

Thought-controlled robotic arm 'makes a big negative a whole lot better'

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Dr. Albert Chi (left) assists patient Johnny Matheny with the robotic Modular Prosthetic Limb. Matheny lost most of his left arm to cancer five years ago.

Dr. Albert Chi, a UA College of Medicine graduate, helped develop a robotic arm and hand that a person can control with his or her thoughts.

Dr. Albert Chi was an undergraduate studying biomedical engineering when a motorcycle accident nearly cost him his left leg and foot. Hospitalized for a month, undergoing repeated surgeries, he was deeply impressed by his doctors' compassion and skill.

He realized then that he had two passions: engineering and medicine.

Now Chi – a 2003 graduate of the UA College of Medicine and a [trauma surgeon](#) at Johns Hopkins Hospital in Baltimore – is part of a team of engineers and surgeons that has achieved what few of us ever would have thought possible.

The breakthrough is the Modular Prosthetic Limb, a [robotic arm](#) and hand that a person can control

with their thoughts.

Johnny Matheny of West Virginia lost most of his left arm to cancer five years ago. Since May 2012, wearing the still experimental robotic limb, he has been able to point his prosthetic finger, grasp a ball and flex his wrist. He can distinguish between his index and little finger as well as detect the difference between soft and hard objects. He can feel his wife's hand touching his artificial hand.

"Getting your arm cut off is a big negative," Matheny said. "Dr. Chi has made my life a whole lot better."

Chi began working on brain control algorithms aimed at controlling robotic arms 20 years ago, while studying biomedical engineering at Arizona State University. His faculty adviser was [neurobiologist](#) Andrew Schwartz, who first linked the information coming from the sensory and [motor neurons](#) in the brain's cortex to a robotic arm and hand – the same [artificial limb](#) Matheny has been testing at the Johns Hopkins Applied Physics lab.

"I was involved with cortical-controlled robotics from the very, very, very beginning," Chi recalled. After graduating cum laude with a bachelor's degree in biomedical engineering, Chi then earned his master's degree cum laude in the same field, both at ASU.

He then started medical school at the UA, "because I wanted to make a greater impact on patients' lives."

Chi stayed at the UA for his general surgery residency, which he finished in 2008. He completed a two-year fellowship at Baltimore's Shock Trauma Hospital, then joined the surgery faculty at Johns Hopkins.

There he is part of the \$150 million Revolutionizing Prosthetics project led by neuro-intensivist Geoffrey

Ling, MD. Revolutionizing Prosthetics is funded by the Defense Advanced Research Projects Agency in response to the more than 1,300 men and women who have come home from war in Iraq and Afghanistan as amputees.

"Specialty centers like Walter Reed Army Hospital do a great job as far as getting a lot of these soldiers back to active duty – as high as 16 percent today, up from around 2 percent in 1980," Chi said. "But there is a huge discrepancy between upper-extremity injury and lower-extremity injury. An upper-extremity injury is pretty much a career-ending injury for you.

"So Dr. Ling challenged the world, led by Hopkins and the Applied Physics Lab, to come up with an engineering solution," Chi said. "And what they came up with is the Modular Prosthetic Limb – modular because it can replace the amputated limb at any injury level. ... It is really the world's most advanced [prosthetic limb](#)."

The modular limb is capable of replacing the natural arm's motor and sensory function. The 100 sensors built into the arm are capable of "feeding back" temperature, pressure, joint angles and acceleration, Chi explained. "If coupled with all of the modular prosthetic limb's capabilities," he said, "the patient could experience feedback not only of temperature and pressure, but also surface texture and proprioception."

In patients who are quadriplegic, the Modular Prosthetic Limb requires cortical implants to convey neuronal information to electronic sensors in the prosthesis. But for patients like Matheny, whose spinal cord is intact, Chi has performed a new surgical technique to control the prosthesis. Called Targeted Muscle Reinnervation, the technique utilizes the still viable nerves and muscles in an amputated limb.

"The patient with an amputated limb might think of moving the missing hand and wrist," Chi explained, "but the signals from his brain go off into space and have nowhere to land – until now."

Chi reroutes the endings of three nerves in the patient's stump to adjacent muscles.

"It's very much like electrical wiring," he said. "Rewiring that information at the amputation site to residual muscles not only allows people to control the Modular Prosthetic Limb, but they have advanced motor control and sensory feedback also."

The patient's arm is given six months to heal before the patient begins what will be a lifelong routine of 15 to 30 minutes a day of mental imagery exercises, which re-establish the cortical signals that can now be transmitted to electrodes in the Modular Prosthetic Limb.

As amazing as all this is, Chi said, "What we really want to do is take the control that patients now have to the next level."

Chi was commissioned into the Naval Reserve in April, and will now work with amputee patients at Walter Reed, in addition to his work at Johns Hopkins.

"I've been really fortunate, in terms of being in the right place at the right time. It was the experience of the motorcycle accident and the hospitalization and my engineering background that's gotten me to where I am, where I can combine both of my passions of surgery and trauma to really empower people."

Chi is amazed every day, he said, by how his patients work to "overcome whatever's thrown at them. It's really just a privilege to be part of these patient's lives."

Provided by University of Arizona

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