Targeted Muscle Reinnervation to Expendable Motor Nerves for the Treatment of Refractory Symptomatic Neuromas in Nonamputees

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Summary: Symptomatic neuromas can cause debilitating pain, significantly impairing patients’ quality of life. There are numerous medical and surgical options for management. Targeted muscle reinnervation (TMR) is a nerve transfer procedure that is now commonly used to prevent or treat symptomatic neuromas or phantom limb pain in amputees. There are a few reports in the current literature about performing TMR in the nonamputee, but no cohort studies to date that report pain outcomes. This study evaluates TMR to treat symptomatic neuromas in nonamputee patients. This is a retrospective cohort study of all patients with symptomatic neuromas treated with TMR over a 1-year period from January 1, 2019, to January 1, 2020, at MedStar Georgetown University Hospital. The neuromas are excised to healthy nerve fascicles, and a redundant donor motor fascicle is selected for nerve transfer. Patients were asked in clinic or via telephone about their preoperative and postoperative pain, function, and quality of life, and postoperative clinic notes were reviewed for complications and motor deficits. Fifteen patients were included in this study. Patients had symptomatic neuromas involving the upper extremity, lower extremity, and trunk. Pain frequency decreased from 6.7 times per week to 3.9 ($P < 0.01$) and from 9.1 times per day to 5.1 ($P < 0.01$). Pain severity decreased from an average of 7.9/10 to 4.5/10 ($P < 0.01$). Overall physical function increased from 3.7/10 to 5.8/10 ($P = 0.01$), and overall quality of life increased from 4.9/10 to 7.0/10 ($P < 0.01$). No patients had demonstrable weakness of the motor function of the donor nerve. Targeted muscle reinnervation is a viable surgical option for the treatment of symptomatic neuromas, particularly in those patients who have previously failed prior neuroma excisions. (Plast Reconstr Surg Glob Open 2021;9:e3436; doi: 10.1097/GOX.0000000000003436; Published online 16 February 2021.)

INTRODUCTION

Symptomatic neuromas can be debilitating and hinder quality of life. Traditionally, symptomatic neuromas were treated passively by resecting the neuroma and hiding the transected nerve in innervated muscle, bone, vein, nerve cap, or centrodural coaptation with another transected sensory nerve.1-4 Targeted muscle reinnervation (TMR) is a newer technique that has gained popularity in preventing and treating neuromas and phantom limb pain in amputees.5-21 TMR is thought to be a more physiologic solution to neuroma pain, as it provides the transected sensory nerve with a denervated motor end plate to interface with, therefore preventing the erratic axonal sprouting that may lead to a scarred neuroma. A donor motor nerve is selected and transected, thereby denervating a segment of muscle to provide the transected end of a sensory nerve a willing target.

Although it has been suggested that TMR can be performed in the nonamputee, no studies to date have reported its use or outcomes.22 The downsides of performing TMR in nonamputees are that the affected sensory nerve will no longer be functional—trading pain for permanent numbness—and the donor motor nerve will no longer be innervating an otherwise previously functional muscle. The goal of this study is to evaluate the...
METHODS

This is a retrospective review of all patients with symptomatic neuromas treated with TMR from January 1, 2019, to January 1, 2020, at the MedStar Georgetown University Hospital. Patients’ charts were reviewed for the nerve involved, cause of neuroma, and preoperative and postoperative pain and quality of life, TMR target, and complications. The survey questions were created to assess outcomes of these patients. Pain severity was assessed on a scale of 0–10. Pain frequency was assessed based on how many times per day patients experience their pain and how many days per week. Quality of life outcomes were also assessed with questions asking the frequency of events per week. Microsoft Excel (Microsoft Corp., Redmond, Wash.) was used to perform all data and statistical analyses. Matched pair t-tests were performed comparing individual patient’s preoperative and postoperative outcomes, with a P value less than 0.05 considered significant.

TECHNIQUE

Once referred to our clinic, a thorough subjective history, review of medical records, and dedicated physical examination are performed to determine if the patient’s pain can be attributed to a symptomatic neuroma. Diagnostic imaging is not routinely performed to confirm the diagnosis. Instead, a peripheral nerve block with a mixture of lidocaine and bupivacaine is administered to the suspected nerve under ultrasound guidance in clinic. If patients experience a significant pain reduction (>50%) and are willing to accept permanent numbness in the distribution of that nerve, then they are recommended for surgery.

Neuroma excisions are planned such that the distal end of the problematic sensory nerve is in close proximity with motor nerves innervating muscles that are redundant in function. The motor nerves to the target muscle are identified proximally, and the identity of the motor nerves is confirmed with nerve stimulation. If the muscle function is essential, the nerve is dissected carefully distally into the target muscle until it arborizes to minimize the proportion of the muscle that will be denervated while also being careful not to avulse the branches not used for transfer. The transfer is performed to a branch of the motor nerve to preserve the remaining native innervation to the muscle. The nerve coaptation is performed using loupe magnification with epineural sutures, sealed with fibrin glue, and anchored into the target muscle away from any weight bearing surfaces.

RESULTS

Patient Demographics

Fifteen patients were included in this study, 12 women and 3 men with an average age of 53.1 years. The average time from suspected initial injury and surgery was 5.1 years. Average follow-up time from TMR was 8.1 months. Eight out of 15 (53.3%) had a prior neuroma excision. Patients had symptomatic neuromas involving the upper extremity, lower extremity, and trunk (Table 1). All motor target nerves were redundant, meaning that the innervated muscle had additional motor nerve branches that were not used as part of the TMR so that native innervation to the muscle was preserved.

Pain and Quality of Life Outcomes

Pain frequency decreased from 6.7 days per week to 3.9 (P < 0.01) and from 9.1 times per day to 5.1 (P < 0.01). Average pain severity decreased from 7.9/10 to 4.3/10 (P < 0.01). Narcotic usage did not change, as 3 out of the 4 patients taking narcotics preoperatively continued postoperatively. Use of nonnarcotic pain medications decreased from 80% to 27% (P < 0.01). Patients were able to sleep better with 4.9 nights of interrupted sleep per week versus

Table 1. List of Nerve Distribution of Symptomatic Neuromas, Etiology, Prior Neuroma Excision, and Motor Nerve Target for TMR

| Symptomatic Neuroma                     | Etiology                                      | Prior Neuroma Excision | TMR Target                        |
|-----------------------------------------|-----------------------------------------------|------------------------|-----------------------------------|
| Upper extremity                         |                                               |                        |                                   |
| Radial sensory nerve                    | DeQuervain tenosynovitis release              | Yes                    | Extensor carpi radialis brevis    |
| Radial sensory nerve                    | Distal radius fracture and wrist fusion       | Yes                    | Extensor carpi radialis brevis    |
| Radial sensory nerve                    | Ulnar shortening osteotomy and                | Yes                    | Extensor carpi radialis brevis    |
| Dorsal cutaneous branch of ulnar nerve  | TFCC repair                                   | No                     | Flexor carpi ulnaris              |
| Lower extremity                         |                                               |                        |                                   |
| 3rd webspace common digital nerve       | Carpal tunnel release                         | Yes                    | Pronator quadratus                |
| Superficial peroneal nerve               | Venous stasis ulcer debridement               | Yes                    | Extensor digitorium longus        |
| Superficial peroneal nerve              | Midfoot fracture and tarsometatarsal fusion   | No                     | Peroneus brevis                   |
| Superficial peroneal nerve              | Ankle synovectomy and talar exostectomy       | No                     | Peroneus brevis                   |
| Superficial peroneal nerve, deep        | Ganglion cyst excision and                    | Yes                    | SPN to tibialis anterior, DPN      |
| peroneal nerve                          | tarsometatarsal fusion                        |                        | to extensor hallucis longus       |
| Superficial peroneal nerve, deep         | Bunionectomy                                  | Yes                    | SPN to peroneus brevis, DPN       |
| peroneal nerve                          |                                               |                        | to extensor hallucis longus       |
| Sural nerve                             | Knee replacement                              | Yes                    | Medial gastrocnemius              |
| Saphenous nerve                         | Ankle fracture                                | No                     | Peroneus brevis                   |
| Saphenous nerve                         | Tibial fracture and knee replacement          | No                     | Sartorius                         |
| Trunk                                   | Open tibial-fibula fracture with rectus       | No                     | Medial gastrocnemius              |
1.5 (P < 0.01). Patients reported 5.6 missed family or social events preoperatively vs 2.6 postoperatively (P < 0.01). Only 4 of 15 patients were employed preoperatively, and an additional 2 patients were able to return to work following their TMR. Overall physical function increased from 3.7/10 to 5.8/10 (P = 0.01), and overall quality of life increased from 4.9/10 to 7.0/10 (P < 0.01).

**Complications**

There were no surgical site infections, hematomas, or wound complications. All 15 patients reported numbness in the dermatome corresponding to the sensory nerve transferred. No one was significantly bothered by the numbness, and all preferred the postoperative numbness to the preoperative pain. As the lack of sensation was not particularly bothersome to any patient, no treatment modalities were provided to alleviate those symptoms. No patients were found to have identifiable functional weakness in their donor muscle target. All patients were found to have 5/5 strength, symmetric with the contralateral side.

**DISCUSSION**

TMR is a physiologic surgical technique that has been demonstrated to prevent and improve neuroma pain.9–21 This is the first study to report the outcomes of a cohort of nonamputees with symptomatic neuromas treated with TMR.

The overall outcomes are very promising. As a whole, patients had significantly decreased pain frequency and severity and required less over-the-counter and neuroleptic medications. Three out of 4 patients taking narcotics preoperatively continued to require narcotics postoperatively. It is difficult to make any definitive conclusions from a small sample size, but the lack of response could be attributed to a more centrally mediated pain mechanism in the chronic pain patient. Patients who suffer from chronic pain and require narcotics should be counseled that they may be at higher risk for persistent pain after TMR.

Following TMR, patients reported improved physical function, overall quality of life, and ability to fulfill social and family obligations. Equally as important, patients did not suffer from significant donor site morbidity. The biggest downside to performing TMR for symptomatic neuromas versus standard treatment is the sacrifice of an otherwise perfectly functioning motor nerve. Motor nerve targets are carefully selected to ensure that the TMR does not deprive the patient of a critical motor function. If a target motor nerve supplies a critical function, such as extensor carpi radialis brevis for central wrist extension, the nerve is dissected distally into the muscle until it arborizes and the transfer is performed to one branch of the nerve, preserving native innervation to the remaining muscle (Figs. 1–3). Patients must also be informed that this procedure results in permanent loss of sensation in the distribution of the affected sensory nerve.

This pilot study is limited by its small sample size, though the differences in pain and quality of life outcome metrics were still statistically significant. It is also retrospective, does not have a comparison group, and has limited follow-up time. That being said, TMR for symptomatic neuromas in nonamputees is a promising new technique that should continue to be explored as a surgical option to improve pain.
CONCLUSIONS

TMR is a viable surgical option for the treatment of symptomatic neuromas. This cohort of nonamputees benefitted from significantly decreased pain, improved quality of life, and had minimal to no donor site morbidity.

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PATIENT CONSENT

Patients provided written consent for the use of their images.

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