

Technical Note

S3 motor branch stimulation failure due to nerve fiber burning at the nerve–wire junction: A historical technical noteZahra Emami, Najme-Sadat Moosavi, Majid Karimi¹, Alexander R. Vaccaro², Vafa Rahimi-MovagharDepartment of Neurosurgery, Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, ¹Zahedan University of Medical Sciences, Zahedan, Iran, ²Department of Orthopedics and Neurosurgery, Thomas Jefferson University and the Rothman Institute, Philadelphia, Pa, USAE-mail: Zahra Emami - emamiz14@yahoo.com; Najme-Sadat Moosavi - ns.moosavi@yahoo.com; Majid Karimi - mkarimi_us@yahoo.com; Alexander R. Vaccaro - Alexvaccaro3@aol.com; *Vafa Rahimi-Movaghar - v_rahimi@yahoo.com

*Corresponding author

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Abstract**Background:** Sacral nerve stimulation is a minimally invasive procedure to treat spinal cord injured (SCI) patients with overactive bladder syndrome or nonobstructive urinary retention that is refractory to conservative treatment.**Methods:** In this paper, we report a case of traumatic cervical SCI with quadriplegia and spastic bladder, which was managed by third sacral motor branch stimulation in 1998.**Results:** In this case, stimulation-induced burning of nerve fibers was seen microscopically during the implantation surgery. At 2 weeks after the index surgery, the stimulator was removed due to ineffectiveness. We hypothesize that the stimulation settings of our stimulator were not appropriate for neural stimulation and led to neural destruction, fibrosis, and treatment failure.**Conclusion:** The device settings of stimulators used in neural stimulation should be appropriate for direct neural stimulation otherwise they can lead to neural destruction and treatment failure.**Key Words:** Nerve root injury, sacral nerve stimulation, spinal cord injury**Access this article online****Website:**www.surgicalneurologyint.com**DOI:**

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Quick Response Code:**INTRODUCTION**

Spinal cord injury (SCI) patients with complete lesions may present with neurogenic bladder dysfunction. The management of lower urinary tract dysfunction still presents a therapeutic challenge despite recent developments. Most patients are initially treated with conservative therapies (bladder retraining, pelvic floor exercises, biofeedback, and intermittent catheterization), often supplemented by pharmacological therapy. When these approaches are unsuccessful, alternative surgical procedures are used. Sacral nerve neuromodulation is a procedure that has been investigated in humans since the early 1980s. Tanagho and Schmidt^[12] demonstrated that continuous

stimulation of the sacral root S3 with an electrode and implanted pulse generator could modulate detrusor and sphincter activity and stabilize micturition reflexes. Sacral neuromodulation (SNM) is approved by the US Food and Drug Administration (FDA) for the treatment of urgency, frequency, urge incontinence, and nonobstructive chronic urinary retention. In this manuscript, we report the first case of S3 motor branch stimulation in Iran in 1998 with subsequent failure due to neural destruction and fibrosis.

CASE REPORT

A 28-year-old male developed a C6-C7 quadriplegia after a motor vehicle accident in 1998. In the acute phase,

he underwent spinal cord decompression and fusion. He developed lower urinary tract dysfunction (LUTD) that did not respond to conservative therapy and subsequently underwent SNM. The patient was operated on in the prone position. A skin incision was made between L5 and S4. L5 and the sacral vertebrae were identified. Sacral laminectomy was performed from S1 to S4. The bilateral L5 and S1 roots were identified and evaluated with electrical stimulation for observation of toe dorsiflexion and plantar flexion, respectively. Sacral roots were identified bilaterally at S2, S3, and S4. To correctly identify sacral roots, a Foley catheter was placed and attached to a micro-set, which was partially filled with normal saline. During the operation, the nerve roots were stimulated and urinary bladder contraction was observed by elevation of fluid in the micro-set. When S2 and S4 roots were stimulated, slight bladder contraction was observed by way of elevation of fluid in the micro-set. However, the maximum elevation of fluid was observed following S3 stimulation. Dorsal and ventral S3 roots were distinguished from each other by anatomical landmarks and size. In each nerve root, the motor rootlets are located ventrally and medially to the sensory rootlets. To prevent cerebrospinal fluid (CSF) leakage, both anterior and posterior S3 roots were cut a few millimeters distal to the dura. Two urethral guide wires were used as electrodes and inserted into the S3 motor branches. The leads were tunneled subcutaneously to the anterior abdominal wall and then they were connected to a receiver block. An external stimulator transmits radiofrequency signals to the receiver block. Our stimulator was a Faradic stimulator. The stimulation was initiated with amplitude of 90-100 milliamperes (mA) and gradually increased until signals excited the sacral ventral roots. Stimulation was delivered to the sacral anterior roots to induce bladder contraction for bladder emptying.

During the surgery, minor thermal destruction of the nerve fibers was seen microscopically due to this stimulation. More powerful stimulation was gradually employed to induce effective bladder contraction over the next 3-4 days. By 2 weeks following the surgery, the electrodes were removed due to ineffectiveness. This patient was followed for 12 years; in 2010 he died from an infectious disease.

DISCUSSION

Stimulation of the anterior (efferent) axons of the sacral nerves was first described by Brindley.^[1] Shortly after that, Sauerwein reported that the combination of sacral stimulation with sacral deafferentation eliminates hyper-reflexia and increases bladder capacity and compliance.^[10] This technique is only used in paraplegic subjects, particularly SCI patients with a complete injury. Increased safety, efficacy, and quality of life in SCI patients has been demonstrated in patients following this procedure.^[9,13] Van Kerrebroeck *et al.*^[13] reported that 170 of 184 patients (92%) had successful use of the stimulator while 8 patients (4%)

combined it with clean intermittent catheterization (CIC), and the other 2% required sphincterectomy. Egon, *et al.*^[2] showed that 89% (83 of 93 patients in the study) used the stimulator alone for voiding, whereas the rest of patients used CIC.

The Finetech–Brindley bladder system has shown good efficacy in adult SCI patients with neurogenic bladder dysfunction, but it is more invasive than other methods such as SNM. The disadvantages of dorsal rhizotomy as part of this procedure are elimination of erection reflex, reflex ejaculation, and reflex defecation.^[15] The Finetech–Brindley stimulator was combined with neuromodulation of the dorsal sacral roots as a result. Neuromodulation instead of the deafferentation abolishes detrusor hyper-reflexia. This method is named SPARSI (sacral posterior and anterior root stimulator implant).^[8]

SNM was developed by Tanagho and Schmidt in the early 1980s.^[11] In SNM, continuous or cycling electrical pulses stimulate the sacral nerves, activating or inhibiting neural reflexes associated with lower urinary tract function. In 1994, Medtronic introduced InterStim in Europe. The FDA approved the device for treating urgency, frequency, and urge incontinence patients in 1997 and for nonobstructive chronic urinary retention in 1999. Resolution of pelvic muscle tension and pain,^[3] interstitial cystitis,^[4] and neurogenic detrusor overactivity^[5] are other indications. In 2006, Medtronic released a smaller neuromodulator (InterStim II).

In the two-stage technique for SNM, all patients initially undergo percutaneous or peripheral nerve evaluation (PNE). The PNE test is divided into acute and subchronic phases; in the former, one tined-lead electrode was implanted in each S3-foramen of the patients under local anesthesia. Correct placement is confirmed by evaluating sensory and motor responses to stimulation. Adequate response in the acute phase was followed by a subchronic phase in which the sacral nerve is stimulated continuously for 4-7 days. Patients with a successful test phase (>50% improvement in symptoms such as the number of voids, postvoid residual urine volume, number of catheterizations, and volume per catheterization) are candidates for the permanent electrode, which is connected to a subcutaneous permanent implantable pulse generator (IPG).

The SNM has achieved wide acceptance to improve the control of voiding dysfunction in neurogenic and nonneurogenic bladders. Many recent studies have discussed the outcomes of the SNM implant. Kessler and associates published a review of the 26 studies that included data on both test and permanent phases of SNM. They reported that pooled success rate was 68% for the test phase and 92% for permanent SNM, with the mean follow-up of 26 months.^[7] In addition, Van Kerrebroeck reported a long-term success rate of 60-77% for SNM treatment.^[14]

Although SNM is a minimally invasive therapy, it is

Table 1: Comparison of the Finetech-Brindley system and InterStim

Characters	Finetech-Brindley system	InterStim
Year	1978	1994
Components	Tripolar electrodes and external pulse generator	Quadripolar electrode and implantable pulse generator
Stimulation	Intermittent, high amplitude	Continuous or cycling, low frequency and amplitude
Mechanism of action	Stimulation of motor sacral nerves with the electrode implanted around it; with dorsal rhizotomy, nerve integrity is absent	Not quite clear, nerve integrity still present
Indication	Neurogenic bladder in spinal cord injured patients	Frequency, urgency and urgency incontinence; chronic nonobstructive urinary retention; interstitial cystitis; pelvic floor dysfunction and pain; neurogenic detrusor overactivity
Disadvantage	Elimination of erection reflex, reflex ejaculation and reflex defecation; weakness of the pelvic floor muscles; contraction of the urethral sphincter	Migration; infection; pain; nerve irritation; bowel dysfunction

associated with some risks and complications such as lead or IPG migration, infection, pain at the lead or IPG site, leg pain, nerve irritation, bowel dysfunction, technical problems, and loss of effect. Despite the high incidence of reported adverse events, there have been no reports of life-threatening complications or death.^[6] The pooled adverse event rate was 0% and 24% for the test phase and permanent SNM, respectively.^[7]

After years of experimental therapy, SNM is nowadays a widely used therapy. Although mechanisms of action are still not completely understood, the therapy has been proven efficient in the long run. Due to less invasive methods and other technical improvements, it is expected that adverse effects will further decrease in the future.

In 1998, we performed the first S3 motor branch stimulation and dorsal rhizotomy case in Iran. In this case we used the faradic electrical stimulation. Faradic stimulation is used for innervated muscle, when the lower motor neurons are intact. Faradic stimulation can be considered to be alternating current (AC) with pulse widths <1 ms and a frequency <100 Hz. According to the depth of electrode insertion, Faradic stimulation divided into four main classes: Transcutaneous, percutaneous, subcutaneous - via peripheral root nerves, subcutaneous - via spinal root nerves.

To stimulate S3 motor branch we used subcutaneous faradic stimulation via spinal root nerves. The model of the device was NMS 3.1 Jaber Model, Iran. In this method electrodes are implanted inside spinal root nerves, for example, sacral roots for bladder stimulation as in this case. In comparison to our method, new sacral stimulation methods become more effective and usable. The features of two common method of nerve stimulation are briefly described in Table 1.

In this case, the nerve fiber burning was seen microscopically at the nerve-wire junction during the surgery. Gradually, the response to electrical stimulation waned and after 2 weeks the electrodes were removed. It seems that the unresponsiveness was due to the nerve root burning observed during surgery. We hypothesize

that the stimulation settings of our stimulator were not appropriate for neural stimulation and led to neural destruction, fibrosis, and treatment failure. The device settings of stimulators used in neural stimulation should be appropriate for direct neural stimulation otherwise they can lead to neural destruction and treatment failure.

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