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Hand/Peripheral Nerve

The Use of Peripheral Nerve Stimulation in Conjunction with TMR for Neuropathic Pain

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Summary: Targeted muscle reinnervation and regenerative peripheral nerve interfaces are increasingly utilized strategies to mitigate phantom and residual limb pain in amputees. These interventions are successful, yet often imperfect in completely ameliorating neuropathic pain following amputation. Implantable peripheral nerve stimulators are another tool in the armamentarium for management of neuropathic pain. These devices have been utilized adjacent to the spinal cord and more recently in the extremities with good results, and there has been additional interest in their utility for nerve regeneration. In this case report, we present the first reported case in the readily available literature of combining contemporary peripheral nerve strategies with an implantable peripheral nerve stimulator for postamputation neuropathic pain. The patient is a 72-year-old man who presented with severe neuropathic pain following prior below knee amputation with an osseointegrated implant and regenerative peripheral nerve interfaces. The authors performed targeted muscle reinnervation with intra-operative placement of a peripheral nerve stimulator. He did well after the procedure, and his pain improved with activation of the device. The most symptomatic nerve is targeted with the nerve stimulator, and it is placed adjacent to the nerve transfer(s). Combining these contemporary techniques may lead to improved prosthetic use and quality of life for these patients. *(Plast Reconstr Surg Glob Open 2021;9:e3655; doi: 10.1097/GOX.0000000000003655; Published online 22 June 2021.)*

The gate control theory of pain is the scientific basis of acupuncture, vibration anesthesia devices for neurotoxin injections, and transcutaneous electrical nerve stimulation.[1,2] The theory posits that, following activation of A-β nerve fibers, the dorsal root ganglion will in turn block the transmission of chronic pain impulses through C fibers. A-β nerves are stimulated by light touch, pressure, and vibration and can be activated by low level input from the implantable nerve stimulators peripherally or centrally.[3] Peripheral nerve stimulation (PNS) and central nerve stimulation have been used by pain management physicians in the treatment of postamputation pain.[4]

Studies have shown promise in PNS reducing residual limb pain (RLP) and phantom limb pain (PLP).[1] In 2019 Gilmore et al published a double-blind randomized controlled trial evaluating the use of PNS on chronic postamputation pain. In this study, the stimulator was placed at the femoral or sciatic nerve percutaneously. The intervention group received 4 weeks of sham stimulation after implantation, and then 4 weeks of active stimulation. Over half the patients had a 50% reduction in pain scores and many had an increase in overall quality of life.[5]

Major limb amputations have changed in the past decade with the advent and interest in targeted muscle reinnervation (TMR) and regenerative peripheral nerve interface (RPNI). These tools have helped; however, chronic RLP and PLP may not entirely resolve after these procedures.[6] Placing the stimulator at the time of a TMR and RPNI procedure may offer a unique opportunity that could provide a synergistic effect on pain improvement after surgery. The stimulators have traditionally

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been placed percutaneously; thus, it is reportedly difficult to place them close enough to the nerve to have the desired effect. Placing them intraoperatively affords the opportunity to place them immediately adjacent to the most impactful nerve, regardless of the anatomic location because it is easily accessible during surgery. In this case report, we present a case of combining TMR with an implantable peripheral nerve stimulator for treatment of profound neuropathic pain following amputation.

CASE REPORT

A 72-year-old man presented with phantom and RLP after a transtibial amputation and osseointegrated (OI) implant placement with RPNI at an outside hospital. Most of his pain was localized to the distribution of the common peroneal nerve. Sterilization and isolation of the OI stump were performed by washing the implant with Duraprep (3M Minnesota, USA), wrapping it in Ioband (3M Minnesota, USA), and washing over the Ioband with additional Duraprep.

The saphenous nerve was first addressed via TMR in the supine position, within Hunter's canal (**See Video [online],** which displays a 72-year-old man who presented with phantom and RLP after a transtibial amputation and OI implant placement. Major limb revision amputation was performed using TMR, RPNI, and an implantable nerve stimulator.) A nerve transfer was performed between the saphenous nerve to a branch to the vastus medialis (Fig. 1). Next, the patient was positioned prone and an incision was made in the midline of the lower leg with care to leave 8 cm from the inferior edge of the incision to the OI stump (Fig. 2). Here, the medial and lateral sural nerves, tibial nerve, and common peroneal nerve underwent TMR with vascularized RPNI, as previously described by the senior authors. This procedure involves a nerve transfer from the proximal mixed motor nerve to a distal motor nerve target followed by creation of a vascularized but denervated cuff of muscle that is wrapped around the coaptation. The muscle is secured with a 4-0 polyglycolic acid suture.[7] The implantable nerve stimulator (StimRouter, Bioness) was placed adjacent to the common peroneal nerve coaptation to the lateral soleus motor nerve (Fig. 3). The nerve stimulator is a wire electrode with a stimulator end and a receiver end.

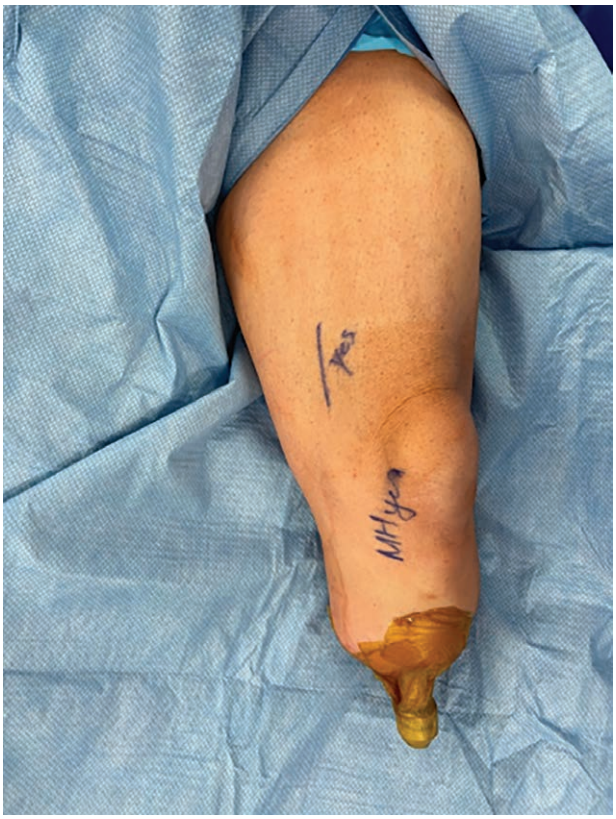

Fig. 1. The procedure was started with an anterior approach to address the saphenous nerve in the antero-medial thigh because of the short residual limb. The implant was sterilized, covered with sterile antimicrobial tape, and then again sterilized.

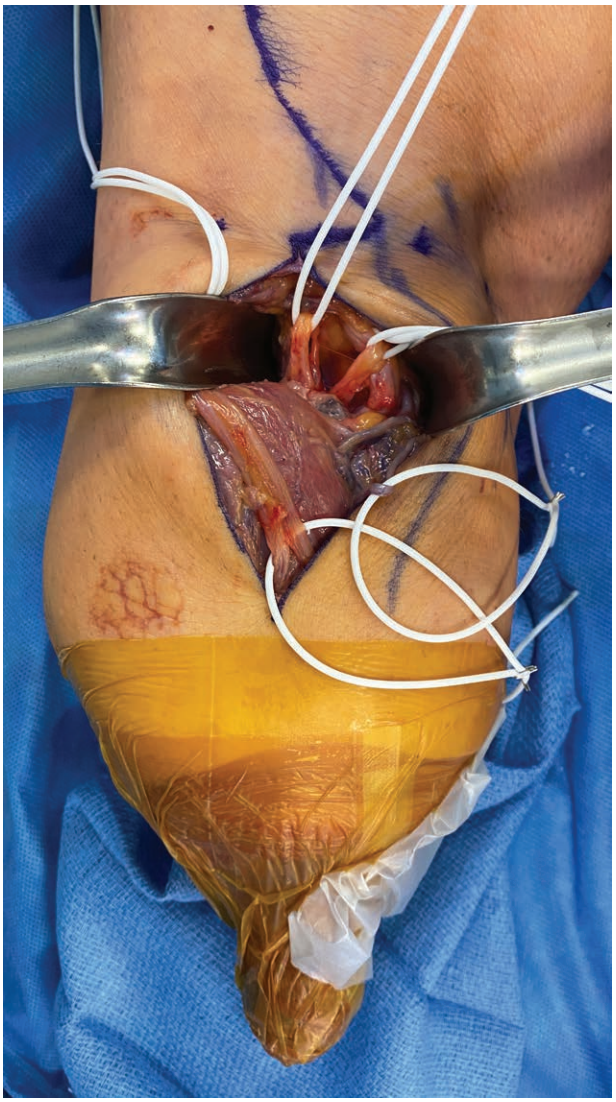

Fig. 2. From the prone position, the tibial nerve, common peroneal nerve, and sural nerves were addressed using the combined TMR and RPNI technique.

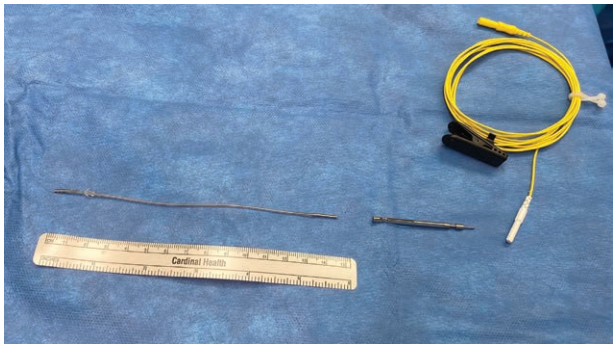

Fig. 3. The implantable nerve stimulator is seen here on the back table.

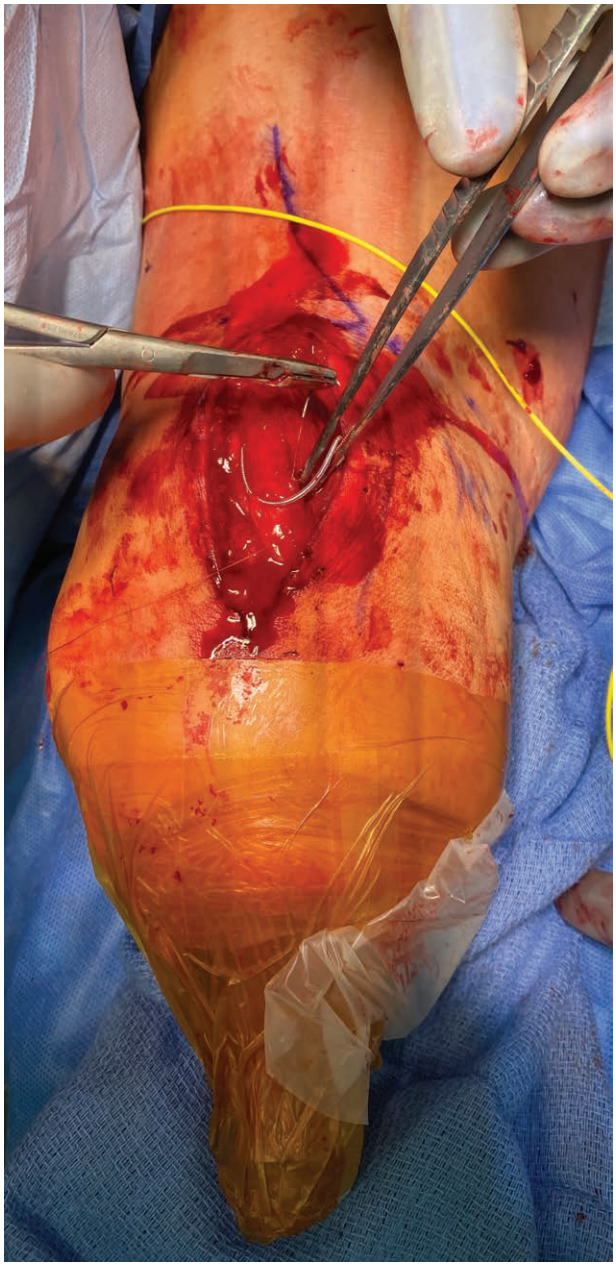

Fig. 4. An implantable nerve stimulator was placed with close proximity to the common peroneal nerve.

The stimulator end is placed next to the intended nerve and then the receiver end is tunneled subcutaneously to lie just below the skin (Fig. 4). An electrode patch sticker connected to an external pulse transmitter unit (EPT) was placed on the skin, over which the receiver end of the wire is located.

In the immediate postoperative period, the patient was able to activate and deactivate the nerve stimulator using a remote control for the EPT. When the stimulator is deactivated, he rated his pain score as an eight. By contrast, when the stimulator was activated, he rated his pain as a four. Postoperatively, he was restricted from use of his OI prosthetic leg to allow for healing of the nerve transfer coaptations. He was allowed to progress weightbearing as tolerated with use of his prosthetic leg at 3 weeks postoperatively.

CONCLUSIONS

TMR was first described as a way to utilize nerve signals to provide intuitive signals for myoelectric prosthesis. Patients serendipitously reported incredible pain relief after this procedure, and it was discovered that guiding axonal growth into a denervated muscle prevented the development of neuromas and improved neuropathic pain. This has led to improved outcomes for amputee patients and is becoming the standard of care at many institutions.[8]

TMR and RPNI can prevent and treat long term pain. The OI implant allows for an easier interface between the prosthetic and the residual limb. The use of a peripheral nerve stimulator has been used to help with postamputation pain in the past but has not yet been combined with TMR, RPNI, or OI. The stimulator provides an opportunity to help patients not only reduce RLP and PLP but also to further improve quality of life after a major limb amputation.

Early in development, nerve stimulators were used around the spinal cord as a central nerve stimulator and required an open spinal surgery for placement. The studies from this era focused on stimulating the dorsal root ganglion and showed stable improvement in PLP.[9] Interest then developed in percutaneously placed devices that could be implanted on an outpatient basis. Combining PNS with other procedures is a natural next step. Postsurgical electrical stimulation may actually speed up the reinnervation process.[10]

Remaining RLP may be due to residual limb nociceptive pain resulting from the bone, pressure on atrophied muscle, or residual neuropathic pain, which is common in the initial months following nerve surgery. Applying an additional nerve stimulator would require an additional, separate receiver and separate remote. While this is possible, we believe that further evaluation of simultaneous placement with TMR and RPNI should be performed before adding more stimulators. There is no limit as to how long the device can stay in place at this time, and the device is designed to remain permanently internalized.

This case report highlights the first use of open placement of a PNS during surgery for TMR and RPNI

for postoperative nerve stimulation. This adds minimal operative time to the surgery as the nerves are already exposed, ensures accurate placement and securing of the nerve stimulator, and offers a low-risk adjunct pain control method in the postoperative period. Further utilization in more patients will allow for better elucidation of full effects to develop formal use recommendations.

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