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Efficacy of TENS in restoring sensory and motor responses in canine spinal cord injury#

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Abstract

Spinal cord injury (SCI) causes remarkable loss of neurological function in dogs. Many therapeutic studies have been conducted, aiming to improve overall function which invariably includes physical rehabilitation. The current study was conducted to evaluate the effect of transcutaneous electrical nerve stimulation (TENS) as an adjunct therapy for SCI in dogs. The present study used a multimodal approach, aiming to ameliorate neurological recovery. The study was conducted on twelve dogs of different age, breed, sex and body weight, presented with clinical signs of SCI. Clinical, neurological and radiographical investigations were made on the day of presentation for localising the lesions. The dogs were randomly divided into two groups Group I and II. Group I was treated with single dose of methyl prednisolone sodium succinate (MPSS) and two doses of polyethylene glycol (PEG) at 48 hours interval intravenously, followed by oral administration of prednisolone while the other group, received TENS therapy for 10 days in addition to the protocol in Group I. All the selected dogs were subjected to clinical and neurological examinations at regular intervals up to eight weeks to assess the efficacy of the treatment employed. All the parameters of clinical and neurological examinations were given grades and scored individually and comparison was made between two groups from the day of presentation to the end of the study. Clinical recovery, neurological grading and the time of recovery were taken into consideration to analyse the efficacy of both treatment protocols. Based on the results of clinical and neurological examination, TENS group was more effective than the group without physiotherapy.

Keywords: *Spinal cord injury, neurological examination, TENS, physiotherapy*

Spinal cord injury (SCI) is a dreadful condition that causes considerable loss of sensory, motor and autonomic functions. The most common aetiologies of SCI in dogs are Hansen type I disc disease, exogenous traumatic events and infarction due to ischemia (Sulla *et al*., 2018a). The pathophysiology of SCI is biphasic which includes primary injury brought on by direct mechanical damage and the subsequent secondary injury brought on by complicated cellular responses which ultimately results in glial scar formation (Alizadeh *et al*., 2019). Neurological signs depend on the location, size and type of the spinal cord lesions (Dewey, 2008). Diagnosis is based on neurological examination,

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Fig. 1. Transcutaneous electrical nerve stimulator

Fig. 2. Application of TENS therapy

Fig. 3. Paraplegic gait

Fig. 4. Absence of conscious proprioception

Fig. 5. Hopping response

Fig. 6. Pedal reflex

Fig. 7. Patellar reflex

Fig. 8. Deep pain perception

plain radiography, myelography, epidurography, computed tomography (CT) and/or magnetic resonance imaging (MRI) (Sulla *et al*., 2018b). Therapeutic measures include methylprednisolone sodium succinate (MPSS), surgical decompression or stabilisation, biomaterials, neurotrophic drugs and physical rehabilitation (Hachem *et al*. 2017). The benefits of MPSS included the preservation of blood flow to the spinal cord, inhibition of lipid peroxidation and enhancement of ionic homeostasis (Nishida *et al*., 2016). When administered intravenously, polyethylene glycol, a hydrophilic polymer, acts as a fusogen, providing sealing effect on damaged membranes and prevents lesion spread (Borgens and Shi, 2000). Methylcobalamine, a neurotropic drug, is required for the synthesis of methionine which is essential for maintaining the integrity of myelin (Hemendinger *et al*., 2011). Pregabalin is considered a first line of treatment for neuropathic pain which acts on calcium channels in the CNS resulting in reduced synthesis of pronociceptive transmitters and facilitated spinal cord's descending pain inhibitory pathways (Walsh, 2016). Enhancing muscle tone and mobility, reactivating preserved intramedullary circuits, preserving current neural cell connections and encouraging synaptogenesis, myelination and neurite sprouting are the benefits of physical rehabilitation (Sulla *et al*., 2018b). Significant research efforts in the field of electrical stimulation therapies have shown promising improvements which includes epidural electrical stimulation, peripheral nerve stimulation and functional electrical stimulation. The mode of action of TENS, a type of peripheral nerve stimulation involves activation of A-beta nerve fibre which closes the pain gate (pain gate theory) (Strand *et al*., 2021). In addition to this, action potential created in these nerve fibres is further carried to multiple synaptic junctions, interneurons and motor neurons which helps to improve locomotor function following SCI (Dorrian *et al*., 2023). Majority of the dogs with SCI suffer from chronic neuropathic pain that is often refractory to interventions. While treatment options to improve outcomes remain limited, significant research efforts in the field of electrical stimulation have produced encouraging breakthroughs. Hence, the present study was aimed at assessing the effectiveness of TENS in the overall recovery of canine SCI as well as the effectiveness of a combinatorial treatment approach.

Materials and methods

The study was conducted in 12 dogs with clinical signs of SCI, presented to the University Veterinary Hospitals at Mannuthy and Kokkalai over a period of 13 months, irrespective of age, breed, gender and body weight.

Dogs underwent detailed general, clinical and neurological examinations. Lesions were localised through neurological examination and the condition was graded according to Tartarelli *et al*. (2005). Orthogonal radiographic views of the suspected area of spinal cord were evaluated. The selected dogs were randomly divided into two groups *viz.*, Group I and Group II. Dogs of both groups were given single dose of intravenous MPSS at the rate of 30 mg/kg body weight and two doses of 30 per cent solution of polyethylene glycol (M.W.4000 Da), at the rate of 4 mL/kg body weight on the day of presentation and at 48 hours interval followed by oral administration of prednisolone at the rate of 1 mg/kg body weight at divided and tapering doses for next 10 days. In Group II, in addition to the above-mentioned protocol, dogs were subjected to transcutaneous electrical nerve stimulation (Fig. 1) at high frequency (100 Hz) and low intensity [30 - 50 mA (*i.e.* started at 30 mA and increased up to 50 mA in subsequent days until a paraesthesia seen or according to patient's tolerability)]. The electrodes were applied (Fig. 2) over the area of spinal hyperpathia (paravertebral) for 10 minutes, daily up to 10 days starting from the day of presentation. All dogs were given oral supportive therapy with methylcobalamine at the rate of 1500 mcg daily for four weeks and pregabalin at the rate of 2.0 mg/kg body weight for 10 days. Both clinical and neurological examinations were conducted on the day of presentation and on Days-7, 14, 21, 28, 42 and 56.

Results and discussion

The signalment and anamnesis of the animals included in the study are given in the Table 1. The incidence was found highest in dogs of age 4 to 6 years and dachshund was the most represented breed in the present study. No sex predisposition was noticed and

Table 1. Signalment and anamnesis

Serial no.	Animal no.	Age (years)	Breed	Sex	Body weight (kg)	Duration of illness (days)	Aetiology
1	I_1	6	Dachshund	Male	9.5	4	Fall from height
2	I_2	3	Non-descript	Female	5.5	1	Fall from height
3	I_3	4	Dachshund	Female	13.6	14	Unknown
4	I_4	1	Rottweiler	Female	37	1	Unknown
5	I_5	1	Siberian Husky	Female	8.8	1	Road Traffic Accident (RTA)
6	I_6	5	Dachshund	Male	9.7	5	Unknown
7	II_1	2	Shih Tzu	Male	6.3	1	Unknown
8	II_2	5	Non-descript	Female	14	2	RTA
9	II_3	6	Dachshund	Male	14	4	Unknown
10	II_4	6	Dachshund	Male	13	2	Unknown
11	II_5	8	Dachshund	Male	10.5	4	Unknown
12	II_6	6	Dachshund	Female	8	2	Unknown

Table 2. Gait improvements across study period

Group	Reflex	Number of animals						
		Day 1	1st wk	2nd wk	3rd wk	4th wk	6th wk	8th wk
I	+	6	4	3	3	3	3	3
	++	-	2	3	1	-	-	-
	+++	-	-	-	2	1	-	-
	++++	-	-	-	-	2	3	3
II	+	6	2	1	1	1	1	1
	++	-	1	2	2	1	1	1
	+++	-	-	-	-	1	-	-
	++++	-	3	3	3	3	4	4

+ Paraplegia/diplegic ++ Severe ataxia +++ Occasional ataxia ++++ Normal gait most of the dogs presented were having body weight less than 10 kg. The exciting cause was unknown in eight cases but remaining had history of trauma such as road traffic accident (RTA) and falling from height. The day of presentation to hospital ranged from day 1 to 14 after the onset of clinical signs. This was consistent with the findings of Salumol (2021).

Clinical signs included gait abnormalities ranging from non-ambulatory paraparesis to paraplegia (Fig. 3), proprioceptive deficits and neuropathic pain. Bladder dysfunction with spastic and flaccid tonicity were observed and the symptoms were urine retention and incontinence respectively. This was in accordance with the findings of Amendt *et al.* (2017).

All the dogs of both groups were found alert except two dogs in Group I on the day of presentation and the depressed dogs became alert in the subsequent week. Transient depression might be caused by systemic problems following SCI (Lorenz *et al*., 2011). Posture was ranging from recumbent to sitting on the day of presentation. Three dogs in Group I and five dogs in Group II were able to stand without support by the end of the study. Improvement was found earlier (first week) in 50 per cent of dogs in TENS group. On the day of presentation, gait was ranging from non-ambulatory paraparesis to paraplegia in all the dogs under study. By the end of the study, normal gait was regained in three dogs of Group I and five dogs of Group II. Fifty per cent of dogs in TENS group recovered by first week of treatment itself (Table 2). Cho *et al*. (2012) reported improved gait function in an experimental study of high frequency (HF) TENS therapy for SCI in rats.

Postural reactions were the intricate responses that regulates posture and movement. It helped in assessing the integrity of general proprioceptive pathways (De Lahunta *et al*., 2021).

Conscious proprioception was found to be normal in forelimbs and absent to normal in hindlimbs on the day of presentation in both the groups (Fig. 4). At the end of the study, normal proprioception in hindlimbs was observed in three dogs of Group I and five dogs of Group II in which, TENS group showed earlier recovery (first week) in 50 per cent of dogs (Table 3). This could be due to neuronal regeneration following TENS therapy which was reported by Sohn *et al*. (2019) in rat model following TENS therapy for SCI.

On the day of presentation, tactile placing reaction was found impaired in hindlimbs and normal in forelimbs of all dogs under the study. At the final assessment, the placing reaction was returned to normal in three and four dogs of Group I and Group II respectively and it was found earlier (first week) in 50 per cent of the dogs in the TENS group. Cho *et al*. (2012) reported that there was progressive return of placing reflex in rats with SCI following TENS therapy.

Hopping reaction test being the sensitive one, was found normal in forelimbs and it was abnormal in hindlimbs of all the dogs (Fig. 5) when presented in which three dogs of Group I and five dogs of Group II restored normal response by the last week of the study. Earliest recovery (second week) was appreciated in TENS group in half of the dogs (Table 4).

Table 3. Strengths of conscious proprioception across study period

Group	Reflex	Number of animals													
		Day 1		1st wk		2nd wk		3rd wk		4th wk		6th wk		8th wk	
		L	R	L	R	L	R	L	R	L	R	L	R	L	R
I	A	6	6	3	3	2	2	2	2	2	2	2	2	2	2
	D	-	-	3	3	4	4	1	2	1	2	1	1	1	1
	N	-	-	-	-	-	-	3	2	3	2	3	3	3	3
II	A	6	6	2	2	1	1	1	1	1	1	-	-	-	-
	D	-	-	1	1	2	2	1	1	1	1	2	2	1	1
	N	-	-	3	3	3	3	4	4	4	4	4	4	5	5

L-left hind limb R-right hind limb A-absent D-delayed N-normal

Table 4. Strengths of hopping reaction across study period

Group	Reflex	Number of animals													
		Day 1		1st wk		2nd wk		3rd wk		4th wk		6th wk		8th wk	
		F	H	F	H	F	H	F	H	F	H	F	H	F	H
I	P	6	-	6	-	6	-	6	2	6	3	6	3	6	3
	A	-	6	-	6	-	6	-	4	-	3	-	3	-	3
II	P	6	-	6	2	6	3	6	3	6	4	6	4	6	5
	A	-	6	-	4	-	3	-	3	-	2	-	2	-	1

F– forelimb H – hindlimb P – present A – absent

Table 5. Strengths of pedal reflex across study period

Group	Reflex	Number of animals													
		Day 1		1st wk		2nd wk		3rd wk		4th wk		6th wk		8th wk	
		L	R	L	R	L	R	L	R	L	R	L	R	L	R
I	0	2	2	2	2	1	1	1	1	-	-	-	-	-	-
	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1
	2	1	1	2	2	3	3	3	3	5	5	5	5	5	5
	3	2	2	1	1	-	-	-	-	-	-	-	-	-	-
II	0	2	2	-	-	-	-	-	-	-	-	-	-	-	-
	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-
	2	1	1	4	4	5	5	5	5	6	6	6	6	6	6
	3	2	2	1	1	-	-	-	-	-	-	-	-	-	-

0-Absent 1- Sluggish 2-Normal 3-Exaggerated L-left hindlimb R-right hindlimb

Table 6. Grades of patellar reflex across study period

Group	Reflex	Number of animals													
		Day 1		1st wk		2nd wk		3rd wk		4th wk		6th wk		8th wk	
		L	R	L	R	L	R	L	R	L	R	L	R	L	R
I	0	2	2	2	2	2	2	2	2	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	2	2	2	2	2	2
	2	2	2	2	2	4	4	4	4	4	4	4	4	4	4
	3	2	2	2	2	-	-	-	-	-	-	-	-	-	-
II	0	2	2	1	1	-	-	-	-	-	-	-	-	-	-
	1	1	1	-	-	1	1	1	1	1	1	1	1	1	1
	2	1	1	4	4	4	4	4	4	4	4	5	5	5	5
	3	2	2	1	1	1	1	1	1	1	1	-	-	-	-

0-Absent 1- Sluggish 2-Normal 3-Exaggerated L-left hindlimb R-right hindlimb

On both sides, hemi-walking was abnormal in all the dogs when presented. Following treatment, three dogs in Group I and five dogs in Group II restored normal response in which, the response was noticed by first week itself in half of the dogs of TENS group. Wheel barrowing response was found normal in forelimbs of all the dogs throughout the study period. This was in accordance with that of Ansari (2012). Abnormalities were not observed in menace reflex, pupillary light reflex, corneal reflex and gag reflex indicating intact function of cranial nerves.

The strength of pedal reflex was normal in forelimbs and absent to exaggerated in hindlimbs of all the dogs when presented (Fig. 6). It became normal in all the six dogs of Group II whereas only in five dogs of Group I by eighth week of treatment. Majority of dogs in TENS group showed earlier recovery (second week) (Table 5). Cho *et al*. (2012) reported restoration of withdrawal reflex in rats with SCI following TENS therapy.

On the day of presentation, the strength of patellar reflex was ranging from absent to exaggerated in all the dogs (Fig. 7) which became normal in four dogs of Group I and five dogs of Group II by the end of the study. Majority of dogs showed improvement by first week in TENS group (Table 6).

The biceps and triceps tendon reflexes were found normal in forelimbs of all the dogs from the day of presentation to the end of the study period. The perineal reflex was ranging from absent to normal when presented. All the six dogs in each group regained normal reflex by the end of study, but the earliest recovery (first week) in majority of dogs was observed in TENS group.

Cutaneous trunci reflex was ranging from absent to exaggerated on the day of presentation which became normal in five dogs of each group by the end of study period but, earliest recovery (third week) in majority of dogs was observed in TENS group.

In all the dogs, the strength of deep pain perception was ranging from sluggish to normal when presented (Fig. 8). Five dogs in Group I and all the six dogs in Group II regained normal response by the end of study period. Earliest recovery (fourth week) was observed in Group II.

On gentle palpation of vertebral column at thoraco-lumbar and lumbar segment, spinal hyperaesthesia was elicited in all the dogs on the day of presentation. Following treatment, pain got abolished in five dogs of Group I and all the six dogs of Group II by the end of the study. Earliest pain management (second week) in majority of dogs was observed in TENS group. This was in accordance with the findings of Krstic *et al*. (2010).

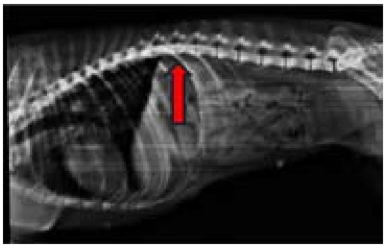


Fig. 9. Intervertebral space narrowing

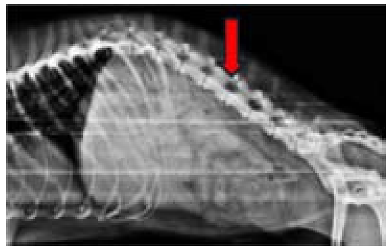


Fig. 10. Vertebral end plate sclerosis

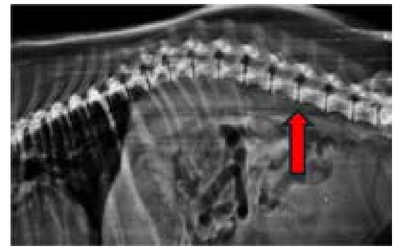


Fig. 11. Enthesophyte formation

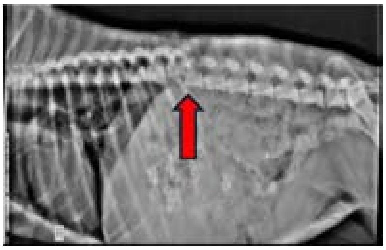


Fig. 12. Vertebral luxation

Fig. 13. Intervertebral disc calcification

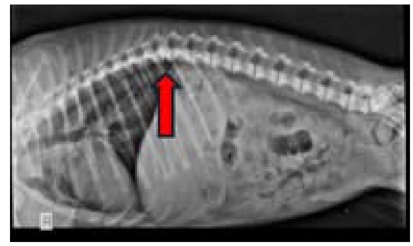
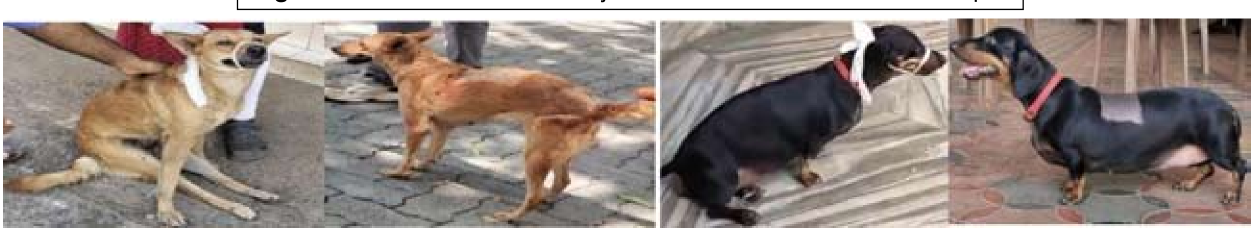


Fig. 14. Vertebral compression fracture

Fig. 15. Observations on recovery before and after treatment in Group I

Day 1 | Day 28 | Day 1 | Day 21

Fig. 16. Observations on recovery before and after treatment in Group II



Day 1 | Day 28 | Day 1 | Day 4

Bladder dysfunction was present in all dogs except two dogs (one from each group) on the day of presentation and they were graded as spastic or flaccid bladder. At the conclusion of study, five dogs in Group I and all the six dogs in Group II regained normal bladder function. Earlier recovery (fourth week) was found in TENS group. This was in accordance with the findings of Parittotokkaporn *et al*. (2021). The results of neurological examination were in accordance with the findings of Cho *et al.* (2012) who reported improvement in neurological reflexes in rats with SCI following TENS therapy. Based on results of clinical signs and neurological examination, dogs were graded according to Tartarelli *et al*. (2005) which included Grade 0 - normal with no neurological deficits, Grade I - spinal hyperesthesia only, Grade II - ambulatory paraparesis, Grade III - non-ambulatory paraparesis, Grade IV – paraplegia, Grade V - paraplegia with urinary incontinence and Grade VI - paraplegia, urinary incontinence and absence of deep pain sensation. In both the groups, three dogs were in grade V, two dogs were in grade IV and one dog was in grade III on the day of presentation. Following treatment, three dogs in Group I and four dogs in Group II improved to Grade 0 by the end of the study. But the earliest recovery (first week) in 50 per cent of dogs were reported in Group II.

Orthogonal radiographic views were obtained to identify the segment of vertebral column suspected of having lesions. Different lesions like intervertebral space narrowing (Fig. 9), vertebral endplate sclerosis (Fig. 10) at T_{11}-T_{12}, T_{12}-T_{13}, L_2-L_3, L_3-L_4 and L_4-L_5 and intervertebral disc calcification (Fig. 13) at L_6-L_7 and L_7-S_1 were identified in a few dogs of both the groups which were suggestive of intervertebral disc degeneration (Lamb *et al.,* 2002). Enthesophyte formation (Fig. 11) was also observed which was suggestive of spondylosis deformans (Widmer and Thrall, 2018). One dog had vertebral compression fracture (Fig. 14) and one dog had vertebral luxation (Fig. 12) at T_{11} and T_{13}-L_1 respectively (Bali *et al*., 2009).

In Group I, two dogs (I_2 and I_5) became ambulatory by 21st day and one dog (I_4) by 28th day (Fig. 15). Three dogs (I_1, I_3 and I_6), each with different grades of neurological deficits did not show any clinical improvement throughout the study period. In Group II, three dogs (II_1, II_5 and II_6) started walking normally by seventh day, one dog (II_2) by 28th day and one dog (II_3) by 56th day (Fig. 16). Clinical improvement was not noticed in one dog (II_4) throughout the study period. None of the animals in the current study showed complications throughout the study period.

Conclusion

Physiotherapy plays a major role in effective rehabilitation strategy in SCI of both human and animal patients. The current study was aimed to evaluate whether the TENS therapy enhances the sensory and motor recovery at the earliest possible. Based on the results of clinical and neurological examination, early restoration of reflexes and ambulation were observed in dogs which received combination of drugs and TENS therapy. Hence, TENS therapy was found to be effective in enhancing the clinical and neurological recovery of spinal cord injured canine patients.

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Conflict of interest

The authors declare no conflicts of interest.

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