Preventing neuromas in amputees

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The problem

- 2 million amputees in USA
- About 185,000 amputations per year
- 95% reported experiencing 1 or more types of amputation-related pain in the past 4 weeks
- 50 to 80% with chronic phantom limb pain

- Ziegler-Graham K et al. Estimating the prevalence of limb loss in the United States: 2005 to 2050. Arch Phys Med Rehabil. 2008;89:422-29.
- Ephraim PL, et al. Phantom pain, residual limb pain and back pain in amputees: Results of a national survey. Arch Phys Med Rehabil. 2005;86:1910-19.
- Schley MT, et al. Painful and nonpainful phantom and stump sensations in acute traumatic amputees. J Trauma. 2008;65:858-64.
- Richardson C, Kulkarni J. A review of the management of phantom limb pain: challenges and solutions. J Pain Res. 2017;10:1861-70

Phantom limb pain

- 53% of patients with PLP and 38% with severe PLP had never been diagnosed or treated
- Many patients may develop pain later following discharge from routine follow-up

- Hanley MA, et al. Self-reported treatments used for lower-limb phantom pain: descriptive findings. Arch Phys Med Rehabil. 2006;87:270-77.

Paradigm shift in treatment of neuromas

Passive/ Ablative	Active/ Reconstructive
Excision only	Targeted muscle reinnervation
Traction neurectomy	
Excision and implantation (muscle, bone)	

Targeted muscle reinnervation

- Amputees have blind-ending nerve stumps which keep growing without a target and can become painful
- Surgical technique which:
  - Improves post amputation nerve pain
  - Allows operation of advanced myoelectric prostheses
- Idea: redirect mixed nerve endings into end motor nerves/ neuromuscular junction

Prosthetics and Orthotics International, 2004, 28, 245–253

The use of targeted muscle reinnervation for improved myoelectric prosthesis control in a bilateral shoulder disarticulation amputee

T. A. KUIKEN*/**, G. A. DUMANIAN***, R.D. LIPSCHUTZ*, L.A. MILLER* and K.A. STUBBLEFIELD*

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a daily basis. After approximately 3 months the patient noticed his first voluntary 'twitches' in his pectoralis muscle when he tried to bend his missing elbow. By 5 months he could activate 3 different areas of his pectoralis major muscle. Trying to flex his phantom elbow would cause a strong contraction of the muscle area just beneath the clavicle. This was consistent with musculocutaneous nerve reinnervation. Closing his phantom hand caused a moderate contraction in the mid-region of the pectoralis major, consistent with median nerve reinnervation. Extending his elbow and hand caused a palpable contraction of the lower pectoralis muscle, consistent with radial nerve reinnervation. No contraction could ever be appreciated on the lateral chest wall indicating that the ulnar nerve to pectoralis minor anastomosis was unsuccessful.

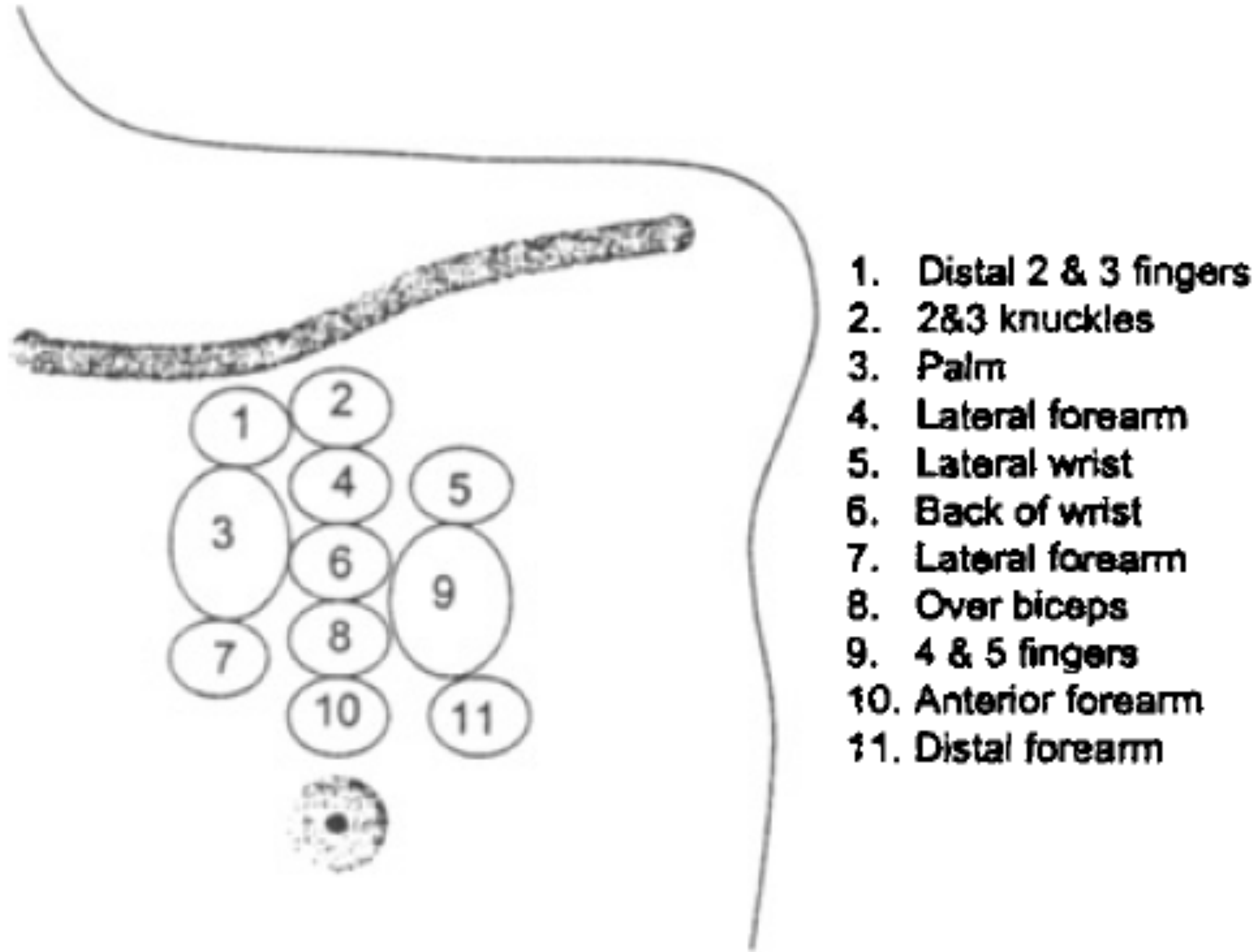

Fig. 2. Diagram of sensory reinnervation of anterior chest wall indication where touching the patient produced sensation in his phantom arm.

Targeted reinnervation for enhanced prosthetic arm function in a woman with a proximal amputation: a case study

Todd A Kuiken, Laura A Miller, Robert D Lipschutz, Blair A Lock, Kathy Stubblefield, Paul D Marasco, Ping Zhou, Gregory A Dumanian

Summary

Background The function of current artificial arms is limited by inadequate control methods. We developed a technique that used nerve transfers to muscle to develop new electromyogram control signals and nerve transfers to skin, to provide a pathway for cutaneous sensory feedback to the missing hand.

Methods We did targeted reinnervation surgery on a woman with a left arm amputation at the humeral neck. The ulnar, median, musculocutaneous, and distal radial nerves were transferred to separate segments of her pectoral and serratus muscles. Two sensory nerves were cut and the distal ends were anastomosed to the ulnar and median nerves. After full recovery the patient was fit with a new prosthesis using the additional targeted muscle reinnervation sites. Functional testing was done and sensation in the reinnervated skin was quantified.

Findings The patient described the control as intuitive; she thought about using her hand or elbow and the prosthesis responded appropriately. Functional testing showed substantial improvement: mean scores in the blocks and box test increased from 4·0 (SD 1·0) with the conventional prosthesis to 15·6 (1·5) with the new prosthesis. Assessment of Motor and Process Skills test scores increased from 0·30 to 1·98 for motor skills and from 0·90 to 1·98 for process skills. The denervated anterior chest skin was reinnervated by both the ulnar and median nerves; the patient felt that her hand was being touched when this chest skin was touched, with near-normal thresholds in all sensory modalities.

Interpretation Targeted reinnervation improved prosthetic function and ease of use in this patient. Targeted sensory reinnervation provides a potential pathway for meaningful sensory feedback.

Lancet 2007; 369: 371–80

See Comment page 345

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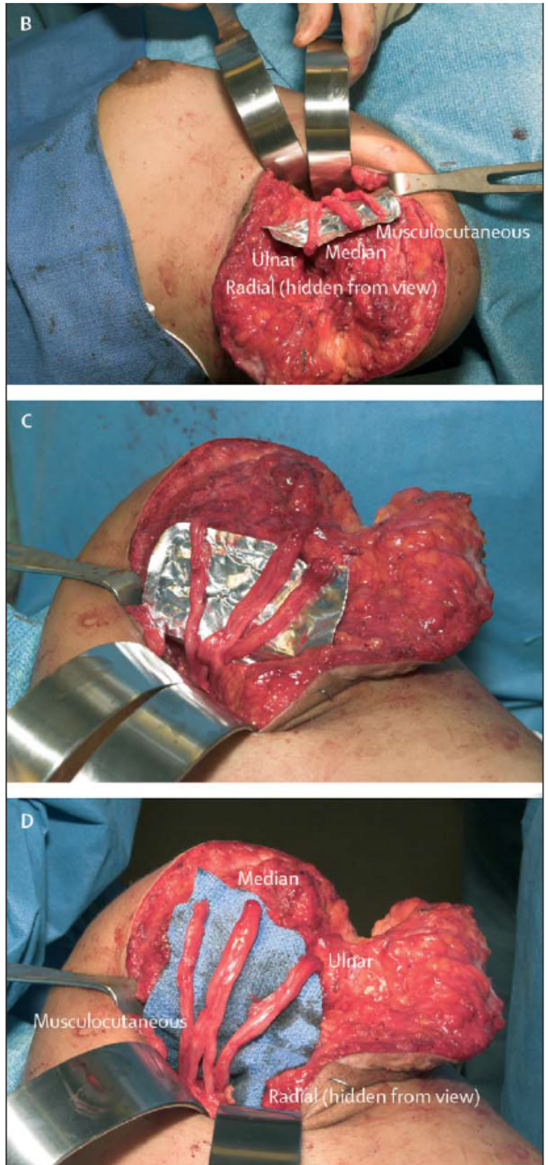
Methods

Patient

The patient was a 24-year-old woman who had a traumatic transhumeral amputation in May, 2004, due to a motorcycle accident. She had severe phantom limb pain



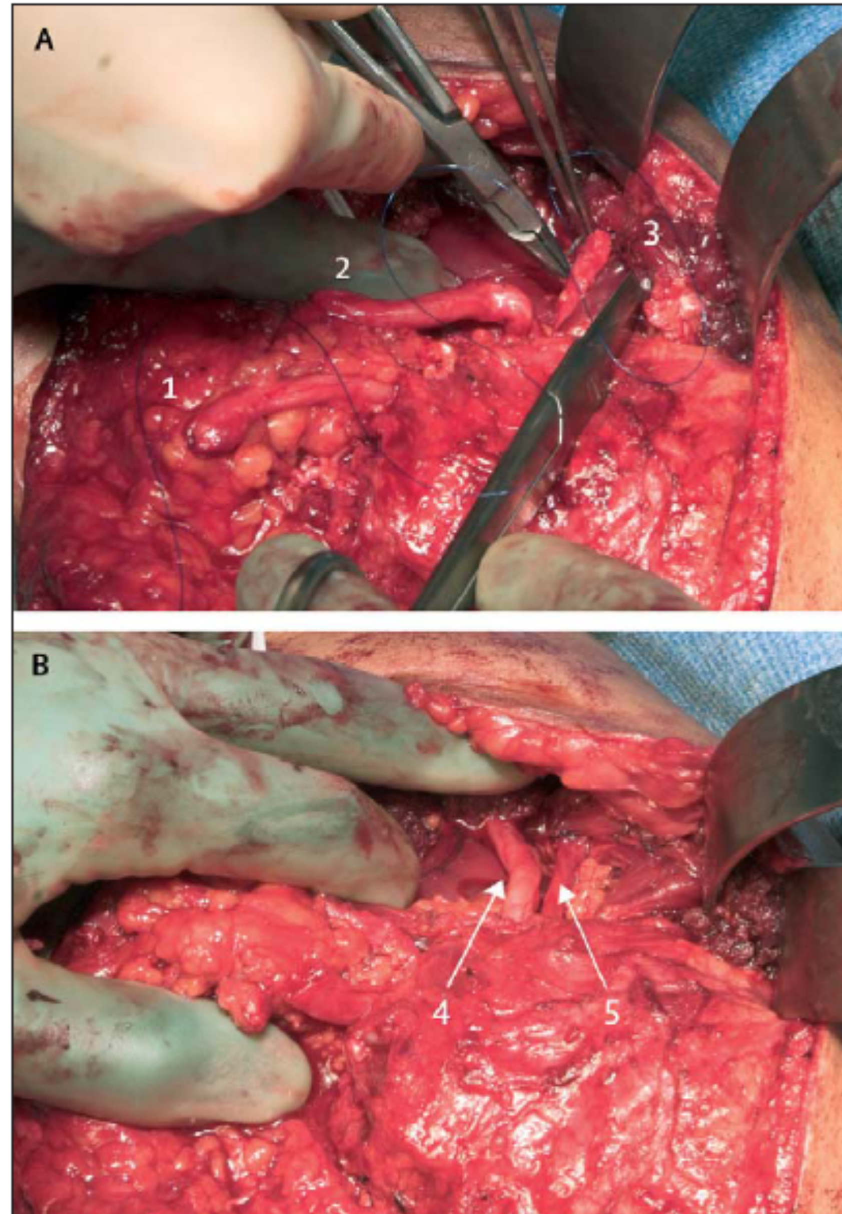


***Figure* 3: Coaptation of nerves to pectoralis major**
(1) Ulnar nerve. (2) Median nerve. (3) Coaptation of musculocutaneous nerve to clavicular head of pectoralis major. (4) Coaptation of median nerve to sternal portion of pectoralis major. (5) Coaptation of musculocutaneous nerve to clavicular head of pectoralis major.

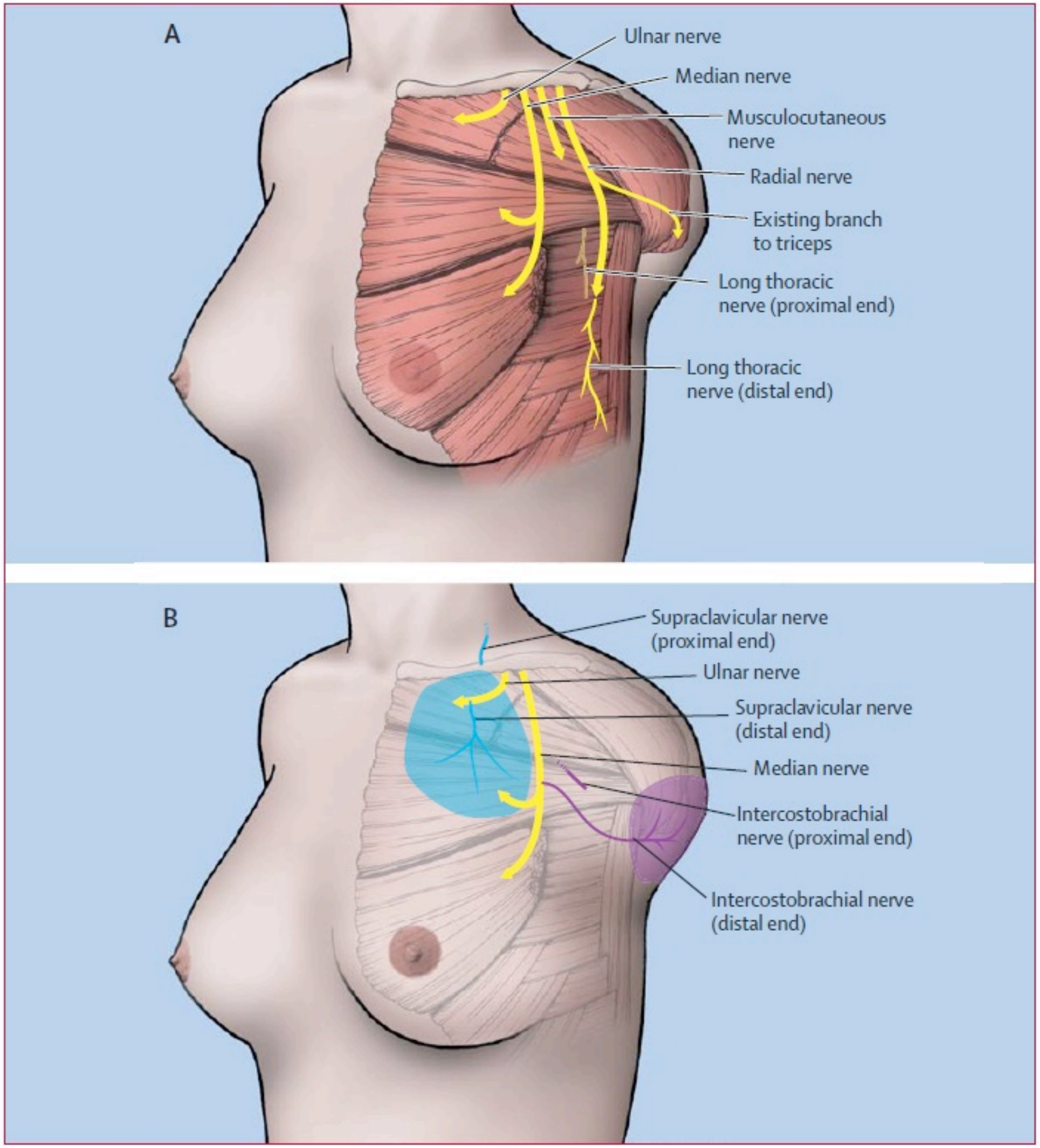
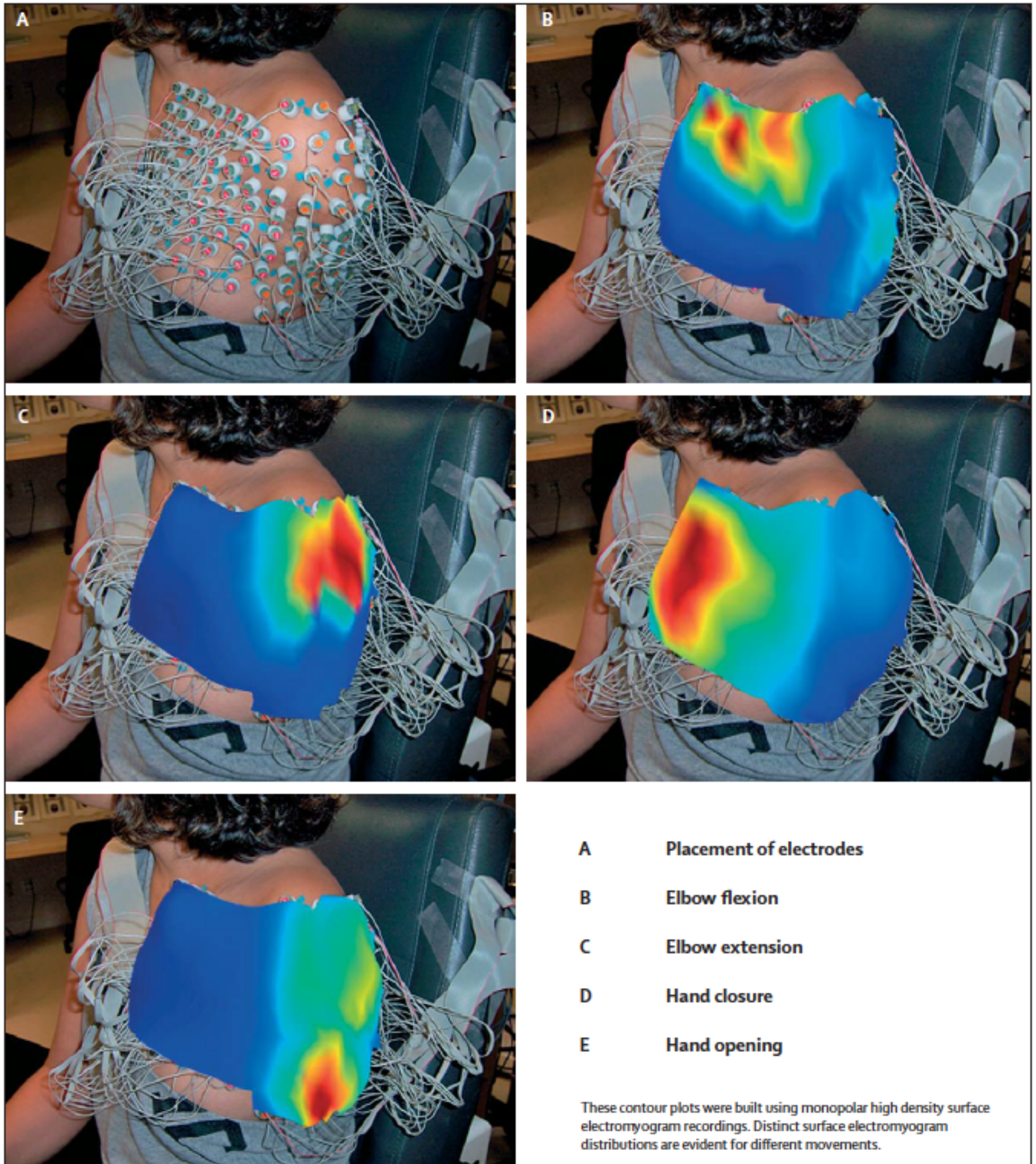


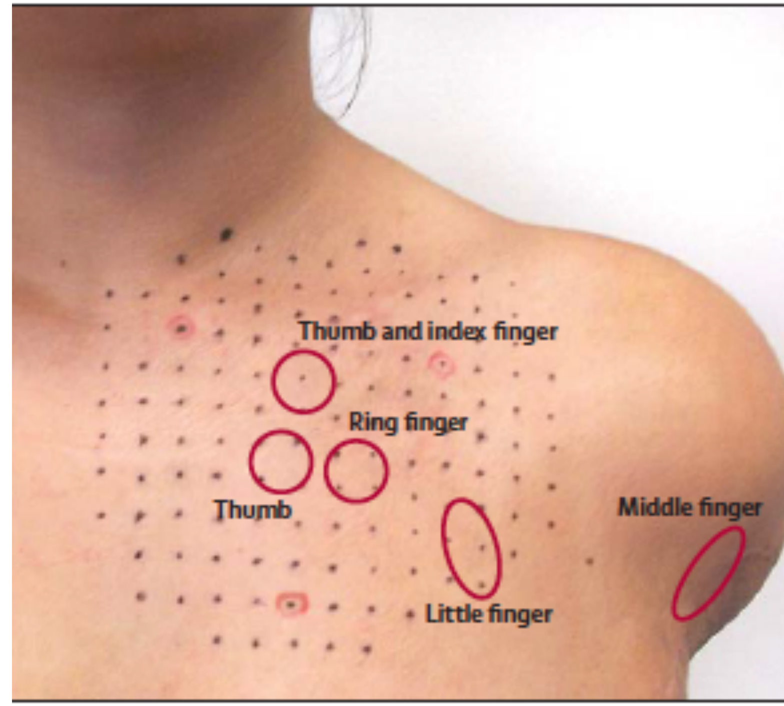
Figure 7: **Diagram of targeted reinnervation surgery**
(A) Targeted muscle reinnervation. The musculocutaneous, ulnar, and median nerves were transferred to separate segments of the pectoralis major muscle. The long thoracic nerve innervating the inferior three slips of serratus anterior was divided and the distal segment was coapted to the radial nerve. (B) Targeted sensory reinnervation. The supraclavicular cutaneous nerve was cut and the distal segment was coapted to the side of the ulnar nerve. The intercostobrachial cutaneous nerve was cut and the distal end was coapted to the side of the median nerve.



A	Placement of electrodes
B	Elbow flexion
C	Elbow extension
D	Hand closure
E	Hand opening

These contour plots were built using monopolar high density surface electromyogram recordings. Distinct surface electromyogram distributions are evident for different movements.

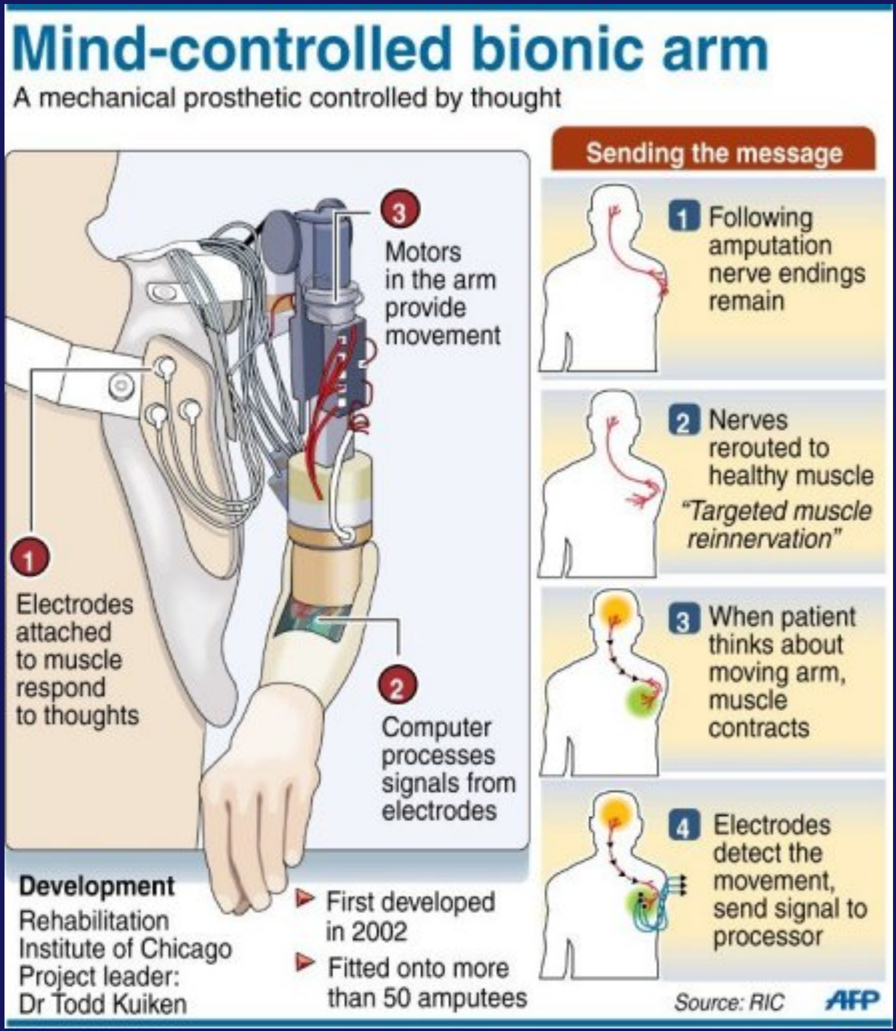
Figure 9: Map of surface electromyogram amplitude for four different movements

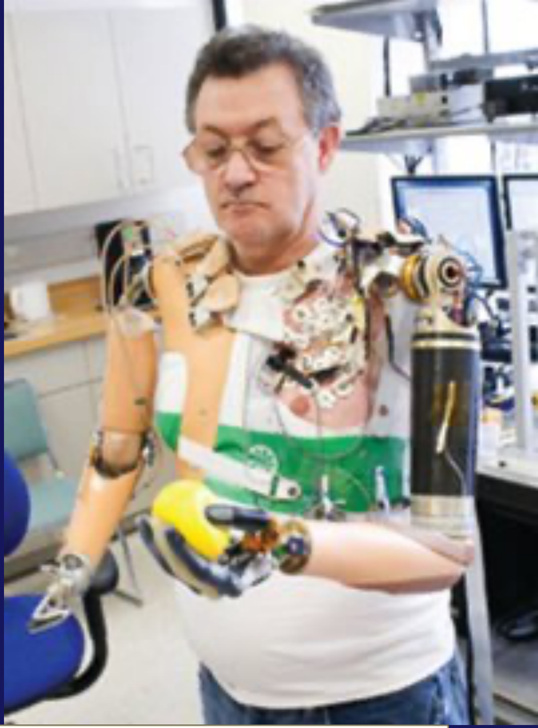


1: Map of areas that the patient perceived as distinctly different in response to touch

Figure 10: Experimental prosthesis consisting of a motorised elbow, wrist, and hand, with passive shoulder components

Jesse Sullivan





Jesse Sullivan and Claudia Mitchell demonstrate the capabilities of their RIC six-motor, neural-controlledprosthetic arms with a high five.
Photo courtesy of the Rehabilitation Institute of Chicago.

Targeted muscle reinnervation

- Allows prostheses with more degrees of freedom
- Allows intuitive, simultaneous control of multiple joints in an advanced prosthesis

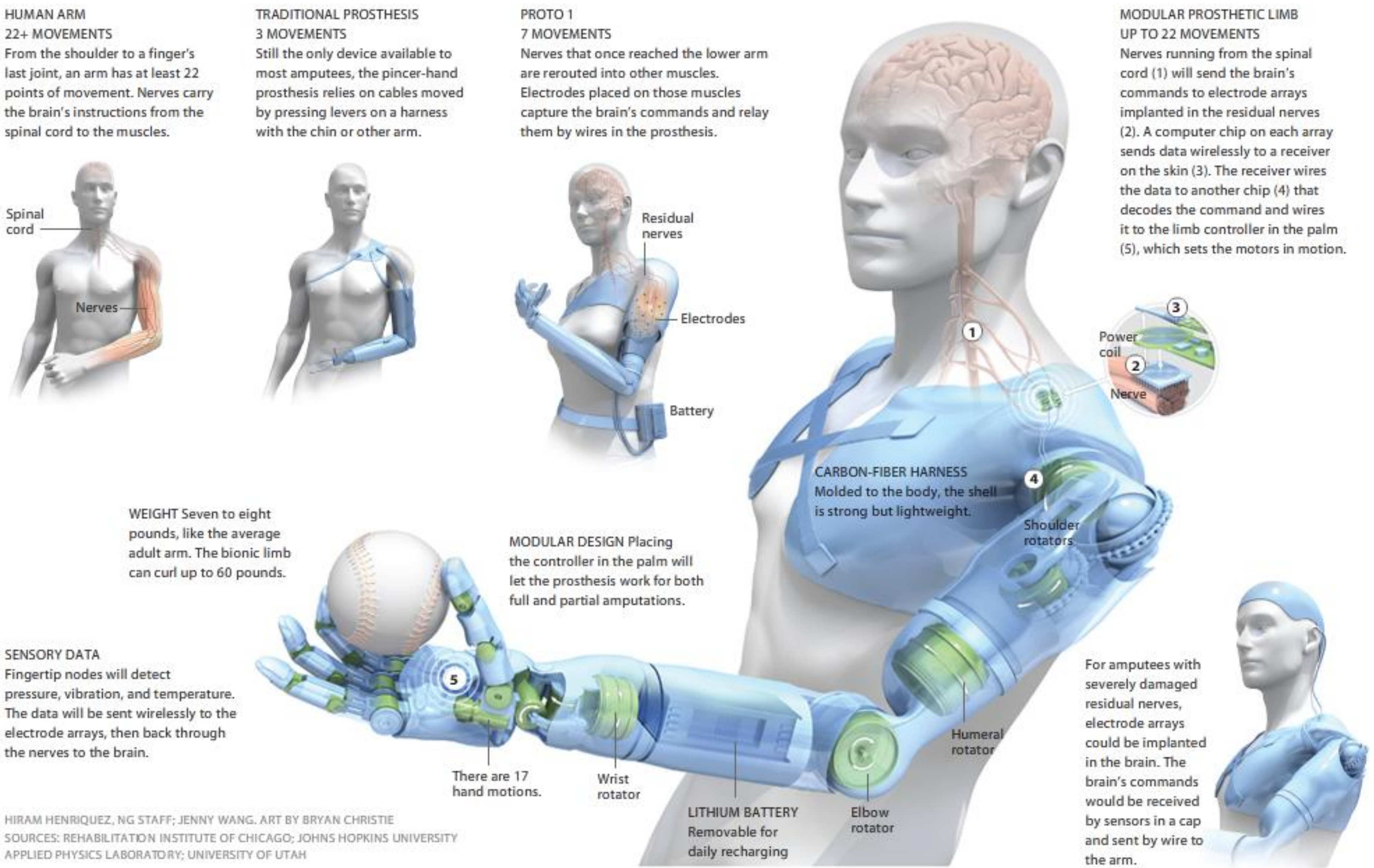
- John Matheny
- First patient at JHH to undergo TMR
- Osseointegrated prosthesis

Targeted muscle reinnervation

- Surgical procedure used to improve intuitive control of upper and lower limb prostheses
- Residual mixed nerves from amputated limbs are transferred to reinnervate new muscle targets that have lost their function
- Reinnervated muscles serve as biological amplifiers of motor signals
- EMG signals interpreted using advanced pattern recognition (APR) algorithms
- Allowing intuitive prosthesis control
- Abiity to perform simultaneous movements with multiple degrees of freedom

Closing in on a Lifelike Limb

THE ABILITIES OF TODAY'S PROTO 1 BIONIC ARM WILL TRIPLE IN THE NEXT PROTOTYPE.



HIRAM HENRIQUEZ, NG STAFF; JENNY WANG. ART BY BRYAN CHRISTIE
SOURCES: REHABILITATION INSTITUTE OF CHICAGO; JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY; UNIVERSITY OF UTAH

NGM.com: Shawn Greene, Greg Harris, Paul Heltzel, Sabi Chawla, Stefan Estrada

Targeted muscle reinnervation

- TMR yields significant improvement in neuroma pain
- TMR style nerve transfer provides end organ/ muscle for nerve to grow into

1. Souza J M, Cheesborough J E, Ko J H, Cho M S, Kuiken T A, Dumanian G A. Targeted muscle reinnervation: a novel approach to postamputation neuroma pain. Clin Orthop Relat Res. 2014;472(10):2984–2990.
2. Pierce R O Jr, Kernek C B, Ambrose T A II. The plight of the traumatic amputee. Orthopedics. 1993;16(7):793–797.

TMR was initially developed for upper extremity amputees but is also now performed routinely for lower extremity amputees

BRIEF REPORT

Robotic Leg Control with EMG Decoding in an Amputee with Nerve Transfers

Levi J. Hargrove, Ph.D., Ann M. Simon, Ph.D., Aaron J. Young, M.S., Robert D. Lipschutz, C.P., Suzanne B. Finucane, M.S., Douglas G. Smith, M.D., and Todd A. Kuiken, M.D., Ph.D.

SUMMARY

The clinical application of robotic technology to powered prosthetic knees and ankles is limited by the lack of a robust control strategy. We found that the use of electromyographic (EMG) signals from natively innervated and surgically reinnervated residual thigh muscles in a patient who had undergone knee amputation improved control of a robotic leg prosthesis. EMG signals were decoded with a pattern-recognition algorithm and combined with data from sensors on the prosthesis to interpret the patient's intended movements. This provided robust and intuitive control of ambulation — with seamless transitions between walking on level ground, stairs, and ramps — and of the ability to reposition the leg while the patient was seated.

CASE REPORT

A 31-year-old man underwent a knee-disarticulation amputation in 2009, approximately 36 hours after a motorcycle collision. During the amputation surgery, two nerve transfers were performed to prevent neuroma formation.[1] The severed sciatic nerve was separated into its tibial and common peroneal branches. Small nerve branches to the distal portions of the residual semitendinosus muscle and the long head of the biceps femoris muscle (Fig. 1) were located and cut where the nerves entered their respective muscles. The tibial nerve branch was then sewn over the motor point on the semitendinosus, and the common peroneal nerve branch was sewn over the motor point on the long head of the biceps femoris, thus allowing the transferred nerves to reinnervate these hamstring muscles. This surgery is analogous to targeted muscle reinnervation (TMR) surgery that is performed as part of arm amputation to improve the control of motorized arm prostheses.[2] As expected from our experience with TMR, discrete contractions in reinnervated muscles developed after a few months. When the patient attempted dorsiflexion of his missing foot, a contraction could be seen and palpated in the distal semitendinosus. Similarly, contraction of the distal long head of the biceps femoris occurred when he attempted plantarflexion of his missing foot.

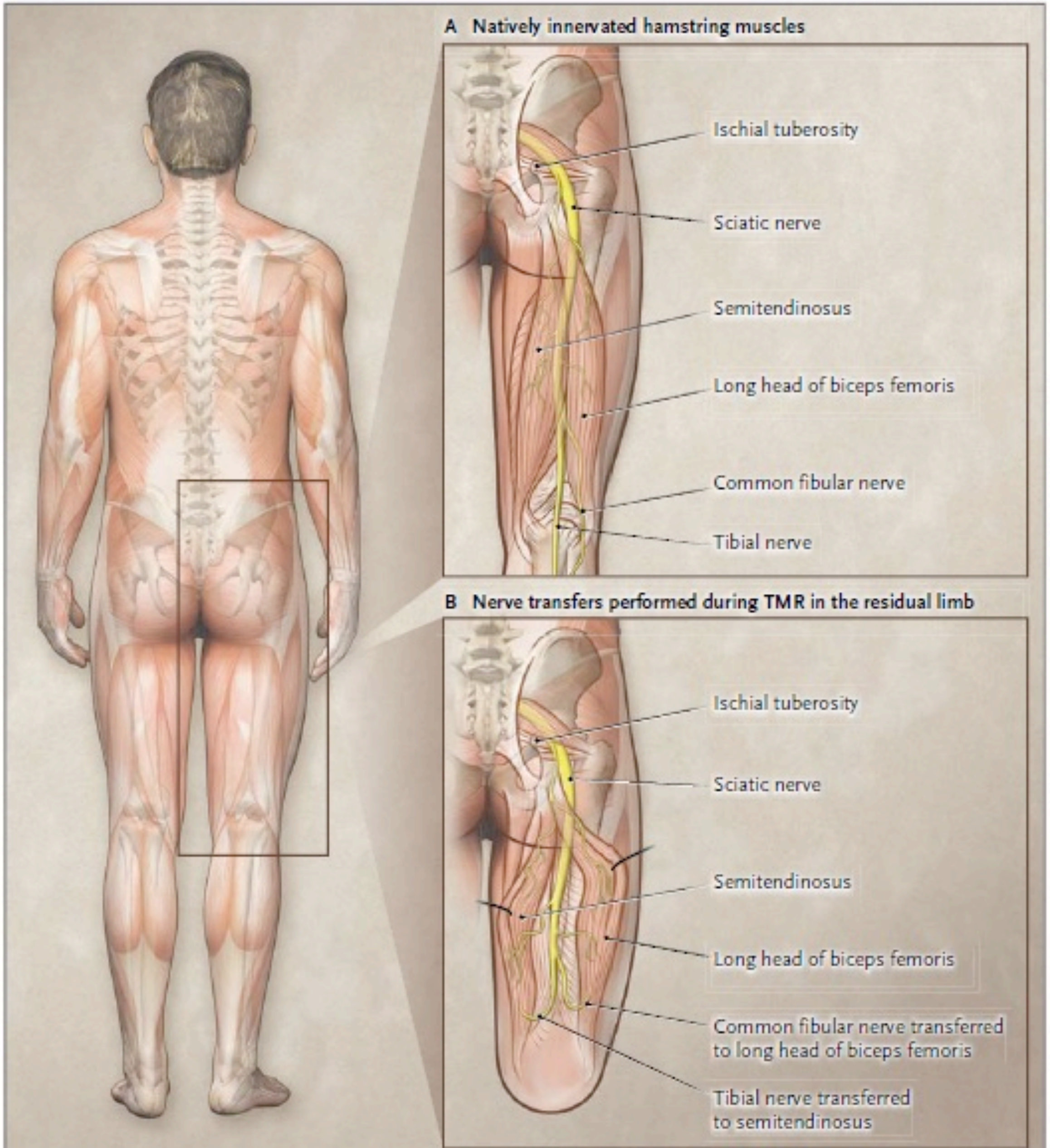


Figure 1. Natively Innervated and Surgically Reinnervated Residual Thigh Muscles.

Posterior views of the anatomy of the upper thigh show natively innervated hamstring muscles (Panel A) and nerve transfers performed during targeted muscle reinnervation (TMR) surgery (Panel B) in the residual limb.

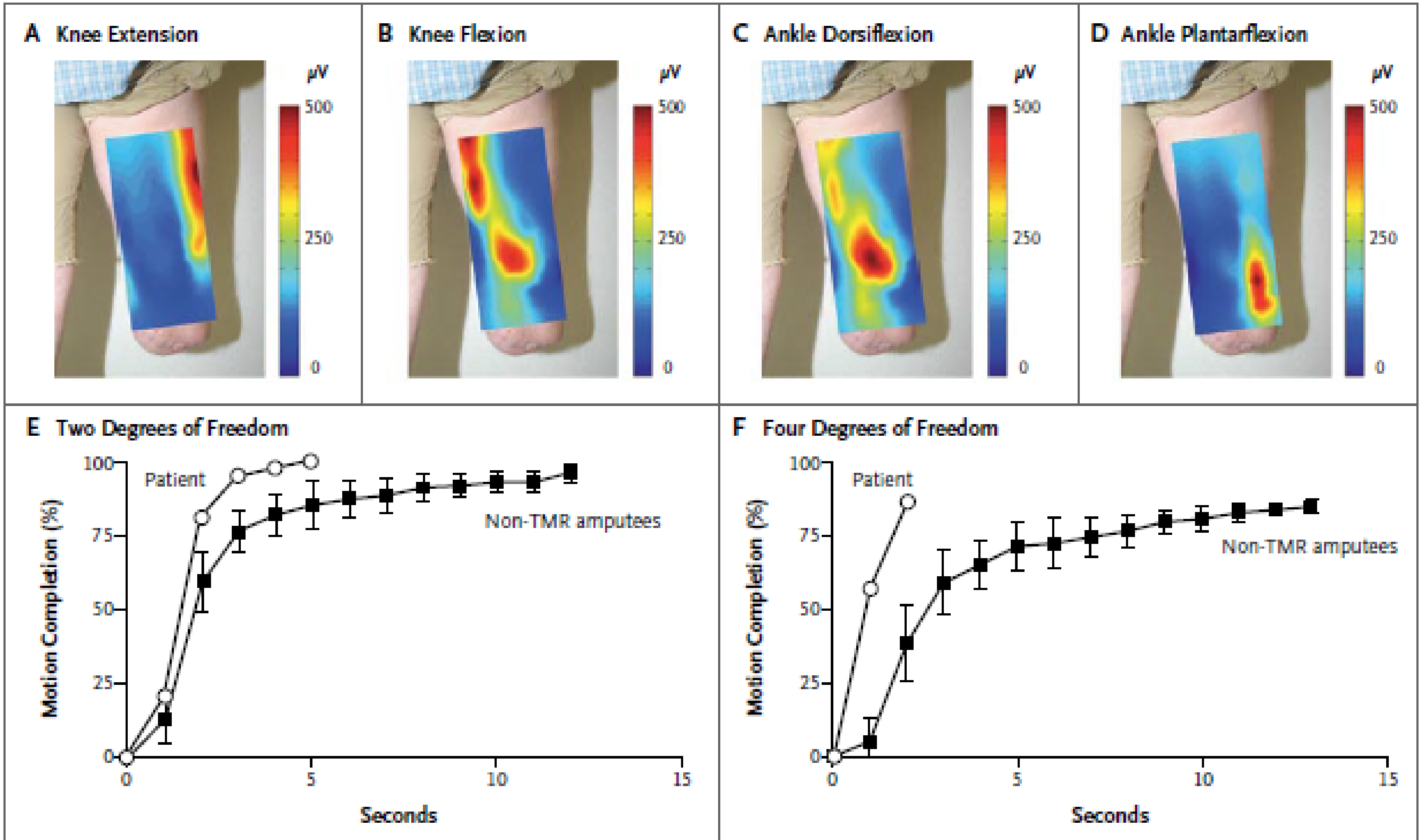
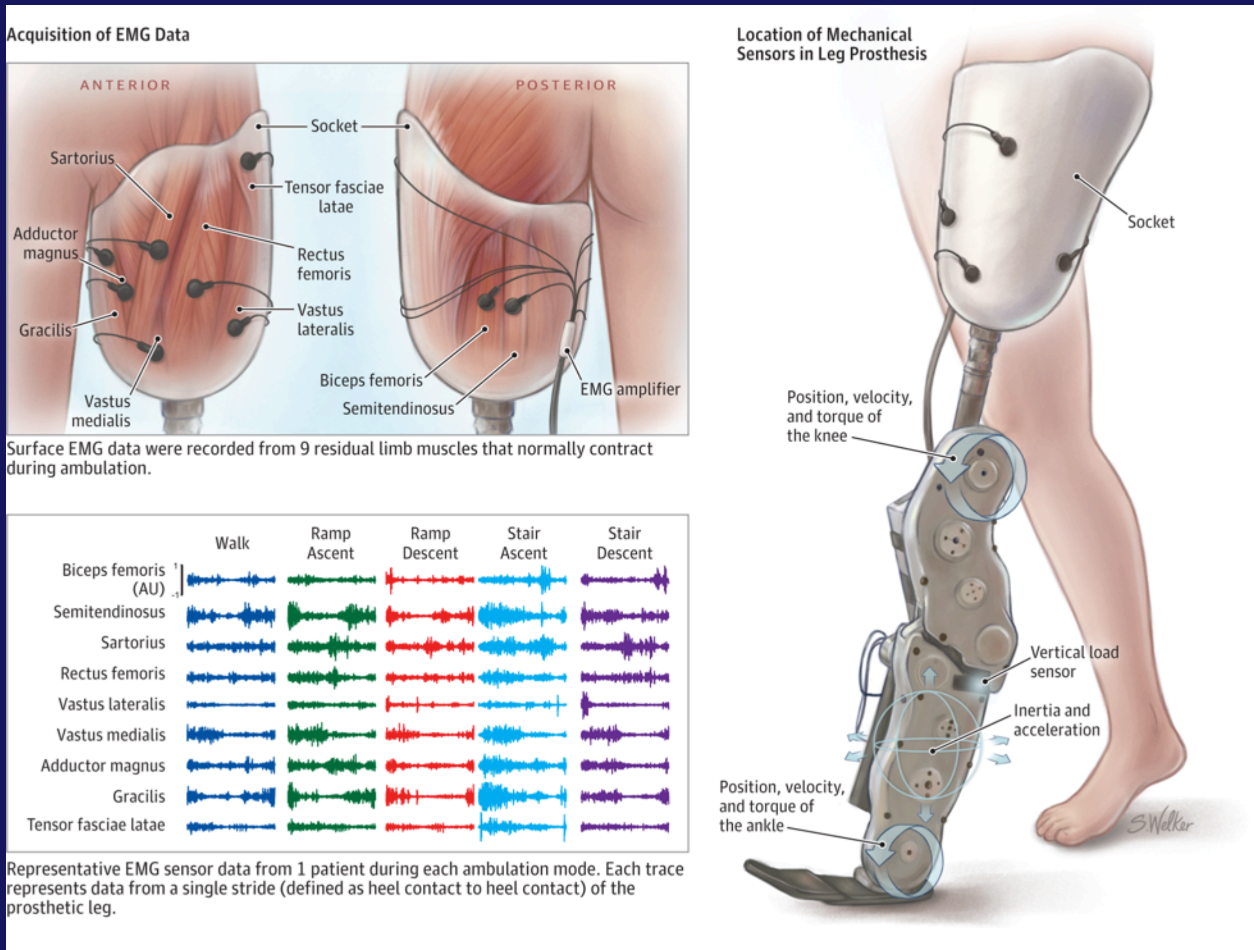


Figure 2. Evaluation of Muscle Reinnervation Patterns.

Photographs show an anterior view of the patient's residual limb with superimposed maps of electromyographic (EMG) signal amplitude corresponding to knee extension (Panel A), knee flexion (Panel B), ankle dorsiflexion (Panel C), and ankle plantarflexion (Panel D). Colors indicate the level of EMG activity: areas of high EMG activity, corresponding to strong muscular contractions, are red; areas with little EMG activity are blue. Real-time testing showed that the patient completed motions faster than did non-TMR transfemoral amputees[4] for both two degrees of freedom (ankle plantarflexion and dorsiflexion and knee flexion and extension) (Panel E) and four degrees of freedom (ankle plantar flexion and dorsiflexion, knee flexion and extension, tibial rotation, and femoral rotation) (Panel F). I bars indicate standard deviations.

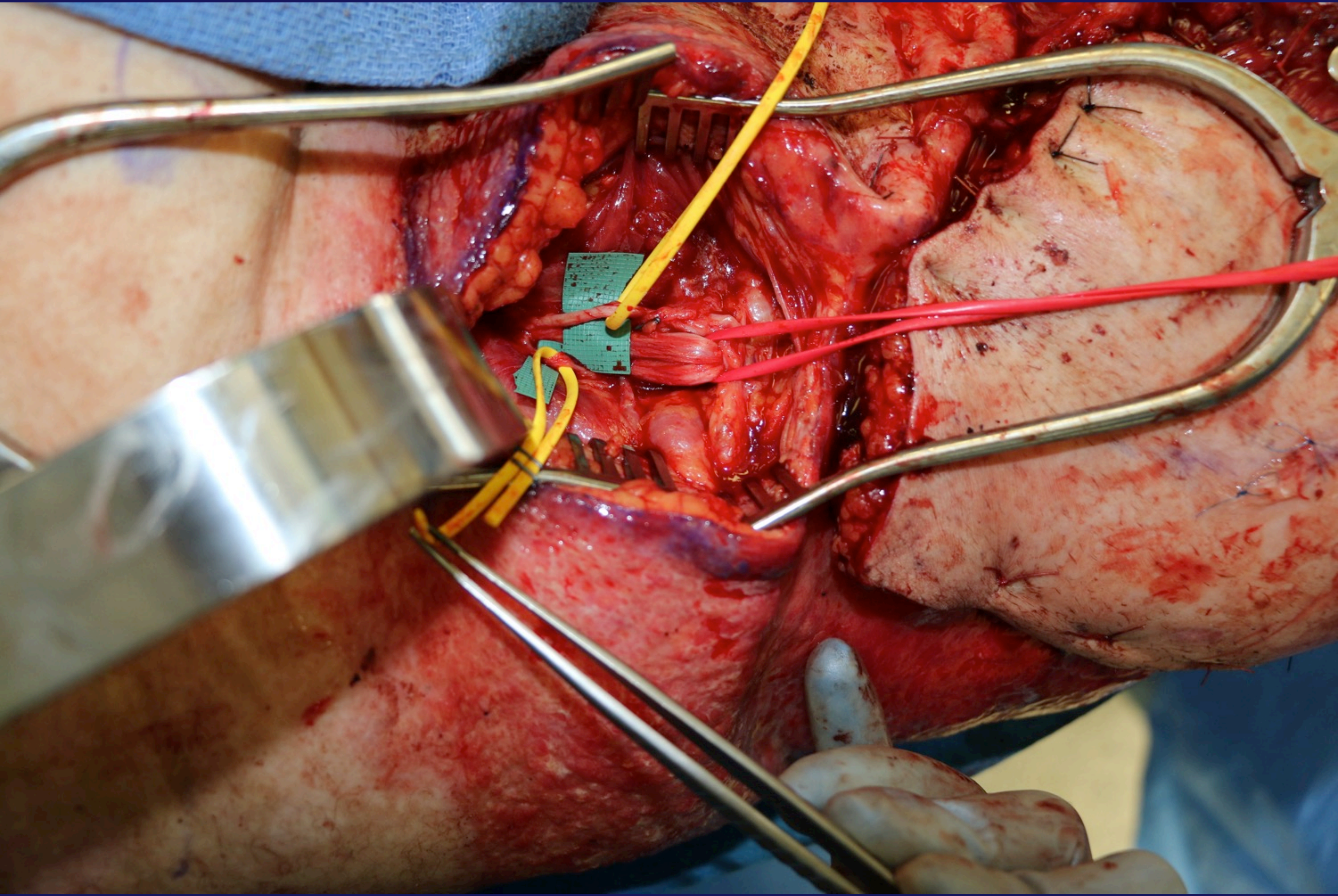
The patient perceived that the TMR-enhanced system provided intuitive control during ambulation and non–weight-bearing activities. The reduced error rate enabled him to ambulate confidently and transition seamlessly among all modes with near-normal gait kinematics. The patient

Figure 3. Stair Ascent with Reciprocal Gait with the Use of the TMR-Enhanced Control System.



Transfemoral amputee

Immediate TMR

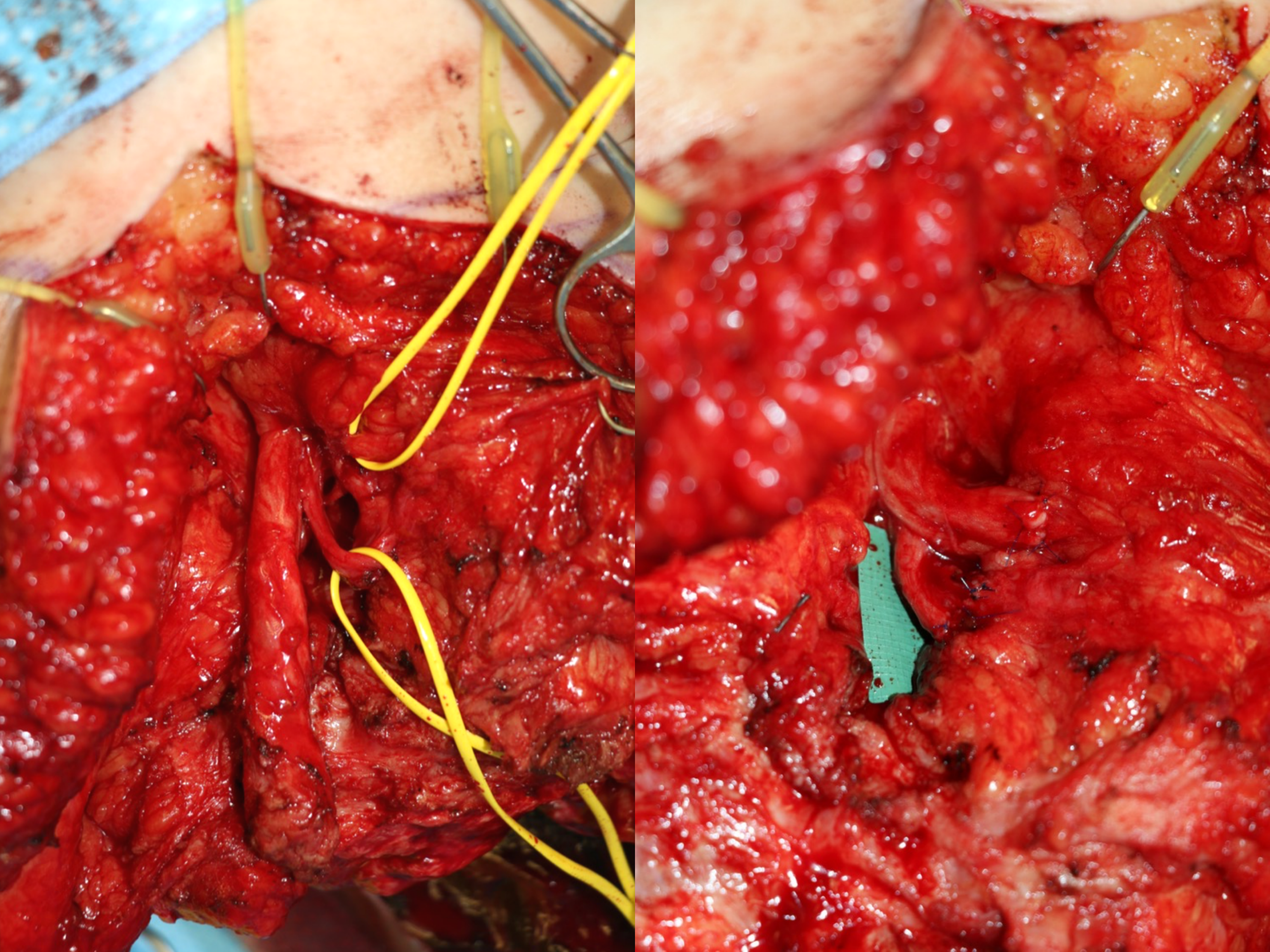


Another UF patient

Delayed TMR

Neuroma pain
Stump pain

Unable to tolerate prosthesis



- Walking with prosthesis without pain
  - Skin grafted area over stump removed
  - Neuroma pain addressed

Targeted Muscle Reinnervation Technique in Below-Knee Amputation

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Summary: Approximately 25 percent of major limb amputees will develop chronic localized symptomatic neuromas and phantom limb pain in the residual limb. A method to treat and possibly prevent these pain symptoms is targeted reinnervation. Previous studies prove that targeted reinnervation successfully treats and, in some cases, resolves peripheral neuropathy and phantom limb pain in patients who have undergone previous amputation (i.e., secondary targeted reinnervation). This article seeks to share the authors' clinical indications and surgical technique for targeted muscle reinnervation in below-knee amputation, a surgical description currently absent from our literature. Targeted reinnervation for the below-knee amputee has been performed on 22 patients at the authors' institution. Each patient has been followed on an outpatient basis for 1 year to evaluate symptoms of neuroma or phantom limb pain, patient satisfaction, and functionality. All subjects have denied neuroma pain following amputation. The majority of subjects reported phantom pain at 1 month. However, at 3 months, all patients reported resolution of this pain. Dumanian et al. first noted the improvement of symptomatic neuroma and phantom limb pain in patients undergoing targeted reinnervation to provide intuitive control of upper limb prostheses. These findings have been substantiated by multiple previous studies at various amputation levels. This study extends the success of targeted muscle reinnervation to below-knee amputations and provides a description for this technique. (*Plast. Reconstr. Surg.* 143: 309, 2019.)

Table 1. Typical Nerve Transfers for Below-Knee Amputation

Donor Nerve	Target Motor Nerve Branches
Posterior tibial nerve	Medial or lateral gastrocnemius; tibialis posterior; medial or lateral soleus
Deep peroneal nerve	Tibialis anterior; peroneus longus; peroneus brevis; medial soleus
Superficial peroneal nerve	Peroneus longus; peroneus brevis
Saphenous nerve	Medial gastrocnemius; medial soleus; vastus medialis
Sural nerve	Tibialis posterior; soleus

RESULTS

Since 2015, we have performed targeted muscle reinnervation on 22 below-knee amputees, 18 primary and four secondary. None have developed symptomatic neuromas postoperatively, with a mean time since surgery of 18 months. Seventy-two percent of the primary targeted muscle reinnervation cohort experience phantom limb pain in the first month, with an abrupt decline to 19 percent at 3 months, and 13 percent at 6 months. These rates of symptomatic neuromas/phantom limb pain are of significant improvement compared with our institutional control groups. Moreover, this topic is specifically analyzed in an ongoing multi-institution study. Average time to prosthetic wear was under 3 months.

RANDOMIZED CONTROLLED TRIAL

OPEN

Targeted Muscle Reinnervation Treats Neuroma and Phantom Pain in Major Limb Amputees

A Randomized Clinical Trial

Gregory A. Dumanian, MD, Benjamin K. Potter, MD,† Lauren M. Mioton, MD,* Jason H. Ko, MD,* Jennifer E. Cheesborough, MD,* Jason M. Souza, MD,† William J. Ertl, MD,‡ Scott M. Tintle, MD,† George P. Nanos, MD,† Ian L. Valerio, MD,§ Todd A. Kuiken, MD, PhD,* A. Vania Apkarian, PhD,¶ Kyle Porter, MAS,|| and Sumanas W. Jordan, MD, PhD*§*

Objective: To compare targeted muscle reinnervation (TMR) to "standard treatment" of neuroma excision and burying into muscle for postamputation pain.
Summary Background Data: To date, no intervention is consistently effective for neuroma-related residual limb or phantom limb pain (PLP). TMR is a nerve transfer procedure developed for prosthesis control, incidentally found to improve postamputation pain.
Methods: A prospective, randomized clinical trial was conducted. 28 amputees with chronic pain were assigned to standard treatment or TMR. Primary outcome was change between pre- and postoperative numerical rating scale (NRS, 0–10) pain scores for residual limb pain and PLP at 1 year. Secondary outcomes included NRS for all patients at final follow-up, PROMIS pain scales, neuroma size, and patient function.
Results: In intention-to-treat analysis, changes in PLP scores at 1 year were 3.2 versus –0.2 (difference 3.4, adjusted confidence interval (aCI) –0.1 to 6.9, adjusted $P = 0.06$) for TMR and standard treatment, respectively. Changes in residual limb pain scores were 2.9 versus 0.9 (difference 1.9, aCI –0.5 to 4.4, $P = 0.15$). In longitudinal mixed model analysis, difference

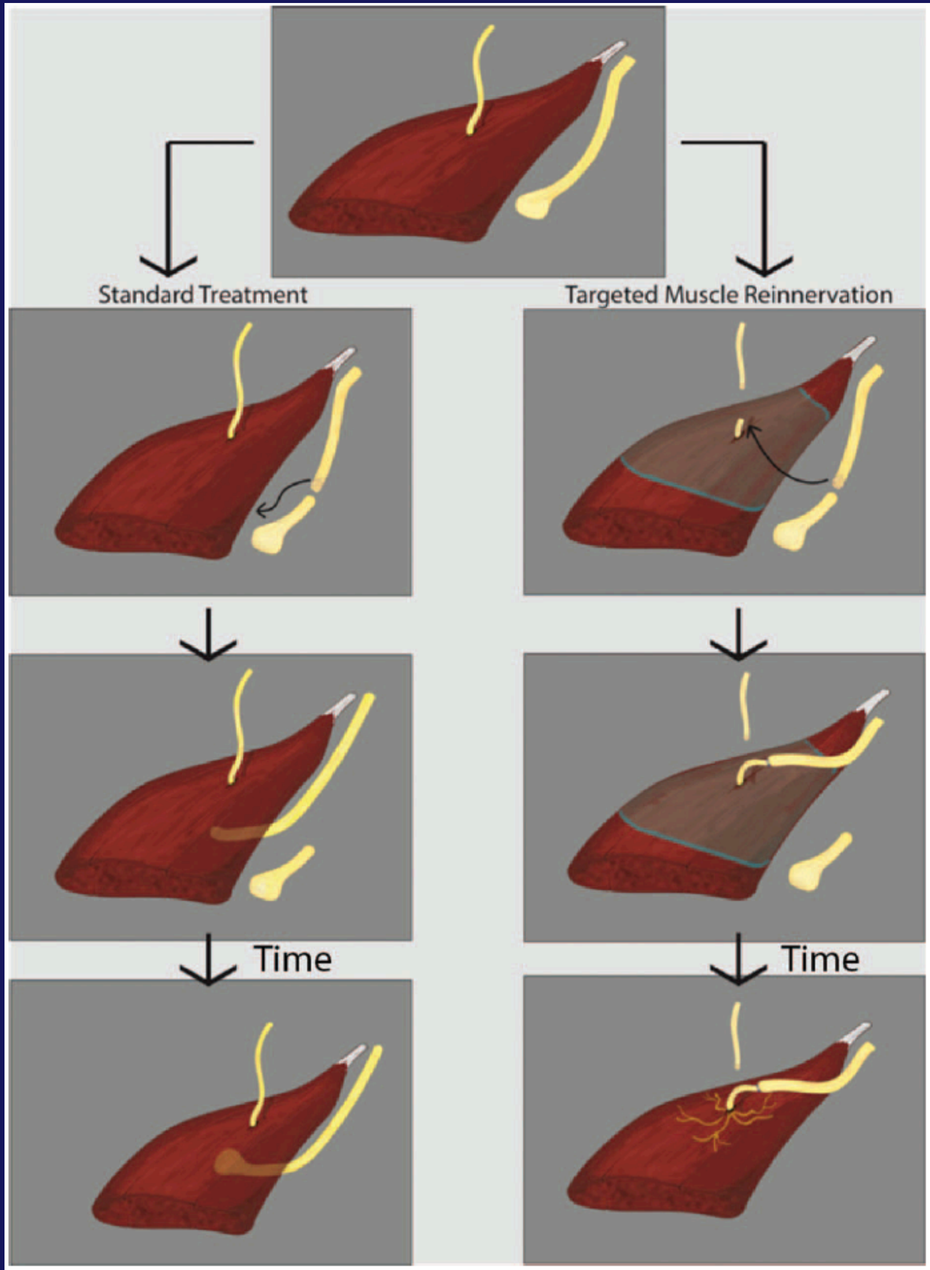


FIGURE 1. *Center top:* Schematic of muscle segment innervated by single motor nerve, and major mixed nerve ending in terminal neuroma. Left: Step 1, neuroma is excised. Step 2, freshened nerve is buried under a nearby muscle. Step 3, Over time, a new neuroma forms but is padded or protected by the overlying muscle. Right: Step 1, neuroma is excised and motor nerve innervating the muscle segment is divided creating a denner-vated muscle segment (blue shading). Step 2, freshened nerves are coapted. Step 3, major mixed nerve reinnervates muscle segment.

Results

- Prospective single blinded RCT
- Northwestern, Walter Reed
- Intended to recruit 200 patients but stopped early
- 28 major limb amputees randomized to standard neuroma surgery vs TMR
- Reduction in phantom limb pain scores at 1 year was significantly greater in the TMR group compared to standard treatment
- Change scores for residual limb pain were favorable for TMR

The move towards immediate TMR for all amputees

Check for updates

Preemptive Treatment of Phantom and Residual Limb Pain with Targeted Muscle Reinnervation at the Time of Major Limb Amputation

Ian L Valerio, MD, MS, MBA, FACS, Gregory A Dumanian, MD, FACS, Sumanas W Jordan, MD, PhD, Lauren M Mioton, MD, J Byers Bowen, MD, Julie M West, MS, PA-C, Kyle Porter, MAS, Jason H Ko, MD, Jason M Souza, MD, Benjamin K Potter, MD, FACS

BACKGROUND: A majority of the nearly 2 million Americans living with limb loss suffer from chronic pain in the form of neuroma-related residual limb and phantom limb pain (PLP). Targeted muscle reinnervation (TMR) surgically transfers amputated nerves to nearby motor nerves for prevention of neuroma. The objective of this study was to determine whether TMR at the time of major limb amputation decreases the incidence and severity of PLP and residual limb pain.

STUDY DESIGN: A multi-institutional cohort study was conducted between 2012 and 2018. Fifty-one patients undergoing major limb amputation with immediate TMR were compared with 438 unselected major limb amputees. Primary outcomes included an 11-point Numerical Rating Scale (NRS) and Patient-Reported Outcomes Measurement Information System (PROMIS) pain intensity, behavior, and interference.

RESULTS: Patients who underwent TMR had less PLP and residual limb pain compared with untreated amputee controls, across all subgroups and by all measures. Median "worst pain in the past 24 hours" for the TMR cohort was 1 out of 10 compared to 5 (PLP) and 4 (residual) out of 10 in the control population ($p = 0.003$ and $p < 0.001$, respectively). Median PROMIS t-scores were lower in TMR patients for both PLP (pain intensity [36.3 vs 48.3], pain behavior [50.1 vs 56.6], and pain interference [40.7 vs 55.8]) and residual limb pain (pain intensity [30.7 vs 46.8], pain behavior [36.7 vs 57.3], and pain interference [40.7 vs 57.3]). Targeted muscle reinnervation was associated with 3.03 (PLP) and 3.92 (residual) times higher odds of decreasing pain severity compared with general amputee participants.

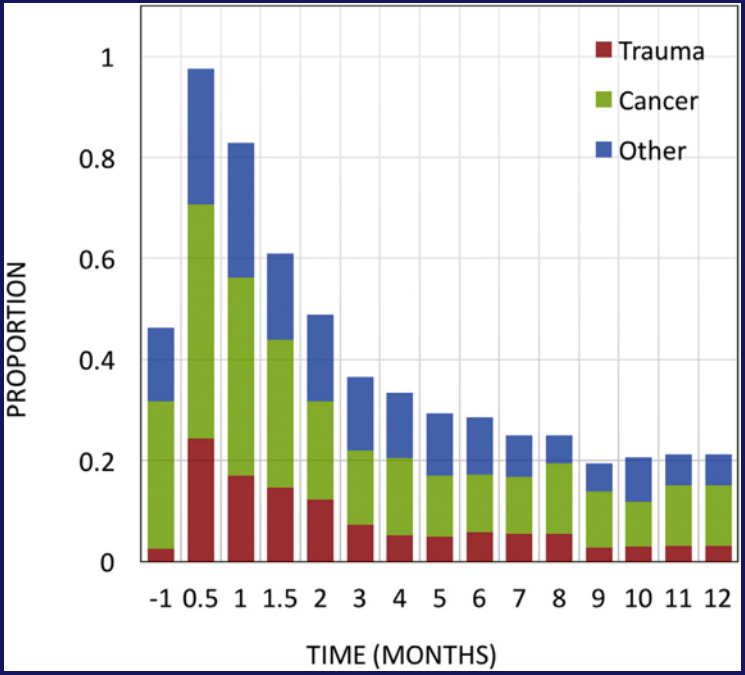
CONCLUSIONS: Preemptive surgical intervention of amputated nerves with TMR at the time of limb loss should be strongly considered to reduce pathologic phantom limb pain and symptomatic neuroma-related residual limb pain. (J Am Coll Surg 2019;228:217–226. © 2019 Published by Elsevier Inc. on behalf of the American College of Surgeons.)

Study Design

- Multi-institutional cohort study
- 51 patients undergoing major limb amputation with immediate TMR
- Compared with 438 unselected major limb amputees
- Primary outcomes
  - 11 point numerical rating scale (NRS)
  - Patient reported outcomes measurement information system (PROMIS) pain intensity, behavior, interference

Results

- Immediate TMR significantly reduced NRS and PROMIS pain scores
- TMR associated with higher odds of decreasing pain severity compared to general amputees
  - Phantom limb pain (3.03)
  - Residual limb pain (3.92)
- Decreased opioid use over time following TMR



RESEARCH ARTICLE

Journal of SURGICAL ONCOLOGY WILEY

Targeted muscle reinnervation in oncologic amputees: Early experience of a novel institutional protocol

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Abstract

Background: We describe a multidisciplinary approach for comprehensive care of amputees with concurrent targeted muscle reinnervation (TMR) at the time of amputation.

Methods: Our TMR cohort was compared to a cross-sectional sample of unselected oncologic amputees not treated at our institution (N = 58). Patient-Reported Outcomes Measurement Information System (NRS, PROMIS) were used to assess postamputation pain.

Results: Thirty-one patients underwent amputation with concurrent TMR during the study; 27 patients completed pain surveys; 15 had greater than 1 year follow-up (mean follow-up 14.7 months). Neuroma symptoms occurred significantly less frequently and with less intensity among the TMR cohort. Mean differences for PROMIS pain intensity, behavior, and interference for phantom limb pain (PLP) were 5.855 (95%CI 1.159-10.55; $P = .015$), 5.896 (95%CI 0.492-11.30; $P = .033$), and 7.435 (95%CI 1.797-13.07; $P = .011$) respectively, with lower scores for TMR cohort. For residual limb pain, PROMIS pain intensity, behavior, and interference mean differences were 5.477 (95%CI 0.528-10.42; $P = .031$), 6.195 (95%CI 0.705-11.69; $P = .028$), and 6.816 (95%CI 1.438-12.2; $P = .014$), respectively. Fifty-six percent took opioids before amputation compared to 22% at 1 year postoperatively.

Conclusions: Multidisciplinary care of amputees including concurrent amputation and TMR, multimodal postoperative pain management, amputee-centered rehabilitation, and peer support demonstrates reduced incidence and severity of neuroma and PLP.

KEYWORDS

neuroma, pain management, phantom limb pain, residual limb pain

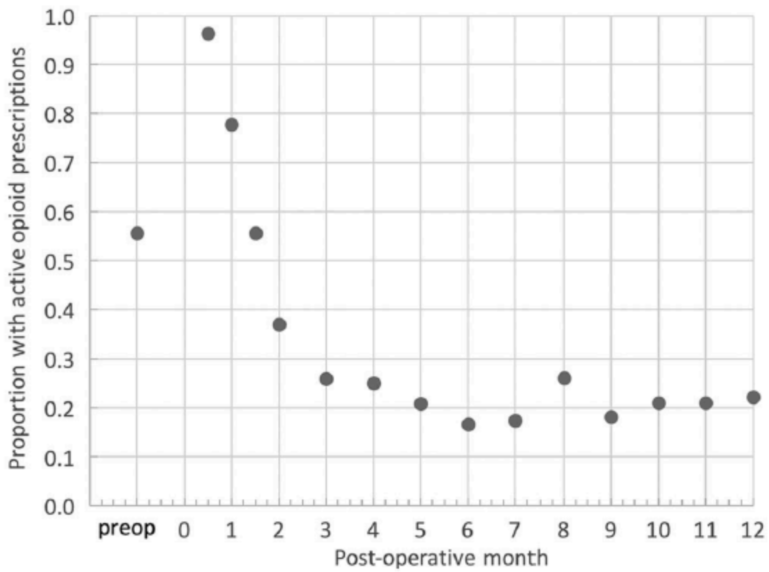

FIGURE 1 Opioid prescriptions for TMR-treated oncologic amputees. Time zero represents the day of amputation and TMR. TMR, targeted muscle reinnervation

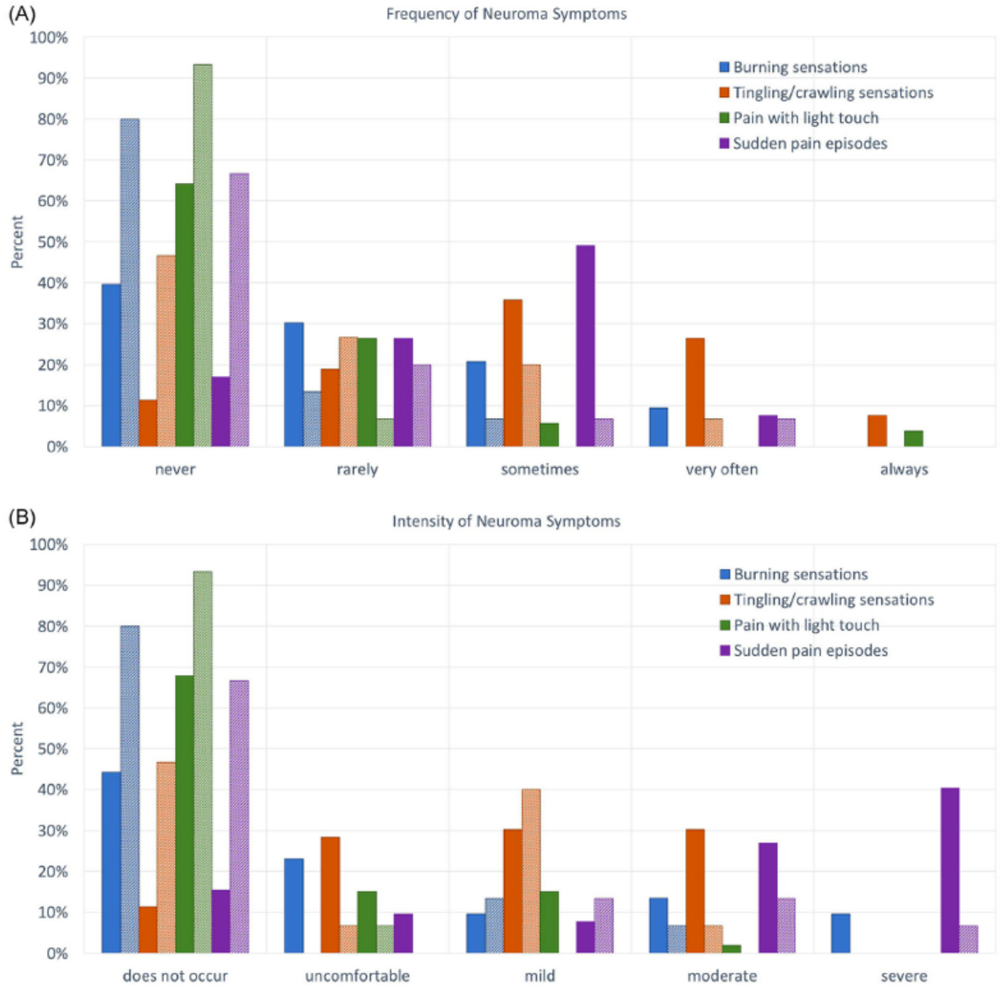

FIGURE 2 Frequency (A) and intensity (B) of neuroma symptoms at last follow-up. Dark solid bars represent the general cohort; lighter shaded bars represent the TMR cohort. All general versus TMR comparisons are statistically significant by nonparametric regression with $P < .05$. TMR, targeted muscle reinnervation [Color figure can be viewed at wileyonlinelibrary.com]

Chronic phantom pain leads to irreversible changes in the brain

Phantom limb pain: a case of maladaptive CNS plasticity?

Herta Flor, Lone Nikolajsen‡ and Troels Staehelin Jensen§*

Abstract | Phantom pain refers to pain in a body part that has been amputated or deafferented. It has often been viewed as a type of mental disorder or has been assumed to stem from pathological alterations in the region of the amputation stump. In the past decade, evidence has accumulated that phantom pain might be a phenomenon of the CNS that is related to plastic changes at several levels of the neuraxis and especially the cortex. Here, we discuss the evidence for putative pathophysiological mechanisms with an emphasis on central, and in particular cortical, changes. We cite both animal and human studies and derive suggestions for innovative interventions aimed at alleviating phantom pain.

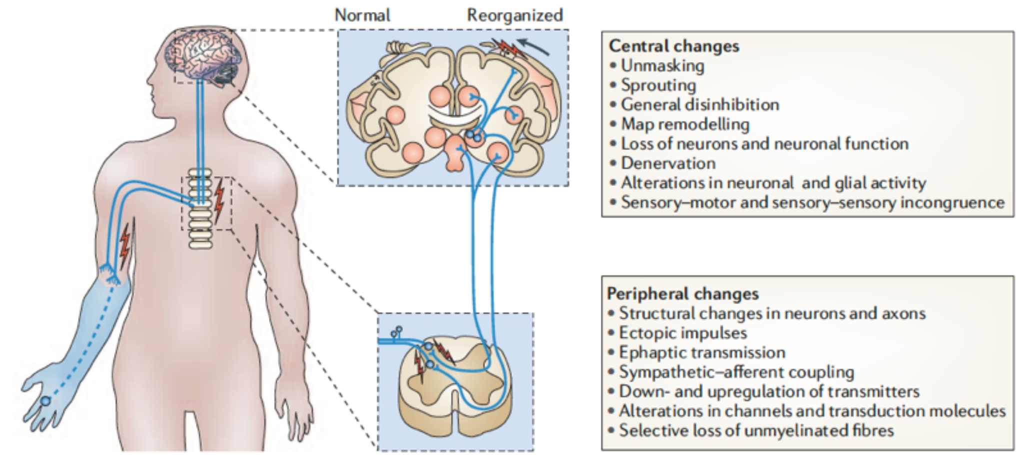

Figure 1 | **A schematic diagram of the areas involved in the generation of phantom limb pain and the main peripheral and central mechanisms.** The peripheral areas include the residual limb and the dorsal root ganglion, and the central areas include the spinal cord and supraspinal centres such as the brainstem, thalamus, cortex and limbic

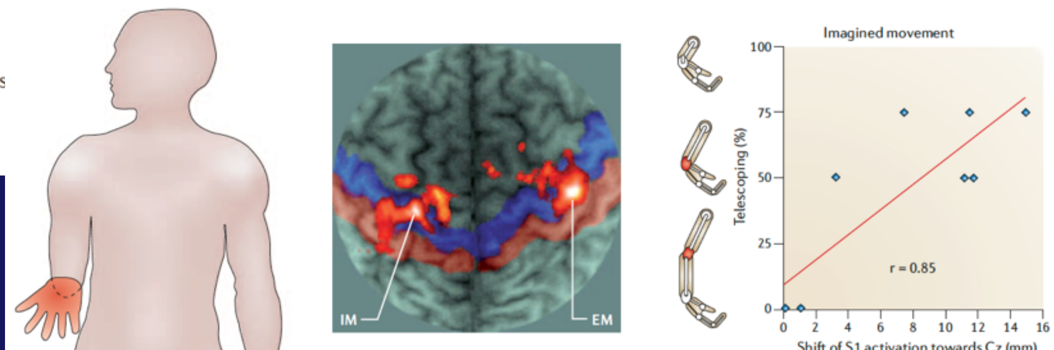

Figure 3 | **Brain correlates of the telescoping phenomenon.** The phenomenon of telescoping refers to the shrinking and retraction of the phantom towards the residual limb (left). The middle panel shows brain activation related to the imagined movement (IM) of telescoped and non-telescoped phantoms. The representation of the movement in the primary somatosensory (SI) cortex (red shading) follows the perceived location of the movement (opening and closing of the hand) and not the actual anatomical location (hand area). Completely telescoped phantoms create activity in the cortical region that represents the shoulder, partially telescoped phantoms in the region of the arm and non-telescoped phantoms in the hand region. EM denotes the cortical activation related to executed movements of the intact hand and indicates where the representation of the hand in the SI cortex is located. The right panel shows the correlation coefficient that was computed for the amount of telescoping (0–100%) and the activation related to the perceived movement of the phantom in the SI cortex with the distance of the maximally activated voxels from the central midline position of the cortex (Cz) computed in millimetres. The correlation was significant in the SI, but not in the primary motor cortex (blue shading). This indicates that pain-free amputees might experience reactivation of the deafferented cortical representation zone related to that hand, whereas amputees without pain might not, which could be related to their pain. The data also indicate that this effect might originate directly in the SI cortex, and is not mediated by the motor cortex.

Immediate TMR may prevent irreversible central changes and development of chronic pain

UF Limb Salvage Team

Improving outcomes through multidisciplinary care

In amputees
But also reducing amputations

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Article Type: Scientific Articles

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Function-Sparing Free Split Latissimus Dorsi Flap for Lower-Extremity Reconstruction

Five-Year Consecutive Single-Surgeon Series

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- Consecutive series of free flaps for lower extremity reconstruction
- N=42
- Flap survival 95.2%
- Eventual limb salvage 100%
- Minimal donor site morbidity
  - Median DASH 0
  - Median SPADI pain/ disability scores 0
  - Median ASES score 100

Conclusions

- Targeted muscle reinnervation (TMR) has been shown to have improved outcomes in amputees
  - Reducing neuroma pain
  - Potential for use of advanced myoelectric prostheses
- Trend towards immediate TMR in many centers
- UF limb salvage team
  - Reducing amputations
  - Improving outcomes for amputees

Thank you!

Questions?

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