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IDEAS AND INNOVATIONS

Hand/Peripheral Nerve

TMRpni: Combining Two Peripheral Nerve Management Techniques

David E. Kurlander, MD*
Corinne Wee, MD*
Kyle J. Chepla, MD*†
Kyle D. Lineberry, MD*‡
Tobias C. Long, MD*‡
Joshua A. Gillis, MD, FRCSC§
Ian L. Valerio, MD, MS, MBA, FACS¶
Joseph S. Khouri, MD*‡

Summary: Amputee patients suffer high rates of chronic neuropathic pain, residual limb dysfunction, and disability. Recently, targeted muscle reinnervation (TMR) and regenerative peripheral nerve interface (RPNI) are 2 techniques that have been advocated for such patients, given their ability to maximize intuitive prosthetic function while also minimizing neuropathic pain, such as residual and phantom limb pain. However, there remains room to further improve outcomes for our residual limb patients and patients suffering from symptomatic end neuromas. "TMRpni" is a nerve management technique that leverages beneficial elements described for both TMR and RPNI. TMRpni involves coaptation of a sensory or mixed sensory/motor nerve to a nearby motor nerve branch (ie, a nerve transfer), as performed in traditional TMR surgeries. Additionally, the typically mismatched nerve coaptation is wrapped with an autologous free muscle graft that is akin to an RPNI. The authors herein describe the "TMRpni" technique and illustrate a case where this technique was employed. *(Plast Reconstr Surg Glob Open 2020;8:e3132; doi: 10.1097/GOX.0000000000003132; Published online 27 October 2020.)*

INTRODUCTION

Amputation has a profound impact on patients' quality of life, with the prevalence of chronic limb and neuropathic pain estimated up to 70%.[1–6] Recently, 2 surgical techniques have gained popularity for sensory or mixed sensory/motor nerve management in the setting of amputation: targeted muscle reinnervation (TMR) and regenerative peripheral nerve interface (RPNI). TMR involves transfer of sensory or mixed sensory/motor nerves to nearby transected motor nerve branches (ie, a formal nerve transfer), denervating the corresponding recipient muscle, and allowing for reinnervation via the proximal regenerating nerve. RPNI is a technique that creates a construct of a transected sensory or mixed sensory/motor nerve implanted into an autologous, denervated free muscle graft. Although TMR and RPNI were designed for improved, intuitive prosthetic motor control, both techniques have compelling evidence for improving neuropathic pain, including residual, phantom, and neuroma-related pain.[7–10] Each technique has been found effective at the time of amputation, as a prophylactic intervention and in the delayed period for treatment of neuropathic pain.[11–16]

The authors have used an evolvement of surgical technique drawing on the beneficial principles of TMR and RPNI. This technical evolution we termed "TMRpni." TMRpni includes performing traditional TMR nerve transfer coaptation and then wrapping the coaptation with an autologous free muscle graft.

INDICATIONS

Any patient who is a candidate for TMR is eligible for TMRpni, including adult and pediatric patients requiring amputation for traumatic, oncologic, infectious, or dysvascular indications.[17,18] TMRpni can be performed at the time of amputation for neuropathic pain prevention and improved intuitive prosthetic control, or as a delayed treatment. TMR has been described for below and above knee, transradial and transhumeral, and forequarter and hindquarter amputations, as well as for treatment of neuroma without any associated amputation.[8,19–24]

TMRpni is particularly useful when the TMR coaptation is performed several centimeters from the recipient neuromuscular junction, as in the case of short donor and long recipient nerves. Additionally, we use this technique when a larger donor nerve is coapted to a much smaller

*From the *Department of Plastic Surgery, Case Western Reserve University, Cleveland, Ohio; †Department of Plastic Surgery, MetroHealth Medical Center, Cleveland, Ohio; ‡Department of Plastic Surgery, University Hospitals Cleveland Medical Center, Cleveland, Ohio; §Department of Plastic Surgery, Western University, London, Ontario, Canada; and ¶Department of Plastic Surgery, Harvard Medical School, Massachusetts General Hospital, Boston, Mass.*

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motor target. It is possible that the excess axons within the donor nerve may exceed the available recipient axons, potentially allowing for donor axonal escape into the extraendoneurial environment and neuroma formation. TMRpni combines the well-documented benefits of TMR and RPNI, with the theory that the free muscle graft will provide a destination for any escaped donor axons to minimize pain at the coaptation. In essence, we hypothesize that this technique acts as a "biologic nerve wrap" that is similar to other wrap techniques shown to reduce nerve coaptation tenderness and pain.[25,26]

TECHNIQUE

TMRpni begins with traditional TMR nerve transfer, as previously described.[20,22,23,27] Briefly, the approach is through the distal amputation exposure if performed at the time of amputation or by proximal incision if performed as a delayed procedure. Under tourniquet, donor sensory or mixed sensory/motor nerves of interest are mobilized. Nearby recipient motor branch targets are identified using a handheld nerve stimulator. The recipient motor nerves are transected close to their muscle insertion, and an end-to-end nerve transfer is performed using an epineural 8-0 suture .

Subsequently, the "RPNI" part of the case ensues. A thin 2–3 × 1 cm^2 free muscle graft is sharply harvested from the nearby muscle or from an uncontaminated amputated specimen, for each TMRpni coaptation. The free muscle graft is wrapped around the TMR coaptation and secured to itself with an interrupted 6-0 absorbable or nonabsorbable suture. A fibrin glue may be used to hold the construct in place. The incision is closed and a compressive bandage is placed. A postoperative block is administered. Early postoperative range of motion exercises are initiated during the immediate recovery period. Multimodal pharmacotherapy is prescribed consisting of a neuromodulator (eg, gabapentin or pregabalin), NSAIDs, and opioid.

An example patient who underwent TMRpni is shown in Figure 1. A 34-year-old male combat veteran suffered from a dysfunctional limb after sustaining a remote high-energy ballistic injury to the left knee during deployment overseas. He underwent multiple limb preservation procedures but had persistent stiffness and pain. After psychiatry clearance, the patient decided to proceed with elective above-knee amputation. TMRpni was performed at the time of index amputation. In the supine position through the distal amputation approach, the saphenous nerve was coapted to a motor branch to semimembranosus. The coaptation was wrapped in a thin 3 cm × 1 cm free muscle graft harvested from the lateral gastrocnemius of the amputated specimen. The incision was closed and the patient was then placed in a prone position. A separate incision was made in the posterior thigh to expose the sciatic nerve. The common peroneal component of the sciatic nerve was dissected and coapted to a motor branch to biceps femoris and the tibial nerve component of the sciatic nerve coapted to a motor branch to semimembranosus. Each coaptation was wrapped with a thin 3 cm × 1 cm free muscle graft from the discarded specimen. The incision was closed, and a compressive dressing applied. At 4 months follow-up, the patient ambulated with his prosthetic leg and reported no residual limb or phantom pain.

DISCUSSION

The efficacy of TMR and RPNI in treating neuropathic pain has been previously reported, with improved pain scores and outcomes compared with those of cohorts undergoing traditional traction neurectomies and cohorts undergoing "burying nerves in the surrounding muscle."[12,16,17] We believe that TMRpni may have advantages compared with TMR or RPNI alone. RPNI is limited by the size of the free muscle graft. If the muscle graft is too small, it will fail to amplify a transcutaneous signal for prosthetic use. If the free muscle graft is too large, it will fail to revascularize and will undergo necrosis. The consequence of a nerve mismatch in TMR is not fully understood but may be a limitation of the technique. It is possible that during distal reinnervation there may be neuronal escape leading to neuroma formation and/or persistent sites of pain. By wrapping the TMR coaptation with a free muscle graft, essentially acting as a biologic nerve wrap, the escape neurons will have a denervated free muscle graft to reinnervate, thereby creating a

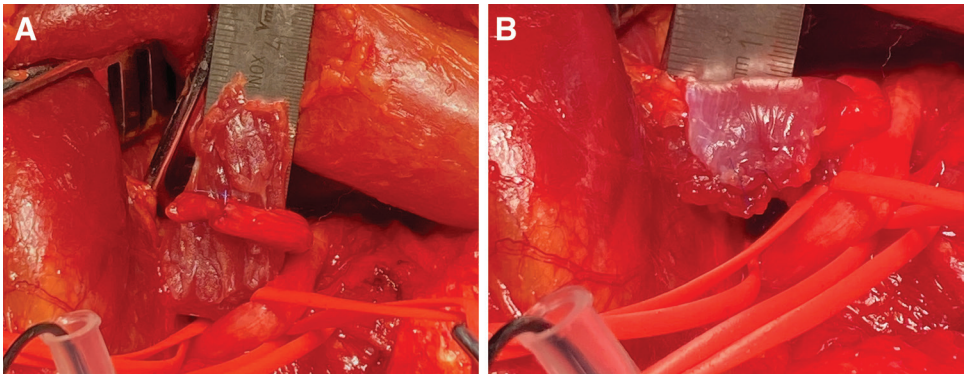

Fig. 1. A 34-year-old man who underwent left above-knee amputation and immediate TMRpni. A, The common peroneal component of the sciatic nerve coapted to the motor branch to biceps femoris. B, Coaption wrapped with a free muscle graft.

construct akin to an RPNI. Other means of managing nerve mismatch include splitting the donor nerve and coapting to multiple motor recipients and performing a TMR combined with vascularized pedicled RPNI.[28] These 2 options may be limited by the local availability of recipient motor nerves and muscle bulk.

TMRpni can be performed with minimal or no additional risk compared with TMR or RPNI surgery and with minimal additional operative time or cost. Future studies will elucidate the reinnervation distribution between the recipient nerve and autologous, denervated muscle graft. Head-to-head study will be required to compare the ability of TMR, RPNI, and TMRpni to treat residual and phantom limb pain, minimize opiate consumption, and improve prosthetic use.

Joseph S. Khouri, MD
University Hospitals Cleveland Medical Center
11100 Euclid Avenue
Cleveland, OH 44106
E-mail: Joe.Khouri@uhhospitals.org

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