ELECTRICAL STIMULATION OF THE CERVICAL DORSAL SPINAL CORD AND ROOTLETS FOR SENSORY RESTORATION IN UPPER-LIMB AMPUTEES

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INTRODUCTION

Numerous studies indicate that sensory feedback could enhance the embodiment, acceptance, and also the ease of use of a prosthetic device. Electrical stimulation of the peripheral and central nervous system is the focus of extensive research as a means to provide sensory feedback. While drawbacks of peripheral nerve stimulation include electrode migration and off-target activation, cortical brain stimulation is an extremely invasive procedure. In contrast, we targeted the dorsal spinal cord and rootlets (DSCR) to provide sensory feedback. This approach affords at least two key benefits. First, the DSCR provide a clear separation between the sensory and motor pathways in the peripheral nervous system. Thus, stimulation at the DSCR will avoid undesired concurrent activation of motor pathways. Second, multiple minimally invasive surgical techniques exist to access the DSCR. In fact, about 50,000 procedures a year are performed in the United States, where spinal cord stimulation (SCS) leads are inserted percutaneously to target the DSCR for alleviating intractable pain. Here, we present observations from human psychophysics experiments performed while stimulating the C5-C8 DSCR in two upper-limb amputees using these FDA-approved SCS leads.

METHODS

All procedures were approved by the University of Pittsburgh Institutional Review Board and the US Army Human Research Protection Office. Two study participants with high-level unilateral upper-limb amputations (>16 years and >5 years post-amputation) were implanted with three percutaneous 16 or 8-contact SCS leads (Boston Scientific) respectively, in the lateral epidural space of the cervical spinal cord. Stimulation was delivered using a customized setup for up to 4 weeks, after which the electrodes were removed. Information regarding the modality, location, and intensity of perceived sensations was provided by the subject using a structured reporting system.

RESULTS

Sensations reported by the subjects included focal percepts localized to the amputated arm, hand, wrist, palm, and fingers. The focality of the sensory percepts could be improved by employing current-steering effects through multi-polar stimulation. Although most of the sensations were reported to be paresthetic in nature, subjects did describe some percepts as touch, pressure and movement of fingers and the arm. The focal locations of the sensations were stable for the entire duration of testing. We found that stimulation frequency had the stronger effect than stimulus amplitude on the intensity of perceived sensations and that it also dictated the perceptual modality of the sensation.

CONCLUSION

With current-steering, DSCR stimulation can generate focal sensory percepts in the missing limb in long-term amputees.