Review Study on the Effect Surface Spinal Stimulation on Autonomic Nervous System in Spinal Cord Injury Patient

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Abstract

Background: Spinal cord injury is a disabling condition can lead to various autonomic disturbances of thermoregulatory dysfunction, autonomic hyperreflexia, vasomotor dysfunction, and bowel and bladder dysfunction. Different treatment techniques have been used for its management. In the present study, surface spinal stimulation has been used to find the effect on bladder, on skin resistance and skin temperature through comparing pre and post- treatment on a male with spinal cord injury.

Method: A 29-year-old-male suffered complete spinal cord injury at level D12 during a car accident. The case was diagnosed and treated for compression fracture of D11-D12 with paraplegia with bowel and bladder dysfunction. The subject was administered surface spinal stimulation with a carrier frequency of 2500 Hz, beat frequency 20 Hz applied continuously for 45 min with two adhesive rectangular electrodes of size (4.5x 9cm) placed on each side of supine 5cm apart over T10- L2 level paravertebrally. *Results and Conclusion:* The present study found that surface spinal stimulation with medium frequency current of beat frequency 20 Hz was effective in improving detrusor pressure, bladder sensations, infused fluid volume and bladder capacity of the patient with spinal cord injury. Electrical stimulation over the paravertebral region also demonstrated improvement in the skin resistance, but had no significant effect over skin temperature.

KEY WORDS: **Surface spinal cord stimulation, Autonomic nervous system, Thermoregulation, Skin resistance, Bowel and bladder control.**

Introduction

Spinal cord injury (SCI) is a global epidemic, and was considered as “untreatable ailment” decades ago. This disabling condition causes paralysis of voluntary musculature which leads to reduced mobility as well as impairment of vocational and self care activities. *(Sunder, 2010).* According to the Indian statistics, about 20 percent of all spinal injuries lead to neurological deficit in the form of paraplegia following thoraco-lumbar spine injuries, or quadriplegia following cervical spine injuries *(Maheshwari, 2006).* The causes of injury could be direct or indirect spinal trauma which causes damage to the cord and the symptom may vary according the level of injury. Cord involvement following neurological lesion could be complete or incomplete. After spinal cord injury, patient presents with primary and secondary complications depending upon the level and type of injury. These complications could be musculo-skeleton and autonomic disturbances.

Date of Communication: Sep.17, 2013
Date of Acceptance: Dec. 28, 2013
SJIF IMPACT FACTOR 2013=4.65

The common autonomic disturbances following spinal cord injury are thermoregulatory dysfunction, autonomic hyperreflexia, vasomotor dysfunction, bowel and bladder dysfunction. The Autonomic Nervous System (ANS) plays a key role in the regulation of many physiologic processes, mediated by supraspinal control from centers in the central nervous system. Disruption of spinal cord decreases the ability to sympathetically control blood pressure and to regulate body temperature, most likely due to the impairment of autonomic and somatic nervous systems *(Hutchinson, 1875).* This condition is described as partial poikilothermia; ability to increase heat production by shivering is decreased. The ability of the body to sweat and to vasodilate the skin is impaired in the area below the spinal lesion *(Attia et al., 1983).* The vasomotor changes following SCI include disturbance or complete loss of internal thermal regulatory responses, causes of this is bladder or rectal distension, pressure sores, urinary stones, bladder infection, urethral or bladder irritation and environmental temperature changes.

Bladder dysfunction has been reported as a serious medical complication following spinal cord injury. There are two main type of bladder dysfunction observed after spinal cord injury, either the patient is unable to store the urine or experiences failure to empty it. The failure to store the urine is detrusor hyperreflexia, often seen in patients above L1, and is characterized by both detrusor and sphincter overactivity, with both contracting reflexively when stretched. This built higher pressures in bladder leads to incontinence, incomplete emptying and reflux. Second type of bladder dysfunction is detrusor-sphincter dyssynergia—impaired coordination between bladder contraction and sphincter relaxation—is also a common finding in patients with SCIs.

Primary goal of bladder management is to empty the bladder under low pressure to prevent renal failure and maintain continence, treatment should be acceptable to the individual. Management of bladder includes periodic complete emptying of bladder with clean intermittent catheterization which is one of the effective ways to manage the patient with detrusor hyperreflexia and incontinence. Common approaches for bladder management include behavioral therapy, catheters, pharmacotherapy and electro-stimulation. Electrical stimulation over the sacral afferent nerves has reported to reduce incontinence and hyperactivity of bladder *(Young et al., 2002).* Sacral anterior root stimulation, S3 neuro-modulation, pudenendal nerve stimulation, anal or vaginal and more general surface spinal stimulation have been evaluated for various conditions, such as stress incontinence, irritative syndrome and to reduce external urethral sphincter spasm *(Amarenco, 2003).*

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Spinal cord stimulation through epidural and surface electrodes was first used for the management of intractable pain, later it has also been for the rehabilitation of multiple sclerosis and other chronic neurological disorders. The workers working with the patients with multiple sclerosis generally observe that the main benefits of spinal cord stimulation are in bladder function *(Abbate et al., 1977).* Following spinal stimulation clinical and urodynamic improvement in the bladder dysfunction has been reported in spinal cord injury *(Richardson and McLone, 1978),* cerebral palsy *(Campos et al., 1978)* and in multiple sclerosis. Apart from the effect on bladder, little attention has been given to the other effects that spinal stimulation may have upon the autonomic nervous system. It was reported that patients with peripheral vascular diseases experience sensation of warmth and alternations in blood flow in the skin after spinal stimulation *(Tallis et al., 1983).* Researcher considers that surface spinal stimulation can influence the function of bladder, skin resistance and skin temperature. The present study was to aimed at finding the effect of surface spinal stimulation on bladder, on skin resistance and skin temperature through comparing pre and post values of urodynamics testing, galvanic skin response and Infra-red thermometer.

Case Report:

A 29 years old male, met with a car accident on April, 2011. His present chief complaints were inability to walk independently, irritation and difficulty in passing the urine. After the accident the patient was taken to the nearest hospital at Shimla. After emergency acute care, patient was referred to NIMS hospital, Mohali. The CT scan and MRI revealed spinal cord injury and D12 compressed fracture. The patient was diagnosed with T12 compressed injury with lower limb paraplegia and bladder and bowel involvement. The patient underwent fixation at D11-L1 level and kept in the hospital for 15 days. He received physiotherapy treatment session from NIMS and Ivy hospital, Mohali. The subject was catheterized for initial 3 months and after that patient was advised to use clean intermittent catheterization after self-voiding. Patient has been taking pruflox (600 mg) to avoid urinary tract infections and medicine for constipation. At rehabilitation centre of Ivy hospital, patient received passive range of motion exercises and stretching for hamstrings, quadriceps and calves. He did standing and walking in parallel bars with hip-knee-foot orthosis (HKFO), balance training on swiss ball and posture training in front of mirror. Patient also did exercises to improve his functional status.

On examination, the vitals of the patient were normal. No abnormality of skin was observed, mid-pitting odema over both ankles was observed. Patient had old scars and marks of stitches were

Date of Communication: Sep.1t, 2013
Date of Acceptance: Dec. 28, 2013

seen over nose and forehead. Patient had developed tightness of left dorsiflexors and foot drop deformity on right side. Patient was able to walk with HKFO and walker under supervision, but was able to use wheelchair independently. The patient was cooperative, alert and well oriented to time, place and person. The higher mental function and cranial nerves were normal. The superficial sensation of light touch, temperature, pin prick and deep sensations were intact upto L4 level. Superficial anal and bulbocavernous reflex were absent. The deep reflexes i.e. biceps, triceps, supinator reflexes were intact and knee jerk, ankle jerk and plantar reflex were absent. The patient had flexor spasm and was caused by any noxious stimulation to the feet.

Materials & Methods

The patient was intructed to lie in the supine position and eight skin temperature measuring sites were marked over the lower limb. Skin temperature was recorded with the help of hand held thermometer (IRL 300, Kusam-Medico), at the distance of 10-15 cm. Cystometric values of prior to surface spinal stimulation, cystometric values of infused fluid volume (IV), detrusor pressure (Pv), first sensation (FS), first desire (FD), normal desire (ND) and bladder capacity (BC) were measured. The actual and basal galvanic skin responses were recorded using galvanic skin meter (GBF-2000, Medic Aid) via applying probes over the 2nd and 4th toe of right foot for 10 to 15 minutes. The surface spinal stimulation with a carrier frequency of 2500 Hz, beat frequency 20 Hz was applied continuously for 45 min with two adhesive rectangular electrodes of size (4.5x9cm) placed on each side of supine 5cm apart over T10-L2 level paravertebrally *(Wang et al., 2000).* Then post-surface spinal stimulation values of cystometric values, GSR and infrared thermometer were recorded in the patient after electrical stimulation.

Results:

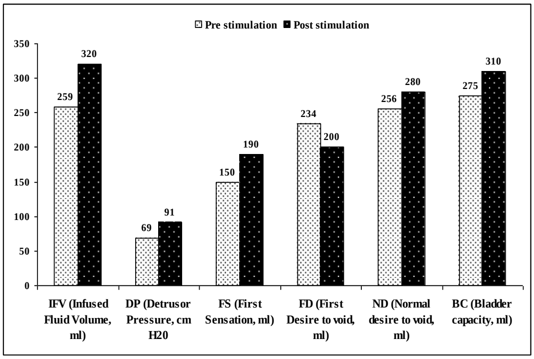

Figure 1: Comparison of Mean Value of Cystometric Variables at Pre- Intervals within the group

Table 1: Staistical comparison of skin temperature measured from thigh area.

Comparison	PRE Vs POST	
	t value	P value
RTAn (°C)	-2.138	P < 0.05
LTAn (°C)	-2.500	P < 0.05
RTPs (°C)	-2.138	P < 0.05
LTPs (°C)	-2.138	P < 0.05
RTLa (°C)	-2.500	P < 0.05
LTLa (°C)	-2.138	P < 0.05
RTM (°C)	-2.138	P < 0.05
LTM (°C)	-2.138	P < 0.05

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The pre and post-stimulation values of three measures were compared. The infused fluid volume (IV) on cystometry of the patient before stimulation was 259 ml and after stimulation was 320 ml. The pre-stimulation detrusor pressure (Pv) of patient was 69cm H_2O, while post-stimulation value was 91cm H2O. The pre-stimulation first sensation (FS) was felt at 150 ml and post-stimulation first sensation was at 190 ml. The pre-stimulation first desire (FD) to void was at 234 ml and post-stimulation value was 200 ml. Pre-stimulation normal desire (ND) to void was 256 ml and post-stimulation value was 280 ml. Bladder capacity on pre-stimulation cystometry was 275 ml and on post-stimulation cystometry was 310 ml. The after stimulation cystometric values of IV, Pv, FS and BC were improved as presented in figure 1.

Table 2 : Staistical comparison of skin temperature of calf and foot areas.

Comparison	PRE Vs POST	
	t value	P value
RCA(°C)	-4.000	$P < 0.05$
LCA(°C)	-4.000	$P < 0.05$
RCP(°C)	-2.138	$P < 0.05$
LCP(°C)	-2.138	$P < 0.05$
RFD(°C)	-1.177	$P > 0.05$
LFD (°C)	-1.633	$P > 0.05$
RFP (°C)	-0.784	$P > 0.05$
LFP (°C)	-0.784	$P > 0.05$

The pre-stimulation values of actual galvanic skin resistance was76 kΩ and post-stimulation values was 246 kΩ. The pre and post-stimulation values basal galvanic skin resistance were 84 kΩ and 271 k Ω (figure 2). The pre-stimulation skin temperature over the thigh area of right leg were 31°C on anterior aspect, 33°C on posterior aspect, 32°C on lateral aspect and 30°C on medial aspect. The post-stimulation values of right thigh were 30°C on anterior aspect, 29°C on posterior aspect, 29°C on lateral aspect and 29°C on medial aspect (figure 3). The pre-stimulation skin temperature of left thigh were 31°C on anterior aspect, 31°C on posterior aspect, 30°C on lateral aspect and 30°C on medial aspect. The post-stimulation values of left thigh were 30°C on anterior aspect, 30°C on posterior aspect, 30°C on lateral aspect and 32°C on medial aspect (Fig.4).

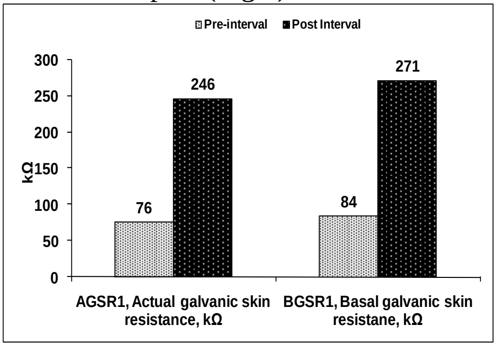

Figure 2: Comparison of Mean Values of AGSR (Actual Galvanic Skin Resistance) and BGSR (Basal Galvanic Skin Resistance) before and after stimulations.

The right foreleg pre-stimulation values 30°C on anterior aspect and 30°C over posterior aspect. The post-stimulation values of right foreleg were 29°C over anterior and 31°C over posterior aspect. Pre-stimulation values of left foreleg over anterior aspect 29°C, over posterior aspect 29°C and post-stimulation values of left foreleg over anterior aspect 30°C, over posterior aspect 30°C (Fig-5). The pre-stimulation value of right dorsal aspect 32°C, right planter aspect 32°C and post-stimulation value of dorsal aspect was 33°C and planter aspect

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was 33°C. The pre-stimulation values of left dorsal aspect was 27°C, 29°C over left planter aspect and post-stimulation value of left dorsal aspect was 29°C and 29°C over left planter aspect.

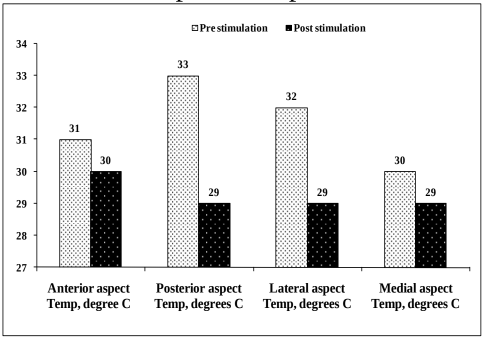

Figure 3: Comparison of Mean Values of Pre- and Post- stimulation Skin Temperature of Right Thigh

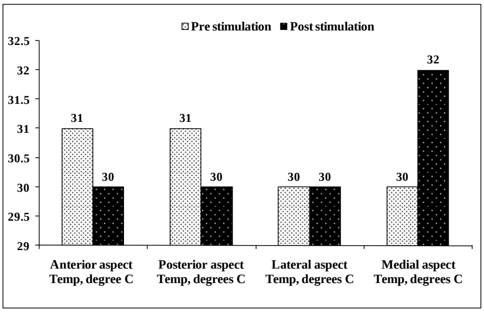

Figure 4: Comparison of Mean Values of Pre- and Post- stimulation Skin Temperature of Left thigh.

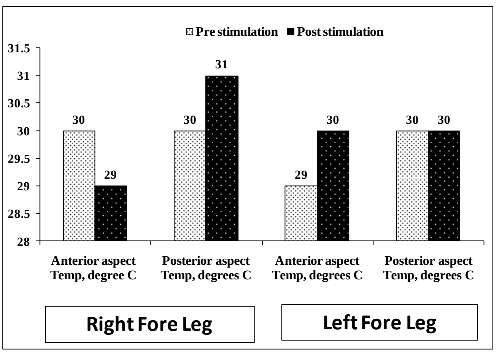

Fig 5: Comparison of Mean Values of Pre- and Post-stimulation Skin Temperature of right & left forelegs.

Discussion

The results of this experimental study demonstrated that surface spinal stimulation improved the cystometric values and skin resistance in spinal cord injury subject. The cystometric values of urodynamics are subjective tool, to assess bladder function. In present study, inhibitory effect of stimulation was observed over the bladder sensations, which increased bladder capacity. The results of the study were in accordance with two studies reported significant reduction of bladder sensations following electrical stimulation of tibial and pudendal nerve stimulation due to inhibitory effect of sacral afferent pathways in hyperreflexic bladder and by depolarization of somatic sacral afferent fibers *(Young et al, 2002; Amerenco et al, 2003).* The possible explanation for the findings was that the low frequency stimulation of 5 Hz, shown optimal inhibitory effect and high frequency current of 50 Hz, reported to achieve urethral closure *(Previnaire et al, 1998).*

Parasympathetic electrical stimulation may activate large diameter afferent fibers of paravertebral region, which may modulate the interneuronic activities of several spinal segments. The same method of electrical stimulation proposed to improve control of stretch reflex and to modulate the transmission of afferent or efferent impulses resulting from generalized desensitization of spinal pathways *(Wang et al., 2000). Brindley (1973)* reported that the smooth muscles

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of detrusor relax more slowly than the striated muscles of urethral sphincter, develop pressure gradient and cause micturition. Sympathetic skin changes are under the control of autonomic nervous system. The results of the present study shown improvement in GSR values following electrical stimulation and the reason for this may be anatomy of conductive pathway in the lower limb from spinal cord at lower thoracic cord (T9-10) *(Ogura et al, 2004).* The intact sympathetic conductive pathway may remains intact in the patient.

Post-stimulation results shown mild improvement in skin temperature and were supported by *Attia et al. (1983),* observed increase in the muscle temperature of 2.9°C, deep body temperature increase 36.9 ± 0.1°C in response electrically induced exercise for 30 min. The sentient skin areas are involved both in sensation and in the autonomic thermoregulatory responses. The possible underlying mechanism of increase skin temperature, below the interrupted autonomic dermatome level in SCI, were the presence of some local reflexes of vasoconstriction and dilation. The immediate increase in the skin temperature following stimulation can be due to the stimulation of A-delta and C-afferent fibers and local vasodilation over the skin. Increase in muscle and skin blood flow of foot occurred due to inhibition of alpha adrenergic vasoconstrictor fibers and stimulation of cholinergic vasodilator fibers *(Rhonda et al, 1995).*

On the basis of results and discussion, present study concluded that surface spinal stimulation has effect over cystometric values of urodynamics, skin resistance and skin temperature in subjects with spinal cord injury. The present study found that surface spinal stimulation with medium frequency current of beat frequency 20 Hz was effective to improve detrusor pressure, bladder sensations, infused fluid volume and bladder capacity of the patient with spinal cord injury. Electrical stimulation over the paravertebral region shown also improvement in skin resistance, but had no significant effect over skin temperature.

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