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Transcutaneous Magnetic Stimulation (tMS) in Alleviating Post-Traumatic Peripheral Neuropathic Pain States: A Case Series

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Abstract

Background. Peripheral nerve injury can result in the formation of neuroma/nerve entrapment, a persistent peripheral neuropathic pain state which is often refractory to invasive interventions or medications. Therefore, there is a need in the field of pain management to develop innovative noninvasive therapy in treating post-traumatic peripheral neuropathic pain states. A new intervention, transcutaneous magnetic stimulation (tMS), is derived from the use of transcranial magnetic stimulation in which a rapid discharge of electric current is converted into dynamic magnetic flux for modulating neuronal functions.

Methods. Low-frequency (0.5 Hz) tMS was developed over the site of neuroma/nerve entrapment in five patients who have failed both steroid injection and conventional pain medications. Four hundred pulses of stimulation were delivered per treatment session. Each patient received three to four sessions of treatment over a period of 2 months. Pre- and post-intervention spontaneous pain levels were assessed with a numerical rating pain scale (NRS).

Result. Five patients with post-traumatic neuroma/nerve entrapment pain received the treatment. Average pre and postscores (±standard deviation) on the NRS were 5.00 (±1.41) and 0.80 (±1.10), respectively, with an average pain reduction of 84 (±21.91)% in the NRS after three to four treatments within 2 months. This analgesic effect appeared to be sustainable with repeated treatment delivered at a 6- to 8-week duration. Pretreatment tactile allodynia found in three patients resolved after the initial 2-month treatment sessions.

Conclusion. tMS offers a noninvasive treatment option for neuroma-related neuropathic pain conditions. Randomized controlled studies are required in further validating the efficacy of this treatment modality. Additional studies are also needed to assess the underlying electrophysiological mechanisms of the observed analgesic benefit.

Key Words. Neuroma; Nerve Entrapment; Transcutaneous Magnetic Stimulation; Analgesia; Neuromodulation; Pain; Neuropathic Pain

Background

Peripheral nerve injury often results in the formation of neuroma/nerve entrapment, a persistent neuropathic pain state with increases in ectopic activity at the site of injury and/or at the dorsal root ganglion (DRG) of the injured axons [1]. Invasive measures such as surgical resection, venous transposition, or local injection of steroid and local anesthetics at the neuroma site are often ineffective in alleviating the neuropathic pain condition. On the other hand, the invasive nature of these interventions can further exacerbate pain associated with the preexisting hypersensitive neuropathic pain states [2]. Therefore, there is a need in the field of pain management in developing means of noninvasive therapy in treating post-traumatic peripheral neuropathic pain states. Here, we reported a case series of five chronic pain patients (please see Table 1)

Table 1 Summary of patients' pain condition, tMS treatment setting, and outcome

Patient	Age	Gender	Site of Neuroma or Nerve Entrapment	Number of tMS Sessions	Frequency of tMS (Hz)	Total Number of Pulses per Session	Pretreatment NRS Score	Pretreatment Allodynia	Post-Treatment NRS Score	Post-Treatment Allodynia	% of Pain Reduction
1	62	Male	Left groin	4	0.5	400	7	Y	0.0	N	100
2	41	Female	Right foot	3	0.5	400	5	N	0.0	N	100
3	51	Female	Abdominal wall	4	0.5	400	5	Y	2.0	N	60
4	56	Male	Left elbow	3	0.5	400	3	N	0.0	N	100
5	25	Male	Left groin	3	0.5	400	5	Y	2.0	N	60
Average	47			3.4	0.5	400	5		0.8		84

N = no; NRS = numerical rating pain scale; tMS = transcutaneous magnetic stimulation; Y = yes.

with a clinical diagnosis of neuroma/nerve entrapment from prior nerve injury. All patients' pain were refractory to medication and/or injections but responded favorably to a new modality of non-invasive neuromodulation called transcutaneous magnetic stimulation (tMS). Patients were selected for this new treatment based on their history of traumatic nerve injury, physical findings of neuroma with palpation near the site of injury, reproducible paresthesia in distribution of the injured nerve with palpation and prior history of inadequate pain relief with oral or topical analgesics, and local steroid and local anesthetics injection.

Innovative Treatment for Post-Traumatic Peripheral Neuropathic Pain States

tMS offers an innovative and non-invasive means of neuromodulation in managing peripheral neuropathic pain via dynamic magnetic flux. This innovative technology derives from the use of transcranial magnetic stimulation (TMS) which uses electromagnetic principles to produce small electrical currents around the neuroma without anesthetics [3–6]. The device usually consists of an insulated coil which can be held over the targeted treatment region either with or without contacting the affected area. This method of pain neuromodulation provides a major advantage in treating patients with increased sensitivity to non-noxious stimuli (allodynia) as the treatment does not require direct device–patient contact or direct tissue penetration. When a current is passed around the coil, a dynamic magnetic flux will pass through the skin and into the first few centimeters of the skin without attenuation. A figure-of-eight coil is commonly used because it gives a focused dynamic magnetic flux from the center of the coil to the target site which can be marked with an extended crosshair (see Figures 1 and 2). This dynamic magnetic flux-induced neuronal stimulation is far more focused than other direct current stimulation modalities such as transcutaneous electrical nerves stimulator. Recently, the use of TMS has been shown to be beneficial in managing intractable central neuropathic states and headaches [7]. TMS

Figure 1 The site of neuroma near the surgical incision site was localized with a crosshair mark.

Figure 2 A figure-of-eight magnetic coil was centered over the crosshair mark during the treatment.

is also known to facilitate nerve repair/regeneration [8]. While high-frequency TMS (>1 Hz) results in neuronal excitation, low frequency TMS (≤1 Hz) results in neuronal inhibition [9]. Therefore, low frequency tMS can also be applied as a treatment option for managing a state of neuronal hypersensitivity known to exist in neuroma/nerve entrapment.

Here, we reported a case series in which tMS was found to be effective in alleviating post-traumatic peripheral neuropathic pain in patients who failed invasive interventions and medication.

Case Series

Case 1

A 62-year-old male patient presented with left groin pain after inguinal hernia repair surgery 5 years ago. Pain was described as continuous, throbbing, worse with activity and at a level of 7/10 in a 0–10 Numerical Pain Rating Scale (NRS). Tactile allodynia to light stroking from a foam paint blush was present prior to the intervention. Patient was diagnosed with left groin neuroma based on physical examination finding of palpable neuroma (1.5 × 1 cm) and paresthesia in the distribution of the genital branch of the left genitofemoral nerve. A CT scan showed no inguinal hernia recurrence. Previous failed pain management therapies include massage, Ibuprofen, Naproxen, Flexeril, and multiple steroid (Depomedrol) and local anesthetic injections without relief. Subsequently, local tMS therapy was initiated at 0.5 Hz. Four hundred pulses were delivered over the site of the neuroma with each treatment. After four sessions of tMS treatment over a period of 2 months, his spontaneous pain level decreased to 0/10 (NRS). His tactile allodynia resolved. He remained pain free with maintenance treatment at the same setting every 8 weeks.

Case 2

A 41-year-old female veterinarian was found to have chronic pain in her right foot near the second toe due to previous work-related injury to the medial plantar nerve. Tactile allodynia was not present prior to the treatment. A neuroma (0.5 × 0.5 cm) was identified with palpation on physical examination. With deep palpation over the neuroma, the pattern of paresthesia was reproducible along the medial plantar nerve. Previous failed treatment included steroid and Lidocaine injections, and topical capsaicin cream. tMS treatment (0.5 Hz, 400 pulses per session) was attempted with initial pain score of 5/10 (NRS), and post-treatment (three sessions over 2 months) pain score was at 0/10 (NPS). She remains pain free with maintenance treatment every 6 weeks.

Case 3

A 51-year-old female with history of Crohn's disease and multiple abdominal surgeries presented with right lower quadrant abdominal pain along the surgical incision site. Two neuromas (1.5 × 1.25 cm and 1.5 × 1.0 cm) were identified with palpation. Paresthesia could be elicited with palpation over the neuroma. Her initial spontaneous pain score was 5/10 (NRS) while she was taking MS Contin 30 mg twice a day. Tactile allodynia to light stroking was present prior to the intervention. She received tMS treatments (0.5 Hz, 400 pulses per session) along the abdominal scar. She received four treatment sessions over a period of 2 months. She rated her post-treatment pain score at 2/10 (NRS). She continued to reported adequate pain relief with maintenance treatment every 6 weeks. She self weaned off the MS Contin.

Case 4

A 56-year-old male presented with chronic elbow pain after left ulnar nerve transposition. A palpable neuroma (1.0 × 0.75 cm) was identified with physical examination. Paresthesia along the ulnar aspect of the left forearm could be elicited with movement of the elbow or palpation over the neuroma. He was diagnosed with ulnar neuroma and prior failed treatment modalities included Vicodin, Gabapentin, Meloxicam, steroid injections, and chiropractic adjustments. Tactile allodynia was not present prior to the tMS. His pretreatment pain score was 3/10 (NRS). He received three tMS sessions over a period of 2 months at a frequency of 0.5 Hz and amplitude of 60–80% (400 pulses per treatment). His post-treatment NRS scores was zero. He continues to report sustainable analgesic benefit with repeated treatment every 6–8 weeks.

Case 5

A 25-year-old male presented with chronic left groin pain, radiating to his anterior and medial thigh after a left inguinal hernia surgery 3 years prior to his presentation. His physical exam was significant for tenderness with deep palpation at the left groin and flexion elicited pain to the left

inguinal region. He was diagnosed with left inguinal nerve entrapment, and his initial pretreatment pain score was 5/10 (NPS). Tactile allodynia was present prior to the intervention. Prior failed attempts in treating his pain condition included Ibuprofen, Lyrica, Amitryptyline, Gabapentin, Lidocaine patch, and steroid injections. tMS treatment was initiated with the frequency of 0.5 Hz and amplitude of 60–70% with 20 pulses per train and average number of 20 trains (400 pulses per session). Patient reported pre- and post-treatment pain level at 5/10 and 2/10 (NPS), respectively. Pain overall was under well controlled with maintenance treatment given every 6 weeks.

Discussion

Peripheral nerve injury can lead to the formation of a neuroma which results from abnormal nerve regeneration. Many cutaneous neuromas derive from chronic irritation, pressure, stretch, and poor repair of nerve lesions of previous traumatic injury. It has been hypothesized that undamaged perineurium is an impeneratrable barrier for regenerating axons. However, if damaged, fascicular escape can occur with regenerating axons migrating into surrounding epineural tissue in a disorganized fashion, accompanied by fibromatosis [10,11].

Significant degree of pain with altered sensitivity at the area of scar or the distribution of the peripheral nerve is the clinical hallmark of a neuroma. A discrete area of pain with a radiating pattern can often be elicited around the area of neuroma with palpation. This post-traumatic neuropathic pain state is sometimes accompanied by a condition known as allodynia in which noxious perception occurs with non-noxious stimuli such as light stroking. The cause of pain can be due to mechanical or chemical irritation of the axon or nerve endings forming the neuroma, and/or spontaneous electrical activities at the site or DRG, resulting in altered transduction and increased conduction of the nociceptive impulses toward the central nervous system. Therefore, modulating afferent sensory input at the site of the injury provides an excellent alternative in managing post-traumatic peripheral neuropathic pain.

Although much has learned about the central pain modulatory mechanisms about TMS, very little is known about its mechanisms and efficacy in modulating peripheral neuropathic pain conditions. In the current case series, all five patients tolerated well with low-frequency tMS and demonstrated appreciable long-term pain relief benefit without any side effects. The observation is in line with previous studies that low frequency TMS provides an inhibitory effect for neuronal activities [9]. However, further electrophysiological studies are needed to further validate the analgesic mechanisms associated with low-frequency dynamic magnetic flux treatment in injured peripheral nerve endings.

In short, tMS can potentially offer a non-invasive treatment option for post-traumatic peripheral neuropathic pain. Randomized controlled studies are required in further validating the efficacy of this treatment modality. Additional studies are required to assess the underlying mechanisms of analgesia.

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