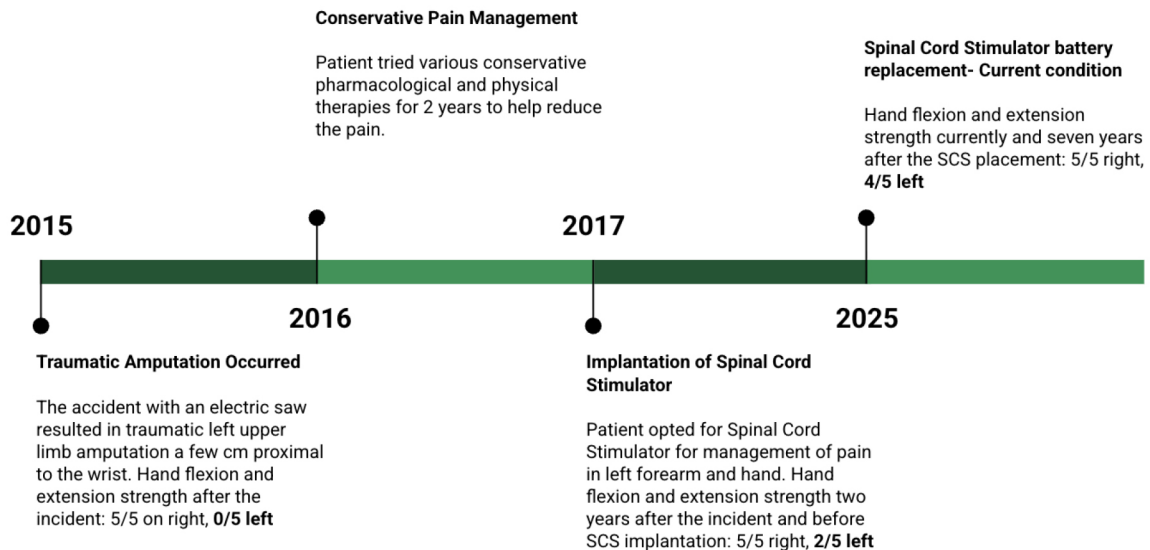


Fig. 4. Chronological timeline from traumatic event in 2015 to current condition in 2025.

can help improve muscle tone and strength, thereby improving quality of life. Given the uniqueness of this case, a similar situation is unlikely to be represented in prospective studies; however, sharing these findings may help inform clinical decision-making when similar patients are encountered. Further research is warranted to determine whether specific SCS programming strategies can reproducibly enhance functional recovery in addition to pain control, thereby broadening the clinical utility of the technique.

Contributions

MF and DN provided substantial contributions to the acquisition of data or to the analysis and interpretation thereof. MF and DN also drafted the article and revised it critically for intellectual content. MG, who served in a supervisory capacity, gave the final approval of the version of the article to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately resolved.

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