OPEN

PRS GLOBAL OPEN

IDEAS AND INNOVATIONS

Hand/Peripheral Nerve

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

Brian L. Chang, MD*
Patrick Harbour, MD†
Josh Mondshine, BS‡
Grant M. Kleiber, MD§

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 4.3/10 ($P < 0.01$). 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 centrocentral coaptation with another transected sensory nerve.[1–8] Targeted muscle reinnervation (TMR) is a newer technique that has gained popularity in preventing and treating neuromas and phantom limb pain in amputees.[9–21] 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

*From the *Department of Plastic Surgery, MedStar Georgetown University Hospital; Washington, D.C.; †Department of Plastic Surgery, MedStar Georgetown University Hospital; Washington, D.C.; ‡Georgetown University School of Medicine, Washington, D.C.; and §Department of Plastic Surgery, MedStar Georgetown University Hospital; Washington, D.C.*

Received for publication November 3, 2020; accepted December 17, 2020.

DOI: 10.1097/GOX.0000000000003436

Disclosure: *The authors have no financial interest to declare in relation to the content of this article.*

patient-reported outcomes of and complications with using TMR to treat symptomatic neuromas in nonamputee patients.

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 epineurial 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	Electrical injury carpal tunnel release	Yes	Extensor carpi radialis brevis
	Dorsal cutaneous branch of ulnar nerve	Ulnar shortening osteotomy and TFCC repair	No	Flexor carpi ulnaris
	3rd webspace common digital nerve	Carpal tunnel release	Yes	Pronator quadratus
Lower extremity	Superficial peroneal nerve	Venous stasis ulcer debridement	Yes	Extensor digitorum 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 peroneal nerve	Ganglion cyst excision and tarsometatarsal fusion	Yes	SPN to tibialis anterior, DPN to extensor hallucis longus
	Superficial peroneal nerve, deep peroneal nerve	Bunionectomy	Yes	SPN to peroneus brevis, DPN to extensor hallucis longus
	Sural nerve	Knee replacement	Yes	Medial gastrocnemius
	Sural nerve	Ankle fracture	No	Peroneus brevis
	Saphenous nerve	Tibial fracture and knee replacement	No	Sartorius
	Saphenous nerve	Open tibial-fibula fracture with rectus femoris and medial gastrocnemius flaps	No	Medial gastrocnemius
Trunk	Intercostal nerve	Laparoscopic cholecystectomy	No	Rectus abdominis

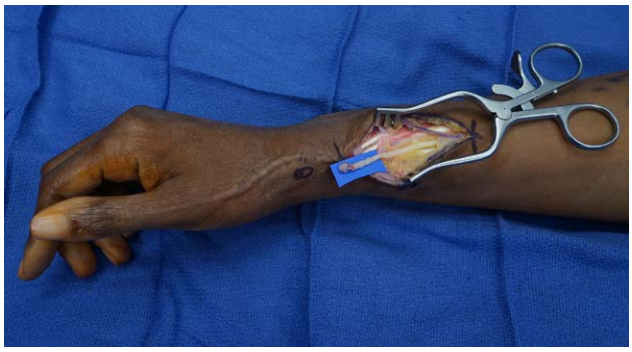

Fig. 1. Terminal neuroma of the radial sensory nerve (blue background).

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.

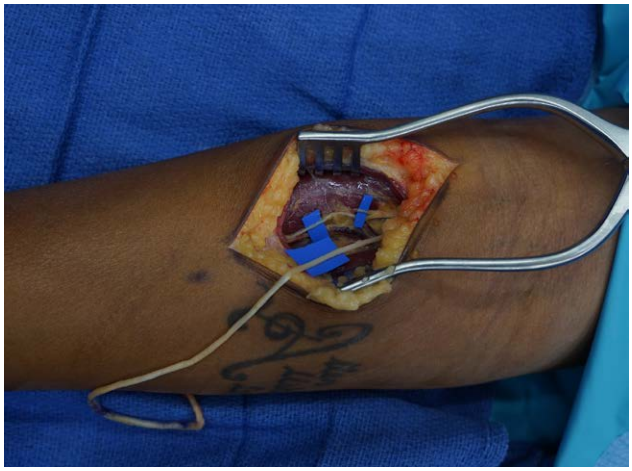

Fig. 2. The extensor carpi radialis brevis motor nerve is exposed through a radial tunnel approach. This is dissected distally until it arborizes into multiple branches (small blue backgrounds above). The radial sensory nerve (large blue background below) has been translocated into the proximal forearm approach for nerve transfer.

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.

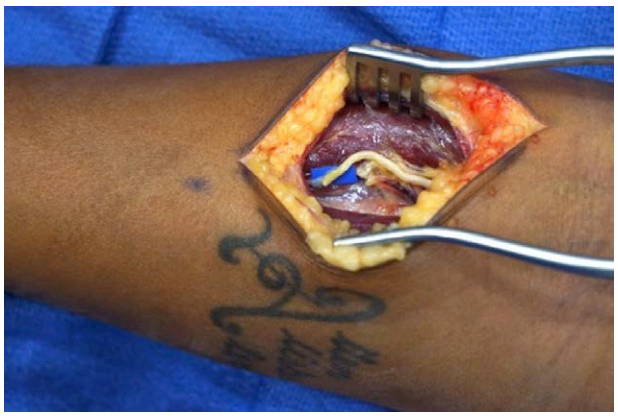

Fig. 3. Nerve transfer of the radial sensory nerve to the distal motor nerve of the extensor carpi radialis brevis (blue background). The proximal motor nerve to the extensor carpi radialis brevis has been preserved.

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.

Grant M. Kleiber, MD
Department of Plastic Surgery
MedStar Georgetown University Hospital
3800 Reservoir Road NW
Washington, DC 20007
E-mail: grantkleiber@gmail.com

PATIENT CONSENT

Patients provided written consent for the use of their images.

REFERENCES

1. Poppler LH, Parikh RP, Bichanich MJ, et al. Surgical interventions for the treatment of painful neuroma: a comparative meta-analysis. *Pain*. 2018;159:214–223.
2. Eberlin KR, Ducic I. Surgical algorithm for neuroma management: a changing treatment paradigm. *Plast Reconstr Surg Glob Open*. 2018;6:e1952.
3. Vernadakis AJ, Koch H, Mackinnon SE. Management of neuromas. *Clin Plast Surg*. 2003;30:247, vii–268, vii.
4. Neumeister MW, Winters JN. Neuroma. *Clin Plast Surg*. 2020;47:279–283.
5. Ives GC, Kung TA, Nghiem BT, et al. Current state of the surgical treatment of terminal neuromas. *Neurosurgery*. 2018;83:354–364.
6. Wolvetang NHA, Lans J, Verhiel SHWL, et al. Surgery for symptomatic neuroma: anatomic distribution and predictors of secondary surgery. *Plast Reconstr Surg*. 2019;143:1762–1771.
7. Lans J, Baker DJ, Castelein RM, et al. Patient-reported outcomes following surgical treatment of symptomatic digital neuromas. *Plast Reconstr Surg*. 2020;145:563e–573e.
8. Domeshek LF, Krauss EM, Snyder-Warwick AK, et al. Surgical treatment of neuromas improves patient-reported pain, depression, and quality of life. *Plast Reconstr Surg*. 2017;139:407–418.
9. Alexander JH, Jordan SW, West JM, et al. Targeted muscle reinnervation in oncologic amputees: early experience of a novel institutional protocol. *J Surg Oncol*. 2019;120:348–358.
10. Valerio IL, Dumanian GA, Jordan SW, et al. Preemptive treatment of phantom and residual limb pain with targeted muscle reinnervation at the time of major limb amputation. *J Am Coll Surg*. 2019;228:217–226.
11. Dumanian GA, Potter BK, Mioton LM, et al. Targeted muscle reinnervation treats neuroma and phantom pain in major limb amputees: a randomized clinical trial. *Ann Surg*. 2019;270:238–246.
12. Bowen JB, Ruter D, Wee C, et al. Targeted muscle reinnervation technique in below-knee amputation. *Plast Reconstr Surg*. 2019;143:309–312.
13. Salminger S, Sturma A, Roche AD, et al. Outcomes, challenges, and pitfalls after targeted muscle reinnervation in high-level amputees: is it worth the effort? *Plast Reconstr Surg*. 2019;144:1037e–1043e.
14. Michno DA, Woollard ACS, Kang NV. Clinical outcomes of delayed targeted muscle reinnervation for neuroma pain reduction in long-standing amputees. *J Plast Reconstr Aesthet Surg*. 2019;72:1576–1606.
15. Eberlin KR. Invited Commentary targeted muscle reinnervation: a significant advance in the prevention and treatment of post-amputation neuropathic pain. *J Am Coll Surg*. 2019;228:226–227.
16. Mioton LM, Dumanian GA. Targeted muscle reinnervation and prosthetic rehabilitation after limb loss. *J Surg Oncol*. 2018;118:807–814.
17. Bowen JB, Wee CE, Kalik J, et al. Targeted muscle reinnervation to improve pain, prosthetic tolerance, and bioprosthetic outcomes in the amputee. *Adv Wound Care (New Rochelle)*. 2017;6:261–267.
18. Souza JM, Cheesborough JE, Ko JH, et al. Targeted muscle reinnervation: a novel approach to postamputation neuroma pain. *Clin Orthop Relat Res*. 2014;472:2984–2990.
19. McNamara CT, Iorio ML. Targeted muscle reinnervation: outcomes in treating chronic pain secondary to extremity amputation and phantom limb syndrome. *J Reconstr Microsurg*. 2020;36:235–240.
20. Kubiak CA, Kemp SWP, Cederna PS, et al. Prophylactic regenerative peripheral nerve interfaces to prevent postamputation pain. *Plast Reconstr Surg*. 2019;144:421e–430e.
21. Santosa KB, Oliver JD, Cederna PS, et al. Regenerative peripheral nerve interfaces for prevention and management of neuromas. *Clin Plast Surg*. 2020;47:311–321.
22. Chappell AG, Jordan SW, Dumanian GA. Targeted muscle reinnervation for treatment of neuropathic pain. *Clin Plast Surg*. 2020;47:285–293.