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Transcutaneous electrical nerve stimulation (TENS) in improving sensorium in transverse myelitis: A case report

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Abstract
Transverse myelitis (TM) is an inflammatory condition affecting the spinal cord, leading to sensory deficits, motor dysfunction, and autonomic disturbances. Transcutaneous Electrical Nerve Stimulation (TENS) is a non-invasive therapeutic modality that has shown promise in alleviating sensory impairments and enhancing sensorium in various neurological disorders. This case study explores the efficacy of TENS in improving sensory functions in a patient with transverse myelitis. We provide an in-depth analysis of the patient's background, intervention, outcomes, and the implications of TENS therapy in the management of TM. A 35-year-old female was complaining of sudden onset of bilateral leg weakness, numbness, and bowel/bladder dysfunction. On investigation MRI confirmed transverse myelitis at the thoracic level. Initial treatment included high-dose corticosteroids and plasmapheresis. On examination there was hypoesthesia below the level of T6, decreased proprioception, and paraesthesia in the lower limbs; resulting in sensory deficits, with MMT graded 3/5 in lower extremities. Physiotherapy interventions consisted of standard TENS for paraspinal region at T6 level along with the dermatomes course of lower limb and strength training and gait training. Duration of the intervention was 8 weeks (40 sessions). Outcome measures were then reassessed for progression at 8 week and was found significant potential in managing sensory deficits and enhancing overall functionality in patients with transverse myelitis (TM).

Keywords: Transverse myelitis, transcutaneous electrical nerve stimulation, sensory deficits, motor dysfunction, hypoesthesia

Introduction
Transverse myelitis (TM) is a rare but serious neurological disorder characterized by inflammation of the spinal cord, which can lead to significant sensory, motor, and autonomic dysfunction. The condition often presents with rapid onset of symptoms, including pain, weakness, and sensory alterations (Kerr & Ayetey, 2002) [1]. Traditional management of TM focuses on reducing inflammation and managing symptoms through pharmacological and rehabilitative approaches (Jacob *et al*., 2013) [2]. One non-pharmacological treatment that has garnered attention is Transcutaneous Electrical Nerve Stimulation (TENS). TENS is a widely used modality for pain relief, delivering low-voltage electrical currents through the skin to stimulate nerves and modulate sensory perception (Sluka & Walsh, 2003) [3]. Although primarily utilized for pain relief, emerging evidence suggests that TENS may also enhance sensory functions and promote neural plasticity in conditions such as TM (Johnson & Martinson, 2007) [4]. This case study examines the application of TENS in a patient with TM, aiming to evaluate its effectiveness in improving sensory functions and overall sensorium.
The patient, a 35-year-old female, presented with sudden onset of bilateral leg weakness, numbness, and bowel/bladder dysfunction. MRI confirmed a diagnosis of transverse myelitis at the thoracic level. Initial treatment included high-dose corticosteroids and plasmapheresis, resulting in partial recovery of motor function but persistent sensory deficits (Pryse-Phillips *et al*., 2002) [5]. At the initial assessment, the sensory examination revealed marked hypoesthesia below the level of T6, decreased proprioception, and paraesthesia in the lower limbs. The motor examination indicated muscle strength graded 3/5 in the lower extremities,

and the patient exhibited incontinence and impaired bladder sensation, highlighting significant autonomic dysfunction.

The TENS intervention protocol involved the use of a standard TENS unit with adjustable parameters. Electrodes were placed in the paraspinal region at the level of the lesion (T6) and along the dermatomes of the lower limbs. The TENS settings included a frequency of 80-100 Hz, a pulse width of 100-150 μs, and an intensity level that was comfortable for the patient. Each session lasted 30 minutes, conducted five times per week for a total of eight weeks. Alongside TENS therapy, the patient continued with conventional physical therapy, including strength training and gait exercises, to provide a comprehensive rehabilitation approach (Taylor *et al*., 2012) [6].

Within two weeks of commencing TENS therapy, the patient reported a decrease in paraesthesia and improved sensation in the lower limbs. Objective testing showed enhanced light touch and pinprick sensitivity. Additionally, there was a slight improvement in muscle strength, particularly in the proximal muscles of the lower extremities (Kumar & Marshall, 1997) [7]. After eight weeks of TENS therapy, the patient exhibited significant improvement in sensory modalities, including vibration sense and proprioception. Noticeable improvement in bladder sensation and control was also observed, reducing the frequency of incontinence episodes. The patient reported enhanced ability to perform daily activities and improved psychological well-being due to reduced sensory discomfort and better motor control.

The use of TENS in this case of transverse myelitis highlights several important aspects of its therapeutic potential. TENS appears to modulate sensory pathways through the spinal cord, possibly by enhancing neural plasticity and promoting recovery of sensory functions. The observed improvements in proprioception and vibration sense suggest that TENS may facilitate the reorganization of sensory maps within the central nervous system (Vance *et al*., 2014) [8]. Additionally, the patient's improved autonomic function aligns with previous findings that TENS can influence autonomic regulation by modulating sympathetic and parasympathetic activities (De Santana *et al*., 2008) [9]. The non-invasive nature of TENS, coupled with its minimal side effects, makes it a valuable adjunct to conventional therapies in the management of TM.

This case study supports the incorporation of TENS into the rehabilitative regimen for patients with TM, particularly those with persistent sensory deficits. Clinicians should consider individualized TENS protocols, tailored to the patient's specific sensory impairments and overall health status. Recommendations include personalizing TENS parameters (frequency, intensity, duration) to maximize therapeutic outcomes, combining TENS with conventional therapies for a holistic approach to TM management, and educating patients on the proper use of TENS devices while monitoring adherence to ensure consistent benefits (Johnson & Martinson, 2007) [4].

Transcutaneous Electrical Nerve Stimulation (TENS) represents a promising therapeutic option for improving sensory functions in patients with transverse myelitis. This case study demonstrates the potential of TENS to enhance sensory perception, promote neural plasticity, and improve overall sensorium in TM. Further research with larger cohorts is necessary to validate these findings and establish standardized protocols for the use of TENS in TM and other neuro-inflammatory conditions (Vance *et al*., 2014) [8].

Demographic data

- **Age:** 35
- **Gender:** Female

Medical History: The patient presented with sudden onset of bilateral leg weakness, numbness, and bowel/bladder dysfunction. MRI confirmed a diagnosis of transverse myelitis at the thoracic level. Initial treatment included high-dose corticosteroids and plasmapheresis, resulting in partial recovery of motor function but persistent sensory deficits.

Initial assessment

- **Sensory Examination:** Marked hypoesthesia below the level of T6, decreased proprioception, and paraesthesia in the lower limbs.
- **Motor Examination:** Muscle strength graded 3/5 in lower extremities.
- **Autonomic Function:** Incontinence and impaired bladder sensation.

Intervention

TENS Protocol

- **Device:** Standard TENS unit with adjustable parameters.
- **Electrode Placement:** Paraspinal region at the level of the lesion (T6) and along the dermatomes of the lower limbs.
- **Frequency and Intensity:** 80-100 Hz frequency, 100-150 μs pulse width, and comfortable sensory level intensity.
- **Duration:** 30-minute sessions, five times per week, for eight weeks.

Table 1: Illustrates the TENS therapy parameters used in this case study, providing a detailed breakdown of the frequency, pulse width, intensity, and duration of each session

Parameter	Value
Frequency	80-100 Hz
Pulse Width	100-150 μs
Intensity	Comfortable sensory level
Session Duration	30 minutes
Sessions per Week	5
Total Duration	8 weeks

Outcomes

Transcutaneous Electrical Nerve Stimulation (TENS) therapy has shown significant potential in managing sensory deficits and enhancing overall functionality in patients with transverse myelitis (TM). This section delves into the short-term and long-term effects observed in the patient following an eight-week TENS intervention.

Short-term effects

Sensory Improvement: Within two weeks of initiating TENS therapy, the patient reported a noticeable decrease in paresthesia and an improvement in sensation in the lower limbs. This was particularly significant, as the patient had been experiencing persistent sensory deficits despite initial pharmacological treatments. Objective sensory testing revealed enhanced light touch and pinprick sensitivity, indicating a positive response to the TENS therapy.

This rapid improvement suggests that TENS may facilitate immediate neural modulation, potentially through mechanisms such as the gate control theory, which posits that non-painful input can close the "gates" to painful input, preventing pain sensation from traveling to the central nervous system (DeSantana *et al*., 2008) [27].

Motor Function: In addition to sensory improvements, the patient exhibited slight improvements in muscle strength, particularly in the proximal muscles of the lower extremities. This was measured using manual muscle testing, which showed an increase in muscle strength grades. Although the primary aim of TENS was to address sensory deficits, the observed motor improvements suggest that TENS may also contribute to enhance motor neuron excitability and muscle function (Kavcic *et al*., 2007) [10]. The slight increase in muscle strength can significantly impact the patient's ability to perform daily activities and participate in rehabilitation exercises, further promoting recovery.

Long-term effects

Sensory Function: After completing the eight-week TENS therapy regimen, the patient exhibited significant improvements in various sensory modalities. Vibration sense and proprioception, in particular, showed marked enhancement. These improvements were assessed using quantitative sensory testing (QST), which demonstrated increased sensitivity to vibration and improved joint position sense. The long-term sensory gains suggest that TENS may promote neuroplastic changes within the sensory pathways, contributing to sustained sensory recovery (Katusic *et al*., 2012) [11].

Neuroplasticity, the brain's ability to reorganize itself by forming new neural connections, is crucial in recovery from neurological injuries and may be facilitated by repetitive sensory stimulation provided by TENS.

Autonomic Function: Noticeable improvements were also observed in the patient's autonomic functions, particularly in bladder sensation and control. Prior to TENS therapy, the patient experienced frequent incontinence episodes due to impaired bladder sensation and autonomic dysregulation. Post-therapy, there was a significant reduction in the frequency of these episodes, suggesting improved bladder control. This improvement in autonomic function is critical for the patient's quality of life, as it reduces the psychological and physical burden of incontinence (Chadi *et al*., 2015) [12]. Enhanced autonomic regulation may be a result of TENS-induced modulation of spinal cord circuits that influence autonomic outflow.

Quality of Life: The cumulative effects of improved sensory and autonomic functions translated into a better quality of life for the patient. Enhanced sensory perception and reduced discomfort allowed the patient to engage more actively in daily activities and rehabilitation exercises. Improved bladder control and reduced incontinence episodes alleviated a significant source of stress and embarrassment, contributing to better psychological well-being. The patient reported a greater sense of independence and confidence, which are crucial components of overall health and recovery (Staas & Cioschi, 1991) [13].

Table 2: Summary of Improvements Post-TENS Therapy

Parameter	Baseline	Post-2 Weeks	Post-8 Weeks
Sensory (Light Touch)	Marked hypoesthesia	Enhanced sensitivity	Significant improvement
Sensory (Pinprick)	Decreased sensitivity	Enhanced sensitivity	Significant improvement
Muscle Strength	3/5 in lower extremities	Slight improvement	Moderate improvement
Vibration Sense	Decreased	Slight improvement	Significant improvement
Proprioception	Decreased	Slight improvement	Significant improvement
Bladder Control	Frequent incontinence	Reduced frequency	Noticeable improvement
Quality of Life	Low	Improved	Significantly improved

The psychological benefits of TENS therapy are often underappreciated but are essential for holistic recovery. The table above summarizes the patient's progress throughout the TENS therapy intervention. It highlights the incremental improvements in sensory and motor functions, autonomic regulation, and overall quality of life. The data underscores the potential of TENS as a valuable therapeutic tool in managing TM.

The outcomes observed in this case study underscore the potential benefits of TENS therapy in managing sensory and autonomic deficits in patients with transverse myelitis. Both short-term and long-term effects indicate that TENS can significantly improve sensory functions, enhance motor strength, and regulate autonomic functions, thereby improving the overall quality of life. These findings align with existing literature on the efficacy of TENS in neuro-rehabilitation and suggest that TENS could be a viable adjunct therapy for TM (Gadsby *et al*., 2017) [14]. Further research with larger sample sizes and controlled trials is warranted to establish standardized protocols and validate these findings.

Discussion

The use of TENS in this case of transverse myelitis highlights several important aspects of its therapeutic potential. TENS appears to modulate sensory pathways through the spinal cord, possibly by enhancing neural plasticity and promoting recovery of sensory functions. The observed improvements in proprioception and vibration sense suggest that TENS may facilitate the reorganization of sensory maps within the central nervous system. The mechanisms by which TENS promotes these sensory improvements can be attributed to several factors. One of the primary mechanisms is the enhancement of synaptic plasticity, which involves the strengthening or weakening of synapses based on activity levels. TENS may promote the re-establishment of functional neural circuits in the spinal cord by providing consistent electrical stimulation that encourages neural connections to adapt and reorganize, thus

enhancing sensory processing (Ridding & Ziemann, 2010) [15].

Moreover, the patient's improved autonomic function aligns with previous findings that TENS can influence autonomic regulation by modulating sympathetic and parasympathetic activities. This is particularly relevant in the context of TM, where autonomic dysfunctions such as bladder control issues are common. TENS has been shown to affect autonomic pathways, potentially by altering the balance between sympathetic and parasympathetic activity, which could explain the observed improvements in bladder sensation and control (Noble *et al*., 2000) [16]. This regulatory effect on the autonomic nervous system further underscores the holistic benefits of TENS therapy beyond mere sensory enhancement.

The non-invasive nature of TENS, coupled with its minimal side effects, makes it a valuable adjunct to conventional therapies in the management of TM. Unlike pharmacological treatments, which often come with a range of side effects and the potential for long-term dependency, TENS offers a safer alternative that can be easily integrated into a patient's daily routine. The simplicity of the device and the ability for patients to self-administer the therapy contribute to its appeal as a long-term treatment option (Johnson, 2007) [4]. Furthermore, TENS provides immediate feedback to the patient, allowing them to adjust the parameters for maximum comfort and efficacy.

Mechanisms of action

Neuroplasticity: TENS may promote synaptic plasticity and the re-establishment of functional neural circuits in the spinal cord. This is achieved through consistent stimulation that encourages neural adaptation and reorganization. Studies have shown that repetitive sensory stimulation can lead to significant changes in the structure and function of neural networks, which is essential for recovery in neurological conditions like TM (Thickbroom, 2007). Neuroplasticity involves the brain's ability to reorganize itself by forming new neural connections throughout life. This ability to adapt and change plays a critical role in the brain's recovery process following injury or disease. In the case of TM, where the spinal cord's neural pathways are damaged, promoting neuroplasticity can help in the recovery of lost functions and improve overall sensory processing.

Gate Control Theory: By stimulating large diameter afferent fibres, TENS may inhibit nociceptive signals and enhance sensory input processing. The gate control theory suggests that non-painful input closes the nerve "gates" to painful input, which prevents pain sensation from traveling to the central nervous system. This theory provides a plausible explanation for the pain relief often reported by patients undergoing TENS therapy (Melzack & Wall, 1965) [19]. The theory posits that the spinal cord contains a neurological "gate" that either blocks pain signals or allows them to pass on to the brain. By providing non-painful stimuli, such as those delivered through TENS, the gate can be closed to painful stimuli, thereby reducing the perception of pain. This mechanism is particularly useful in managing chronic pain conditions associated with TM.

Endogenous Opioid Release: TENS can stimulate the release of endogenous opioids, contributing to pain relief and sensory modulation. Endogenous opioids are natural pain-relieving chemicals produced by the body. Their release can help to modulate pain perception and enhance overall sensory experience. This mechanism is particularly beneficial for patients with chronic pain conditions, as it provides a natural method of pain control without the need for external medication. The release of these opioids can provide significant pain relief, which is critical for improving the quality of life in patients suffering from TM. Additionally, this natural pain relief mechanism helps reduce reliance on pharmacological treatments, which often have side effects and the potential for addiction.

Implications for clinical practice

This case study supports the incorporation of TENS into the rehabilitative regimen for patients with TM, particularly those with persistent sensory deficits. Clinicians should consider individualized TENS protocols, tailored to the patient's specific sensory impairments and overall health status. The flexibility of TENS parameters allows for a personalized approach that can maximize therapeutic outcomes for each patient.

Recommendations

Personalized Therapy: Tailor TENS parameters (frequency, intensity, duration) to maximize therapeutic outcomes. Each patient's condition and response to therapy can vary, so it is crucial to adjust the TENS settings to meet individual needs effectively. Regular assessment and adjustment of these parameters can help to optimize the benefits of the therapy (Vance *et al*., 2014) [8]. For example, a patient experiencing severe sensory deficits might benefit from a higher frequency and intensity of stimulation, while a patient with milder symptoms might require less intensive treatment. By customizing the therapy, clinicians can ensure that each patient receives the most effective treatment possible.

Multimodal Approach: Combine TENS with conventional therapies for a holistic approach to TM management. Integrating TENS with physical therapy, occupational therapy, and other rehabilitative interventions can enhance overall treatment efficacy. A multimodal approach addresses the various aspects of TM, including motor, sensory, and autonomic dysfunctions, providing a comprehensive treatment plan (Kumar & Marshall, 1997) [7]. This approach ensures that all aspects of the patient's condition are addressed, promoting more comprehensive recovery. For instance, while TENS can improve sensory and pain outcomes, physical therapy can enhance motor function, and occupational therapy can help patients regain independence in daily activities.

Patient Education: Educate patients on the proper use of TENS devices and monitor adherence to ensure consistent benefits. Proper training on the use of TENS units and adherence to the prescribed regimen are essential for achieving optimal outcomes. Educating patients about the benefits and correct application of TENS can empower them to take an active role in their rehabilitation process (Robinson *et al*., 2011) [20]. Patients should be instructed on how to properly place the electrodes, adjust the settings, and use the device safely. Regular follow-up appointments can

help ensure that patients are using the device correctly and receiving the maximum benefit from the therapy.

The promising results observed in this case suggest that TENS could become an integral part of TM management, providing patients with a non-invasive, effective, and adaptable treatment option that addresses multiple aspects of their condition.

Conclusion

Transcutaneous Electrical Nerve Stimulation (TENS) represents a promising therapeutic option for improving sensory functions in patients with transverse myelitis (TM). This case study demonstrates the potential of TENS to enhance sensory perception, promote neural plasticity, and improve overall sensorium in TM. The benefits observed in this case provide a foundation for further exploration and validation through extensive research and clinical trials.

The patient in this case exhibited significant improvements in sensory modalities, including vibration sense and proprioception, following an eight-week regimen of TENS therapy. These enhancements suggest that TENS can facilitate the reorganization of sensory maps within the central nervous system, contributing to better sensory processing and integration. This neuroplasticity is critical for recovery in TM, where the spinal cord's neural pathways are often damaged. The ability of TENS to promote synaptic plasticity and re-establish functional neural circuits underscores its therapeutic potential.

Furthermore, the improvement in the patient's autonomic function, particularly in bladder sensation and control, aligns with the broader regulatory effects of TENS on the autonomic nervous system. This case highlights the ability of TENS to modulate sympathetic and parasympathetic activities, which can significantly impact the quality of life for patients with TM. Autonomic dysfunctions are common in TM and addressing these through non-invasive methods like TENS can provide substantial relief and improve daily living.

The non-invasive nature of TENS, coupled with its minimal side effects, makes it a viable adjunct to conventional therapies. Unlike pharmacological treatments, which often come with a range of side effects and the potential for long-term dependency, TENS offers a safer alternative that can be easily integrated into a patient's daily routine. The simplicity of the device and the ability for patients to self-administer the therapy enhance its appeal as a long-term treatment option. This accessibility is crucial for chronic conditions like TM, where continuous management is necessary.

The immediate feedback provided by TENS allows patients to adjust the parameters for maximum comfort and efficacy, ensuring personalized treatment. The flexibility in TENS parameters (frequency, intensity, duration) allows for a customized approach tailored to the patient's specific needs and conditions. This adaptability is critical in maximizing therapeutic outcomes, as each patient's response to TENS can vary.

The case study also underscores the importance of a multimodal approach to TM management. Combining TENS with other conventional therapies, such as physical therapy and occupational therapy, can enhance overall treatment efficacy. This comprehensive approach addresses the various aspects of TM, including motor, sensory, and autonomic dysfunctions, providing a holistic treatment plan that promotes recovery on multiple fronts.

Incorporating TENS into the rehabilitative regimen requires careful consideration of individualized protocols. Clinicians should tailor TENS settings to the patient's specific sensory impairments and overall health status. Regular assessment and adjustment of these parameters can help optimize the benefits of the therapy. Additionally, educating patients on the proper use of TENS devices and ensuring adherence to the prescribed regimen are essential for achieving optimal outcomes. Proper training and follow-up can empower patients to take an active role in their rehabilitation process, enhancing the overall effectiveness of the treatment.

The promising results observed in this case suggest that TENS could become an integral part of TM management, providing patients with a non-invasive, effective, and adaptable treatment option. However, further research with larger cohorts is necessary to validate these findings and establish standardized protocols for the use of TENS in TM and other neuro-inflammatory conditions. Largescale clinical trials can provide more comprehensive data on the efficacy and safety of TENS, helping to refine treatment protocols and expand its application.

Moreover, exploring the long-term effects of TENS on sensory and autonomic functions can provide insights into its potential as a sustainable treatment option. Understanding how prolonged use of TENS influences neuroplasticity and sensory integration can help in developing strategies for chronic management. Research can also investigate the optimal duration and frequency of TENS sessions to achieve the best therapeutic outcomes.

Collaboration between researchers, clinicians, and patients is vital in advancing the understanding and application of TENS in TM. Patient-reported outcomes can provide valuable feedback on the effectiveness and acceptability of TENS therapy, guiding further improvements in treatment protocols. Clinicians' insights can help identify the practical challenges and opportunities in integrating TENS into routine clinical practice.

Additionally, the development of advanced TENS devices with improved functionality and user-friendly features can enhance patient compliance and therapeutic outcomes. Innovations such as wireless devices, mobile app integration for parameter adjustments, and data tracking can provide more personalized and efficient therapy. These advancements can make TENS more accessible and convenient for patients, further supporting its use as a long-term management strategy.

The integration of TENS into the rehabilitative regimen for TM should be pursued with careful consideration of individualized treatment plans, patient education, and a multimodal approach. The continued exploration and innovation in TENS technology and application can significantly impact the management and recovery of patients with TM, providing them with a viable and effective therapeutic option.

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Competing Interests
The authors declare that they have no financial or other conflicts of interest in relation to this research and its publication.

Consent for publication
The authors have obtained the patient's informed written consent for print and electronic publication of this case report, including reproduction of any images seen herein.

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