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A novel nerve isolation technique for targeted muscle reinnervation during below knee amputation

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Major limb amputation can be the unfortunate consequence of nonreconstructable peripheral arterial disease and chronic limb threatening ischemia. Phantom limb pain (PLP) and neuroma-associated limb pain remain significant challenges for many specialists who treat patients after major amputations. PLP is the perception of discomfort in the limb no longer present.[1] The prevalence can be as high as 80% depending on how this outcome is measured.[2] One of the primary causes of PLP is symptomatic neuromas.[3]

Several groups have reported various techniques for reinnervation, including targeted muscle reinnervation (TMR) and regenerative peripheral nerve interface.[1,4] Both are nerve transfer procedures believed to decrease neuroma formation by providing a "home" for the nerve in the remaining distal target muscle. This seems to be a more physiologic innervation that might prevent pathologic central reorganization and PLP.[1]

A recent study demonstrated a benefit to preemptive treatment of PLP with muscle reinnervation performed concurrently with an amputation for nonischemic reasons.[1] Another study demonstrated significant improvement in both ambulation and PLP in patients receiving TMR concurrently with amputation.[2] The effect of muscle reinnervation in amputations primarily for ischemic limbs is unclear. Vascular disease accounts for >50% of amputations in the United States, with vascular surgeons performing many of these procedures.[5] By presenting our novel technique for nerve isolation and subsequent reinnervation, more patients could have access to this potentially life-altering preemptive intervention.

The workup and level of amputation should proceed in accordance with the current practice patterns of the surgeon. Our group has performed >75 of these procedures. The patient provided written informed consent for the report of his case details and imaging studies (available on request). We demonstrate our technique in the Supplementary Video (online only). For the below knee amputation, we prefer to design the flaps using the two-third and one-third technique. We use ultrasound to mark the location of the great and small saphenous veins distal to the incisions for the flaps. The leg is then prepped and draped in the usual sterile fashion.

Four nerves are identified before initiating the amputation. The fifth major nerve, the tibial nerve, is isolated after dividing the tibia and fibula. We start by identifying the saphenous nerve with an incision in the calf distal to the anterior amputation flap over the previously marked saphenous vein. We use sharp dissection to isolate the saphenous nerve, which is generally located just posterior to the great saphenous vein.

The knee is then bent and rotated medially. A longitudinal incision is made over the previously marked small saphenous vein. Sharp dissection should begin laterally to the vein to identify a quite robust sural nerve.

A longitudinal incision is then made over the lateral third of the anterior compartment. The compartment is opened, and the tibialis anterior and extensor digitorum longus are separated. The anterior tibial artery and vein are approached using sharp dissection. The deep peroneal nerve is generally located lateral within this bundle. Through a separate longitudinal incision, parallel to the previous one, the lateral compartment is entered just lateral to the anterior intermuscular septum. The superficial peroneal nerve usually lies immediately underneath the fascia of the lateral compartment and adjacent to the septum. Care should be taken when opening the lateral compartment because the nerve can be easily injured.

The amputation incisions are then begun in typical fashion, taking care to preserve the isolated nerves. After the tibia and fibula are divided, the distal transected bones are elevated, and the neurovascular bundle is

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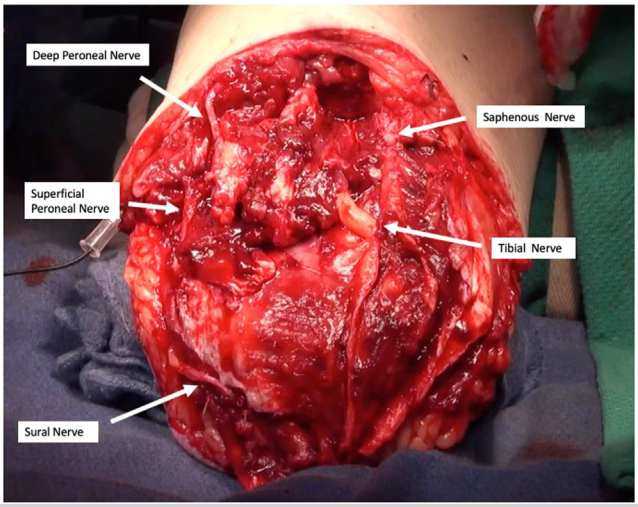

Fig. Below knee amputation flap demonstrating targeted muscle reinnervation (TMR) of all five major nerves typically coapted during a reinnervation procedure, including the saphenous, sural, superficial peroneal, deep peroneal, and tibial nerves.

identified just deep to the tibialis posterior muscle. Next, 8 cm of the tibial nerve is isolated and then sharply divided. The remainder of the leg is amputated, taking special care to preserve sufficient length for all isolated nerves and ensure the flaps are adequate for closure.

Using the checkpoint nerve stimulator (Checkpoint Surgical Inc), appropriate terminal motor nerves are identified in the remaining muscle. These are not named nerves but rather the terminal branches of motor nerves as they course in the muscles of the calf. Once a good target region has been identified, jeweler forceps and micro-dissecting scissors are used to dissect through the muscle fibers down to the recipient nerve. Once identified, the recipient nerve is divided sharply with the micro-dissecting scissors.

The previously harvested peripheral nerve is then gently stretched and cut to length. Neurorrhaphy is performed in standard fashion using two or three interrupted 8-0 nylon sutures to coapt the perineural tissue (Current Procedural Terminology code 64905). We use 3.5× surgical loupes to perform neurorrhaphy. The checkpoint nerve stimulator should be used to stimulate the peripheral nerve at the lowest necessary setting to ensure energy transfer across the neurorrhaphy into the motor nerve home. We use 4-0 Vicryl suture to create a cerclage of muscle around the neurorrhaphy. This is repeated for all five major nerves (saphenous, sural, superficial peroneal, deep peroneal, and tibial) in the lower leg (Fig). The amputation flaps are then approximated in standard fashion with 2-0 Vicryl fascial stitches and staples. We find that TMR adds ~90 minutes to a standard below knee amputation once a surgeon is familiar with the procedure.

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