Validation of Regenerative Peripheral Nerve Interfaces for Control of a Myoelectric Hand by Macaques and Human

Melanie G Urbanchek, PhD; Ian C Sando, MD; Zachary T Irwin, PhD; Philip Vu, MSE, Shoshana L. Woo, MD; Cynthia A Chestek, PhD; Paul S Cederna, MD

Disclosure/Financial Support: This work was sponsored by the Defense Advanced Research Projects Agency (DARPA) MTO under the auspices of Dr. Jack Judy through the Space and Naval Warfare Systems Center, Pacific Grant/Contract No. N66001-11-C-4190. None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this manuscript.

INTRODUCTION: Regenerative Peripheral Nerve Interfaces (RPNIs) are promising for interfacing human intentions to myoelectric prostheses. Rat studies led to proof of internal RPNI long-term function and high signal to noise ratio with no adverse biological effects.[1] Validation of voluntary and independent RPNI function has also been determined.[2] However, true voluntary fine control of fingers and hand myoelectric prostheses requires RPNI real time validation with voluntary control. Our purpose was to validate voluntary RPNI control of a myoelectric hand in both macaque and human models.

METHODS: The RPNI consists of a free muscle graft implanted on the end of a transected nerve fascicle. RPNIs were implanted in the forearms of two macaques (n=3/macaque). Intramuscular electromyography (EMG) electrodes were also implanted in each macaque RPNI. Macaques were trained to perform index finger movements to acquire virtual targets on a computer screen.[3] The human RPNIs were implanted to treat neuroma pain. The human had fine wire electrodes temporarily placed in the RPNIs. Voluntary RPNI EMG that represented control was recorded.

RESULTS: With continuous EMG decode using 10-fold cross-validation, the resulting predicted finger position had a, correlation coefficient ρ=0.82 between predicted and true finger positions for Macaques. The EMG decode correctly classified 97.7% of movements. The human ulnar nerve RPNIs were able to control thumb key pinch to first finger and thumb to little finger. Thumb abduction trials were 96% correct. At harvest macaque RPNIs were well vascularized; RPNI muscle fibers continued to regeneration after 1 year.

CONCLUSIONS: Macaques voluntarily controlled virtual finger movements with nerve signals transferred through implanted RPNIs. The human controlled an advanced myoelectric prosthetic thumb with RPNIs implanted in the ulnar nerve RPNI. Voluntary RPNI control of a myoelectric hand was validated by both macaque and human models.

REFERENCES:

1. Kung T, Langhals N, Martin D, Cederna P, Urbanchek M. Regenerative Peripheral Nerve Interface Viability and Signal Transductions with an Implanted Electrode. Plast Rec Surg. 2014; 133(6): 1380-94
2. Ursu D, Urbanchek MG, Nedic A, Cederna P, Gillespie R. In Vivo Characterization of Regenerative Peripheral Nerve Interface Function. J Neuro Engin. 2016 April;13(2):026012
3. Irwin Z, Thompson D, Schroeder K, et al. IEEE Enabling Low-power, Multi-modal Neural Interfaces through a Common, Low-bandwidth Feature Space. Trans Neural Sys & Rehab Engin. 2015 DOI 10.1109/TNSRE.2015.2501752