PATIENT-SPECIFIC CONSIDERATIONS IN IMPLEMENTING ARTIFICIAL SENSORY LOCATIONS

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INTRODUCTION

Sensory restoration is critical for natural prosthesis control. Electrical stimulation of nerves through cuff electrodes restores sensation across the hand. Preliminary studies show that multi-contact stimulation can refine, shift, and create new sensory locations beyond those achievable using single-contact stimulation. Manually tuning these locations is time intensive. Implementing optimized sensations in a clinically viable period requires use of computational models that depend on patient-specific anatomy and cognitive state.

METHODS

To date, four trans-radial amputees have had nerve cuffs implanted on the median, radial, and ulnar nerves. Nerve anatomy and somatotopy was determined using intraoperative ultrasound. After a post-surgical recovery period, subjects underwent a limited mapping study in which they received single-contact stimulation and reported the location of the evoked sensation.

Using the fascicular geometry and initial mapping data, patient-specific models were developed to predict multi-contact stimulation parameters needed to evoke sensation in targeted locations. Finally, subjects underwent a second mapping protocol to map the new and refined sensory locations predicted by these models.

RESULTS

Sensory locations were dependent on cognitive state. Subjects perceived artificial sensations independently of their pre-existing phantom sensation; artificial sensation did not replace the phantom sensation. Thus, we found that the subjects' understanding of their phantom without stimulation affected their perception of the stimulation-evoked sensations. Subjects with poor visualization of their phantom were initially not able to localize sensation on the hand. However, after undergoing visualization training and mirror box therapy aimed at improving subjects' perception of the phantom independent of stimulation, evoked sensations became localized.

Once a clear image of the phantom was established, single contact stimulation elicited unique percepts across the phantom hand for all subjects. As expected, the activated axon population and ensuing sensory location were driven by the fascicular geometry. For example, subjects with more proximal implants reported more diffuse sensations across the hand. Patient-specific models captured these dependencies and enabled us to efficiently determine novel stimulation paradigms in order to evoke sensation in new, functionally relevant locations.

CONCLUSIONS

Providing sensory percepts in functionally relevant locations is dependent on of the patient's nerve anatomy, implant location, and the patient's relationship with their phantom. Patients need a clear understanding of their phantom in order to be able to perceive localized sensations. These locations can be further refined or expanded using computational model derived stimulation parameters.