WOMEN'S HEALTH RESEARCH INSTITUTE
NORTHWESTERN UNIVERSITY
Science to Care

Todd Kuiken, MD, PhD: "Building Bionics"
Director, Center for Bionic Medicine
January 21, 2014 Forum

Dr. Kuiken's research team is working to develop a neural-machine interface to improve the function of artificial limbs. A main research focus of the lab is developing a technique to use nerve transfers for improvement of robotic arm control. By transferring the residual arm nerves in an upper limb amputee to spare regions of muscle, it is possible to make new signals for the control of robotic arms. These signals are directly related to the original function of the limb and allow simultaneous control of multiple joints in a natural way. This work has now been extended with the use of pattern recognition algorithms, enabling the intuitive control of more functions in the prosthetic limbs. Similarly, hand sensation nerves can be made to grow into spare skin so that when this skin is touched, the amputee feels like their missing hand is being touched.

The History and Evolution of Artificial Limbs
Traditionally, artificial limb research and design has had a male-oriented patient focus due to the types of professions that are more likely to lead to limb loss: military, factory work, etc. Now, however, due to the increasing prevalence of diabetes, and the increased participation of women in the military and workforce, women's injuries resulting in limb loss are becoming more prevalent. Up until recently, the 1912 prosthesis (designed like a bike cable and socket) has changed very little. These heavy and cumbersome prostheses were not designed with women in mind, and limit the function of the artificial limb to just a few movements. Now, with modern technological advances, improvements in prosthesis design have expanded to use brain signals and nerve transfers to operate prosthetic limbs more naturally.

Targeted Reinervation
Targeted Reinvervation involves taking four major pectoral nerves and moving them to spare muscles to use the muscle signals as input for the artificial arm. The nerve-transfer surgery distributes one chest signal to four hand signals by "crossing the wires" of these nerves. Giving these nerves new purpose and control over an artificial limb enables the amputee to use their hand signals six times faster than an old prosthesis would. Furthermore, these nerve transfers have been found to give back the sensation of touch to the patient through the nerves in the patient's chest.

Nerve transfer prostheses are much faster and have more control over original prostheses. In fact, 94% of nerve transfers are successful in producing usable EMG signals. Once perfected, this procedure was able to elicit patients 2.5-7 times faster on the Box and Blocks Test, and 50% faster on the Clothespin Test. Pattern Recognition Control in these types of prostheses were essential to make it available and reliable to the masses. During this pattern recognition stage, the prosthesis goes through a brief, one-minute "training" while it boots up—going through motions that the wearer must replicate. After this minute, the prosthesis is ready to be in use for several days, or even a week at a time before another Pattern Recognition Control is required.

Prioritizing Women in Prosthesis Design
A US Army-sponsored research project at the Rehabilitation Institute of Chicago has enabled the RIC Arm System, a prosthesis designed with women in mind. The model is molded to the 25 percentile of women and is 30% lighter than commercial arms. The goals of this arm are to be a smart, affordable

arm that will help in daily tasks. The designing and early trial phases of the RIC Arm System has been in the works for the past four years and a field trial is set to start this April 2014.

Leg Prostheses

Dr. Kuiken's research has naturally brought up the idea of using a neural interface to improve leg prostheses. In general, Leg prostheses are less technological than their arm counterparts, because less movement and range of motion is needed in a leg, compared to the intricacies of wrist and individual finger movement/dexterity in the hand, for example. However, targeted reinnervation may allow the amputee to feel his/her foot as he/she walks, which is no small improvement. Improving leg prostheses can also help the flow of walking from a level surface to stairs or a ramp. Without manually changing a setting on the prosthesis, itself, a patient can think about the movement change and direct the nerves to change the type of motion when needing to walk up or down stairs or a ramp.

Targeted Muscle Reinnervation and Neuroma Pain

Neuroma pain happens when severed nerves (due to a traumatic amputation) attempt to repair themselves, but instead grow in clusters at the severed point because the nerve has nowhere to grow into. This leads to extreme sensitivity and pain for the patient. Dr. Kuiken and his fellow researchers hypothesized that adding muscle to the other end of the severed nerve will help the nerve fiber grow and heal more naturally, thereby reducing neuroma pain. In an experiment to test this hypothesis, his team added muscle to the severed tip, and of the 15 patients who experienced painful neuromas before the surgery, all but one had their nerve pain resolved.

Advances in the care and treatment of amputee patients leads to improved quality of life, reduced pain, and increased aptitudes for more natural and fluid motion in artificial limbs.