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EPIDURAL STIMULATION GIVES PARALYZED PATIENTS HOPES FOR A BETTER LIFE

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Summary
Introduction. Spinal cord injury is a damage to spinal cord caused by trauma or diseases. Nerve damages cause loss of function, such as mobility and/or feeling. Rehabilitation consists of exercises, therapeutic methods, and modalities, but none of them returns lost functions.
Method. This study is a meta-analysis, literature review of 10 randomized control trails of the last 20 years. All studies have a major focus on the use of electrical stimulation in patients with spinal cord injury. The methodology of studies varies in randomized trails, including 174 patients. Data are extracted from 4 medical data bases. The evaluation is realized with the PED-ro scale. On the other hand we took in consideration 17 case reports diagnosed with spinal cord injury (level C5-C6-C7 and T5-T6 and T7) who received implantation of epidural stimulation device. Device Mapping and therapy were carried out after surgery for 35 days, then patients were discharged.
Results. The literature used in this study claimed that electrical stimulation is effective in improving of muscular function, spasticity, and independence in daily living activities. According to PED-ro 3 studies (30%) have 3 points 2 studies, respectively 20%, have medium level 4-6 points and 5 studies (50%) have high level with 7-10 points. On the other hand, 17 people in clinical trial, treated with epidural stimulation, achieved big improvements in balance, coordination, and muscle mass, while bladder and bowel control are not improved.
Conclusion. We conclude that epidural stimulation is the best solution for spinal cord injuries.
Keywords: rehabilitation, spinal cord, epidural stimulation, balance, coordination

What is spinal cord injury?

The spinal cord is a bundle of nerves and other tissue that the vertebrae of the spine contain and protects. A spinal cord injury is damage to the spinal cord. After spinal cord injury (SCI), there is a rapid and dramatic loss of muscle mass in the lower limbs, which may predispose individuals with SCI to impaired glucose control, pressure sores and an increased risk of fracture. Loss of sensorimotor function after SCI induces musculoskeletal and metabolic adaptations, which are associated with a higher risk of cardiovascular disease compared with the general population.

The prediction of neurological recovery after spinal cord injury (SCI) has been based on physical examination of the acute patient, the degree of spared volitional control, such as walking ability. Rehabilitation programs after SCI have, traditionally, focused on achieving optimal independence expected for a specific injury level, given the identified activity limitations and participation restrictions, and may rely on compensatory strategies. While this approach may result in improvements in independent function, it does not promote recovery of motor control in the paralyzed limbs.

Regular physical activity can improve fitness and psychosocial well-being in the SCI population. The concept of activity-based therapies arose from research in animals and humans, showing that recovery of function could be enhanced through activity-dependent plasticity driven by neuromuscular activation below the level of injury. These therapies include locomotor training and functional electrical stimulation (FES)–assisted exercise.

A device, a surgery and a world of unimaginable possibilities for people with Spinal Cord Injuries. That is Epidural Stimulation, the most advanced treatment for empowering patients who have lost voluntary control of their limbs and must endure many other demoralizing spine-injury symptoms. It is a new beginning, approved by the FDA (Food and Drug Administration) for trials. After surgery comes 35 days of extensive rehabilitation with our spine specialists, and that's when your quality of life will really start to improve. Standing and stepping, enhanced motor skills, more muscle mass and stamina, less fatigue and pain, and better control over bladder and bowel.

Material and methods

This study is a meta-analysis, literature review of 10 randomized control trails of the last 7 years. All studies have a major focus on the use of electrical stimulation in patients with spinal cord injury. The methodology of studies varies in randomized trails, including 174 patients. Data are extracted from 4 medical databases. The evaluation is realized with the PED-ro scale. On the other hand, we took in consideration 17 case reports diagnosed with spinal cord injury (level C5-C6-C7 and T5-T6 and T7) who received implantation epidural stimulation device to compare with electrical stimulation.

Intervention therapy

All people included in this review were diagnosed with spinal cord injury. 174 patients underwent a program training, such as locomotor training, functional electrical stimulation-assisted leg cycling, and trunk and lower extremity exercises. Patients were divided in two groups.

After a Spinal Magnetic Resonance Imaging (MRI) scan, electromyography (EMG), and comprehensive blood work, patients underwent Laminectomy and implantation of the Epidural stimulation device. The surgeries were completed without issue and no serious complications were reported during the postoperative hospital stay. Surgical wounds healed normally, and no spinal cord or superficial wound infection was reported. Device Mapping and therapy were carried out after surgery for 35 days, then patients were discharged.

Searching strategy

Data are extracted from 4 medical databases, like TRIP, MEDLINE, Pubmed, Cochrane library. The evaluation is realized with the PED-ro scale which shows the validity of each study.

Table 1

The specified criteria used for the review

Included criteria	Excluded criteria
RCT (Randomized Controlled Trails) studies	Non free studies
Studies of the last 7 years	Review studies
English studies	Studies that are made before 2005
Free studies	Studies with no good results

In these table we showed 10 studies that we are analyzing in this review. Eight studies valued effects of electrostimulation combined with exercises and two studies valued effects of exercises.

Table 2

The frequency of therapy used in studies of the review

Therapy	Nr of studies	Frequency
Electrostimulation	8	80%
Exercises	2	20%

Table 3

Quality of studies according to PED-ro Scale (Physiotherapy Evidence Database)

PED-ro Scale													
Nr	**Study**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**All**
1	Baldi JC, et al. Muscle atrophy is prevented in patients with acute spinal cord injury using functional electrical stimulation.	0	1	0	1	0	0	0	0	0	0	1	3
2	Ping Ho, et al. Immediate effect of transcutaneous electrical nerve stimulation on spasticity in patients with spinal cord injury.	0	1	0	0	0	0	0	1	0	1	1	4
3	Harvey LA, et al. Electrical stimulation plus progressive resistance training for leg strength in spinal cord injury: a randomized controlled trial.	0	1	0	1	0	0	0	1	0	1	1	5
4	Giangregorio L, et al. A randomized trial of functional electrical stimulation for walking in incomplete spinal cord injury: effects on body composition.	1	1	0	1	0	0	1	0	1	1	1	6
5	Gorgey AS, et al. Neuromuscular electrical stimulation attenuates thigh skeletal muscles atrophy but not trunk muscles after spinal cord injury.	1	1	1	1	0	0	1	1	0	1	1	7
6	Herrity AN, et al. Lumbosacral spinal cord epidural stimulation improves voiding function after human spinal cord injury.	0	1	0	0	0	0	1	1	0	0	0	3
7	Sivaramakrishnan et al. Comparison of transcutaneous electrical nerve stimulation (TENS) and functional electrical stimulation (FES) for spasticity in spinal cord injury - A pilot randomized cross-over trial.	0	1	0	1	0	0	0	1	0	1	1	5
8	Galea MP, et al. SCIPA Full-On: A Randomized Controlled Trial Comparing Intensive Whole-Body Exercise and Upper Body Exercise After Spinal Cord Injury.	0	1	1	0	0	0	1	0	0	1	1	5
9	North RB, et al. Redefining Spinal Cord Stimulation "Trials": A Randomized Controlled Trial Using Single-Stage Wireless Permanent Implantable Devices.	0	1	1	0	0	0	1	1	0	1	1	6
10	Bergmann M, et al. The Effect of Functional Electrical Stimulation and Therapeutic Exercises on Trunk Muscle Tone and Dynamic Sitting Balance in Persons with Chronic Spinal Cord Injury: A Crossover Trial.	0	1	0	0	0	0	1	0	0	1	1	4

Table 4

Results after implantation of Epidural Stimulation Device in the human body

Level of Injury	No of patients	Therapy	Improvements	Not improvements
C5-C6	8	Laminectomy, Syringostomy and implantation of the Epidural Stimulation. Device Mapping and therapy were carried out after surgery for 35 days, then patient was discharged.	Standing with support Stepping with support Gross motor skill Balance Coordination Muscle mass Stamina Bowel control	Spasm Spasticity Bladder function Sweating ability
T6-T7	9		Standing with support Stepping with support Gross motor skill Balance Coordination Muscle mass Stamina Bowel control	Spasm Spasticity Bladder function Sweating ability

Results

According to literature review 10 studies showed that electro stimulation combined with exercise is an effective way to treat muscular atrophy. The muscles also gained the right tone. The patients can stand independently in sitting balance because trunk muscles are stronger.

In lower limbs we saw improvements in full-range passive ankle dorsiflexion and ankle clonus, but we do not see any other improvement in standing and balance.

While on the other hand, after implantation of Epidural stimulation device, we saw very big improvements. Patients can stand with support at a parallel bar when the Epidural Stimulation device is switched on.

Patients can lock his hips, which allows him to stand. While standing, patient has good upper trunk control, but limited lower trunk control. They apply more weight to his right leg than left leg. Patients can take steps with a walking frame, no hoist required, and is able to lift both feet when taking steps. They have very good coordination between left and right foot when taking steps. Patients do not require assistance with foot placement when taking short steps, but do when taking longer steps.

Patient's Gross Motor Skills have improved significantly, particularly ankle, hip, and knee flexion, and knee extension (kicking out) when Epidural Stimulation device is switched on. Patients have good static sitting balance, and no support is needed. However, during dynamic sitting, balance is poor due to weak lower trunk muscles. Static standing balance is good at the parallel bar.

Spasms and spasticity are reduced when Epidural Stimulation device is switched on. Muscle mass and endurance were improved upon discharge. There was no noticeable improvement to his neurogenic bladder and bowel.

Discussion

Patients with spinal cord injury usually encounter spasticity in their lower limbs. Although some patients utilize this spasticity to maintain muscle tone and some use it to assist them in transfer and ambulatory activities, it can also cause pain and dysfunction. Therefore, clinical decisions for spasticity treatment in patients with spinal cord injury should be made with caution. Spasticity should only be treated if the patient may have a significant improvement in function and/or quality of life after the treatment. The subjects recruited in the current study had developed different degrees of spasticity in their plantar flexors. This could make stretching of the calf muscles difficult and result in muscle tightness which in turn dampens the progress of functional training such as gait re-education.

Theoretically, the action of electrostimulation in reducing spasticity over the lower limbs post spinal cord injury could be mediated by two mechanisms: modulation of spinal inhibitory circuits and stimulation of the plasticity of the central nervous system. Pain and spasticity are interrelated in patients with spinal cord injury. It is possible that spasticity of patients with spinal cord injury could be reduced after pain treatments. However, it could be difficult to quantify pain in patients with spinal cord injury, as some of the patients may have complete loss of sensation below their waist.

Electrostimulation device is doing a very big revolution in treating patients with spinal cord injury. After implantation, patients follow a program with exercises which gives positive results in standing and coordination, which give independency to patients. This way, they feel useful for themselves. It is important to note that these multiple autonomic changes developed even though the stimulation parameters were aimed at influencing the motor system and the execution of specific motor tasks. The most important thing for a patient with spinal cord injury is controlling the bowel, but with this device and exercise we see improvements in controlling the bowel. We have previously shown that locomotor training alone was sufficient to induce significant improvements in multiple bladder parameters, such as

increased capacity, voiding efficiency, detrusor contraction duration, as well as decreased detrusor leak point pressure.

Animal models have shown that localization of epidural electrodes relative to the level of the dorsal roots plays a critical role in determining the intensity of stimulation required to activate select spinal circuit, and this dependency can vary at a submillimeter resolution. Monitoring intraoperative electrophysiological responses in real time allowed for precise placement of the epidural electrode array. By applying stimuli at multiple different regions of the spinal cord using specific electrode configurations, selective activation of spinal sensorimotor networks was achieved and interpreted from EES-evoked motor response recordings.

Darrow et al, 2019: Recovery of any volitional movement allows patients with complete SCI to participate in active rehabilitation exercises such as aided treadmill stepping, which have been shown to have positive long-term effects on walking capabilities. Insurance coverage for rehabilitation may be a result of prognostic factors for recovery. Injury severity is the greatest predictor of recovery, with motor complete injury having the least chance of recovery. The precise contribution of eSCS (Embryonic Stem Cells) to the restoration of volitional movement had been unknown because previous reports applied both pre-habilitation and eSCS in all participants. Although rehabilitation may play a significant role in recovery, especially in chronic SCI, these data raise questions about the relative importance and timing of intensive rehabilitation and eSCS. While physical therapy is clearly an important component of rehabilitation after SCI, the monetary costs and time investments required could preclude optimal efficacy. Our preliminary results indicate that eSCS, even in participants with long-standing injury, can immediately expand the capacity for volitional movement in participants with SCI. As such, eSCS may facilitate more significant rehabilitative therapy.

A recent similar study, utilizing stand and step training in individuals with SCI, documented one adverse event of a hip fracture in one of four participants, which was known to the investigators of this study before implementing that portion of the planned protocol. Multiple previous studies show an association between SCI and accelerated osteoporosis, which added to the context of the decision to forgo standing assessments. In a fashion similar to our remote data collection app, we hope a home rehabilitation program focused on improving bone density and atrophy during eSCS may result in candidacy for more advanced forms of therapy such as locomotor training in a safe and cost-effective manner.

Conclusion

This approach may eventually permit the complex sensorimotor integration in order to generate the most successful and functionally efficient locomotor output. However, as time-dependent changes occur in the circuitry with progression of stimulation and motor therapy, the initial segmental specificity and configurations might alter as well. Continuous improvements in electrophysiological techniques, further development of high-density electrodes, and understanding the mechanisms of spinal cord plasticity in preclinical studies will lead to the most effective therapies for regaining meaningful sensorimotor function after an SCI in humans. Along the same lines, inquiries stemming from clinical trials will need to be addressed experimentally using more clinically relevant injury models, such as incomplete SCIs that are more specific to the human.

Epidural stimulation device gives a simultaneous progress in basic research on spinal reflex circuits, organization of inputs to spinal intraneuronal populations, flexibility of operation of intraneuronal circuits and final common intraneuronal pathways, and on central pattern generators for locomotion. The possibility of activating spinal networks involved in generating functional synergistic movements, opens a new avenue with great potential for human neurophysiological studies of intrinsic spinal cord functional properties, and may contribute to the development of new methodologies, technologies, and clinical practice for restoration of movements in SCI people. Epidural stimulation gives hope for a normal life for patients with spinal cord injury.

Bibliography

1. Baldi JC, Jackson RD, Moraille R, Mysiw WJ. Muscle atrophy is prevented in patients with acute spinal cord injury using functional electrical stimulation. Spinal Cord. 1998;36(7):463-469. doi:10.1038/sj.sc.3100679
2. Ping Ho, Chung B, Kam Kwan Cheng B. Immediate effect of transcutaneous electrical nerve stimulation on spasticity in patients with spinal cord injury. Clin Rehabil. 2010;24(3):202-210. doi:10.1177/0269215509343235
3. Harvey LA, Fornusek C, Bowden JL, et al. Electrical stimulation plus progressive resistance training for leg strength in spinal cord injury: a randomized controlled trial. Spinal Cord. 2010;48(7):570-575. doi:10.1038/sc.2009.191
4. Giangregorio L, Craven C, Richards K, et al. A randomized trial of functional electrical stimulation for walking in incomplete spinal cord injury: effects on body composition. J Spinal Cord Med. 2012;35(5):351-360. doi:10.1179/2045772312Y.0000000041
5. Gorgey AS, Dolbow DR, Cifu DX, Gater DR. Neuromuscular electrical stimulation attenuates thigh skeletal muscles atrophy but not trunk muscles after spinal cord injury. J Electromyogr Kinesiol. 2013;23(4):977-984. doi:10.1016/j.jelekin.2013.04.007
6. Herrity AN, Williams CS, Angeli CA, Harkema SJ, Hubscher CH. Lumbosacral spinal cord epidural stimulation improves voiding function after human spinal cord injury. Sci Rep. 2018;8(1):8688. Published 2018 Jun 6. doi:10.1038/s41598-018-26602-2
7. Sivaramakrishnan A, Solomon JM, Manikandan N. Comparison of transcutaneous electrical nerve stimulation (TENS) and functional electrical stimulation (FES) for spasticity in spinal cord injury - A pilot randomized cross-over trial. J Spinal Cord Med. 2018;41(4):397-406. doi:10.1080/10790268.2017.1390930
8. Galea MP, Dunlop SA, Geraghty T, et al. SCIPA Full-On: A Randomized Controlled Trial Comparing Intensive Whole-Body Exercise and Upper Body Exercise After

Spinal Cord Injury. Neurorehabilitation and Neural Repair. 2018;32(6-7):557-567.
9. North RB, Calodney A, Bolash R, et al. Redefining Spinal Cord Stimulation "Trials": A Randomized Controlled Trial Using Single-Stage Wireless Permanent Implantable Devices. Neuromodulation: Technology at the Neural Interface. 2019;23(1):96-101. DOI: 10.1111/ner.12970
10. Bergmann M, Zahharova A, Reinvee M, Asser T, Gapeyeva H, Vahtrik D. The Effect of Functional Electrical Stimulation and Therapeutic Exercises on Trunk Muscle Tone and Dynamic Sitting Balance in Persons with Chronic Spinal Cord Injury: A Crossover Trial. Medicina (Kaunas). 2019;55(10):619. Published 2019 Sep 21. doi:10.3390/medicina55100619
11. Shealy CN, Mortimer JT, Reswick JB. Electrical inhibition of pain by stimulation of the dorsal columns: preliminary clinical report. Anesth Analg. 1967;46(4):489-491.
12. Shealy CN, Mortimer JT, Hagfors NR. Dorsal column electroanalgesia. J Neurosurg. 1970;32(5):560-564. doi:10.3171/jns.1970.32.5.0560
13. Waltz JM, Andreesen WH, Hunt DP. Spinal cord stimulation and motor disorders. Pacing Clin Electrophysiol. 1987;10(1 Pt 2):180-204. doi:10.1111/j.1540-8159.1987.tb05947.x
14. Herman R, He J, D'Luzansky S, Willis W, Dilli S. Spinal cord stimulation facilitates functional walking in a chronic, incomplete spinal cord injured. Spinal Cord. 2002;40(2):65-68. doi:10.1038/sj.sc.3101263
15. Bochkezanian V, Raymond J, de Oliveira CQ, Davis GM. Can combined aerobic and muscle strength training improve aerobic fitness, muscle strength, function and quality of life in people with spinal cord injury? A systematic review. Spinal Cord. 2015;53(6):418-431. doi:10.1038/sc.2015.48
16. Sandrow-Feinberg HR, Houlé JD. Exercise after spinal cord injury as an agent for neuroprotection, regeneration and rehabilitation. Brain Res. 2015;1619:12-21. doi:10.1016/j.brainres.2015.03.052
17. Harkema SJ. Neural plasticity after human spinal cord injury: application of locomotor training to the rehabilitation of walking. Neuroscientist. 2001;7(5):455-468. doi:10.1177/107385840100700514
18. Hicks AL, Adams MM, Martin Ginis K, et al. Long-term body-weight-supported treadmill training and subsequent follow-up in persons with chronic SCI: effects on functional walking ability and measures of subjective well-being. Spinal Cord. 2005;43(5):291-298. doi:10.1038/sj.sc.3101710
19. Johnson MI, Bjordal JM. Transcutaneous electrical nerve stimulation for the management of painful conditions: focus on neuropathic pain. Expert Rev Neurother. 2011;11(5):735-753. doi:10.1586/ern.11.48
20. Ngamkham S, Vincent C, Finnegan L, Holden JE, Wang ZJ, Wilkie DJ. The McGill Pain Questionnaire as a multidimensional measure in people with cancer: an integrative review. Pain Manag Nurs. 2012;13(1):27-51. doi:10.1016/j.pmn.2010.12.003

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