NEURAL INTERFACE TECHNOLOGY TO RESTORE NATURAL SENSATION IN LOWER-LIMB AMPUTEES

Hamid Charkhkar[1,2], Courtney Shell[2,3], Paul Marasco[2,3], Dustin Tyler[1,2], Ronald Triolo[1,2]

[1]Department of Biomedical Engineering, Case Western Reserve University, 10900 Euclid Avenue, Cleveland, OH 44106, USA

[2]Louis Stokes Cleveland Veteran Affairs Medical Center, 10701 East Boulevard, Cleveland, OH, 44106, USA

[3]Department of Biomedical Engineering, Lerner Research Institute, Cleveland Clinic, 9500 Euclid Avenue, ND20, Cleveland, OH, 44195, USA

ABSTRACT

Sensory input in lower limb amputees is critically important to maintaining balance, preventing falls, negotiating uneven terrain, responding to unexpected perturbations, and developing the confidence required for societal participation and public interactions in unfamiliar environments. Despite noteworthy advances in robotic prostheses for lower limb amputees, such as microprocessor knees and powered ankles, natural somatosensory feedback from the lost limb has not yet been incorporated in current prosthetic technologies.

To compensate for this lack of sensation, amputees rely on visual monitoring of their prosthetic limbs, and often increase loads applied to their intact limbs during standing and walking, putting them at risk for long-term damage. Although there have been numerous attempts to provide sensory feedback via tactile or electro-cutaneous sensory substitution, nothing to date has successfully restored natural sensation that is perceived immediately and directly as coming from the missing limb.

In this work, we report eliciting somatic sensation with neural stimulation in two transtibial amputees. The participants received high-density, flexible, 16-contact nerve cuff electrodes for the selective activation of sensory fascicles in the nerves of the posterior thigh above the knee. In the first subject, the cuff electrodes were implanted on the sciatic nerve just above, and on the tibial and fibular nerves just below the bifurcation. The second subject had two cuff electrodes implanted 3cm apart on the sciatic nerve and one on the tibial nerve. Multiple cuff electrodes were deployed to maximize spatial resolution and increase the likelihood of isolating the desired sensory axons, as well as to explore the degree of selectivity and overlap in responses produced from distal and proximal locations on the nerves. Electrical pulses at safe levels were delivered to the nerves by an external stimulator via percutaneous leads attached to the cuff electrodes.

The neural stimulation was perceived by participants in the study as sensation originating from the missing limb. We quantitatively and qualitatively ascertained the quality, intensity, and modality (pressure, touch, and proprioception) as well as the location of the perceived sensation. Stimulation through individual contacts within the nerve cuffs evoked sensations of various modalities and at discrete locations referred to the missing toes, foot and ankle, as well as in the residual limb. About 60% of 48 contacts in the cuffs produced perceptions 3 months post-implant in response to electrical stimulation.

Based on our findings, the high-density cuff technology is suitable in restoring natural sensation to lower limb amputees.

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