Laparoscopic implantation of neuromodulators for treating bladder and lower limb spasticity and promoting micturition in spinal cord injured patients

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Abstract: Introduction: Pelvic organ autonomic disorders and lower limb spasticity and atrophy are among the most important factors affecting morbidity and quality of life of thoracic spinal cord injured patients. Recently, the laparoscopic implantation of neuroprosthesis (LION) is figuring as a possibly more specific and selective treatment for these affections. *Objective*: evaluate the effect of the LION procedure at on bladder and rectal function and lower limb spasticity and contractility, to promote an alternative locomotion to thoracic spinal cord injured patients. Methods: we report our first case of a LION procedure. The patient is a 29 year-old man, with C7-Th1 (neurological Th3) car spinal cord injury since age 18 years, classified as grade B (ASIA), only due to rudimentary anal sensitiveness. Electrodes were implanted juxtaneurally to the pudendal, sciatic and femoral nerves. *Results*: at one month follow-up bladder spasticity was completely resolved and bladder capacity doubled (190mL pre-op to 380mL post-op). Moreover, the patient was able to extend the knee from postoperative day one. Thirty-two days after surgery, the right femoral nerve electrode was misplaced, requiring a reintervention and postponed the standing up training. At two-months follow-up thighs circumference increased from 38.5 cm (right) and 42 cm (left) to 40 cm (right) and 42 cm (left), he is showing some voluntary pelvic floor contraction, sensitivity improved on Th4 to Th11 and L2 to S4 dermatomes with the stimulator turned on and on Th4 and Th5 with it turned off. The stand up and walking training is planned to start at post-operative three months, in January. *Conclusion*: The LION procedure offers new target nerves for modulation and is a promising method for motor and urologic rehabilitation in spinal cord injured patients.

Key words: Bladder; Lower limb; Spasticity; LION; Neuromodulation.

INTRODUCTION

"Spinal cord injury (SCI) has been described as one of the greater calamities that can befall humans. Learning of the paralysis, bladder and bowel dysfunction, dependence on others, mobility limitations, and high risks of complications (such as pressure ulcers) that a spinal injury entails, most people who contemplate being forced to live this way cannot see anything but a life of low quality and conclude that they would rather be dead. Many individuals who actually incur an SCI indeed feel this way, at least initially. Some people with SCI very rationally decide to commit suicide, and others may do so during a period of depression and despair that is not uncommon after SCI. The suicide rate among individuals with SCI is about five times as high as the population at large and may be underestimated because of the "indirect suicides" achieved by prolonged self-neglect". (Paragraph fully transcribed from Dijkers, 2005).[1]

Pelvic organ autonomic disorders and lower limb spasticity and atrophy and their consequences (pressure ulcers, recurrent urinary infections, chronic renal failure etc.) are among the most important factors affecting morbidity and quality of life of thoracic spinal cord injured patients[2,3] and recovery of bladder and bowel function are the highest priority among para and tetraplegic patients.[4]

ELECTROSTIMULATION FOR THE TREATMENT OF NEUROGENIC BLADDER DYSFUNCTION

The first reported attempt to electrically stimulate the neurogenic bladder was reported in 1878, when Saxtorph MH described a catheter shaped electrode to work as a cathode – a method that showed acceptable results in treating bladder hypotonia in children[5], but not in spinal cord injured patients.[6] Poor results were also observed with direct detrusor stimulation, since the current intensity needed to achieve an effective bladder contraction was too high, causing pain and simultaneous urethral and pelvic floor muscles contraction.[7]

Attempts of deep spinal cord stimulation were made by means of a needle electrode implanted in the posterior horns, with up to 60% of the patients achieving satisfactory micturition (low residual volume), diminishing the incidence of lower urinary tract infections, increasing bladder capacity and decreasing the need for catheterization. On the other hand, the unspecific stimulation of the posterior horn had many undesirable effects like inducing detrusor-sphincter dyssynergia, autonomic responses (swheating, tachycardia etc.) and muscle spasms on the lower limbs. In this manner, despite the acceptable success rates, the high invasiveness and the 40% failure rate hindered the progress of this technique.[8]

Idealized by Brindley in 1977,[9] sacral nerve roots stimulation by means of a neuroprosthesis implantation showed good results and became commercially available (Finetech-Brindley Bladder System®, Finetech Medical® Ltd., Welwyn Garden City, UK), with more than 2500 procedures performed worldwide, reaching 20 years of follow-up.[10] The prerequisites for implantation were the integrity of the preganglionic parasympathetic neurons and a detrusor muscle preserved contractility.[11] Posterior rizotomy was performed at the moment of implantation, to treat the neurogenic detrusor overactivity and pain.[11,12] After the procedure, most of the patients became or remained continent, had their bladder capacity increased and managed to void with low residual (less than 30mL) without the need of self-catheterization, which drastically reduced the incidence of urinary infections.[13] Moreover, many reported electrically induced bowel movements and penile erection.[13,14]

The low success of this device was due to the necessity of a highly invasive, difficult and hardly reproducible procedure and to the irreversibility of the posterior rizo-

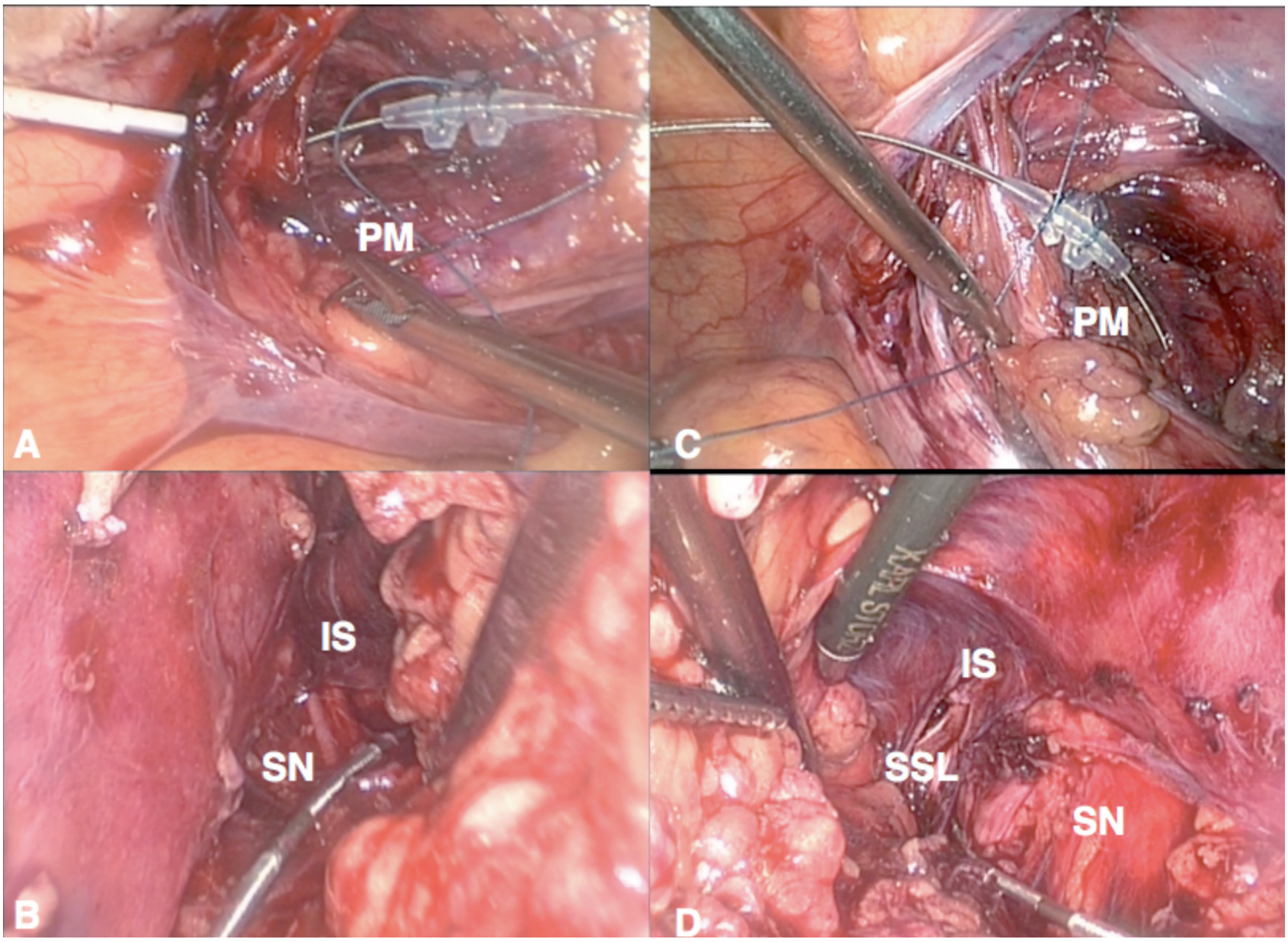

Figure 1. – Electrodes Placement: A - left femoral nerve; B - left sciatic and pudendal nerves; C - right femoral nerve; D - right sciatic and pudendal nerves (PM - Psoas Muscle; IS - Ischial Spine; SN - Sciatic Nerve; SSL - Sacrospinous Ligament).

tomy, which, in cases of partial success or failure would mean loss of reflex induced micturition, erection and bowel movements and the loss of residual perineal sensibility on patients with incomplete lesions.[7] The percutaneous implanted quadripolar electrode (Interstim®, Medtronic®, Minneapolis, USA) was developed in an attempt to overcome those difficulties. It has managed to increase bladder capacity in incomplete spinal cord injured patients[15-17] but with much inferior results in complete injury patients,[16-17] indicating that its main mechanism of action would be the modulation of the remaining spinal-bulbo-spinal paths.[18]

The laparoscopic implantation of neuroprosthesis (LION) has become possible through the Laparoscopic Neuronavigation (LANN) technique, which was developed in an attempt to preserve intrapelvic nerves during radical gynecological surgeries.[19-22] It consists of a series of nerve dissection techniques by using intraoperative neurostimulation to laparoscopically expose and identify the intrapelvic nerves, leading to a great evolution on the anatomic knowledge of the retroperitoneal spaces.[23]

The first LION procedures performed were rescue procedures after the explantation of a Brindley stimulator.[24] The patients had previously undergone a dorsal implantation of a Brindley stimulator and needed to have it explanted, due to cable or pulse generator infection or malfunction. Electrically induced micturition and defecation was obtained in six out of the eight patients. In the other two patients, irreversible damage to the nerve roots was observed.

The next obvious step was to use the LION as the primary procedure, since laparoscopy is a minimally invasive approach, as opposed to the posterior laminectomy and posterior rizotomy of Brindley's procedure. The proposed operative plan was to modulate the S2 and S3 nerve roots, femoral and pudendal nerve, with the objective of treating bladder and inferior limb spasticity and allowing for function recovery regardless of the absence of remaining spinal-bulbo-spinal paths. In all patients, bladder capacity was substantially increased and electrically induced micturition micturition was achieved, leaving them free of self-catheterization; lower limb spasticity was achieved; in the two men, electrical induction of a satisfactory, sustained, erection was also possible; and, at last, at 3, 6 and 9 months postoperatively, patients were able to stand up by means of an electrically induced contraction of the quadriceps.[25]

History has taught that the more peripheral (i.e. the more specific) electrodes are implanted, the better are the results. We are now conducting at our institution a randomized controlled trial with implantation of electrodes on the femoral, sciatic and pudendal nerves (Figure 1) with the objective of controlling bladder and lower limb spasticity and allowing for standing up and some limited walking. The preliminary results of this promising study are to be published on the next two years.

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