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Amputees help advance thought-controlled prosthetic technology

Former North Baltimore teacher among patients working with Hopkins, companies

By Scott Dance, The Baltimore Sun
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Anne Mekalian, Joppatown, a quadruple amputee, has been fitted with a thought-controlled robotic hand at Johns Hopkins Medicine.

One minute, Anne Mekalian's brain is telling her prosthetic arm to unstack a set of multicolored plastic cones, and the shiny black metal limb is listening. Every now and then, the plastic clatters to the table, but quickly the cones are separated and restored to a neat pile.

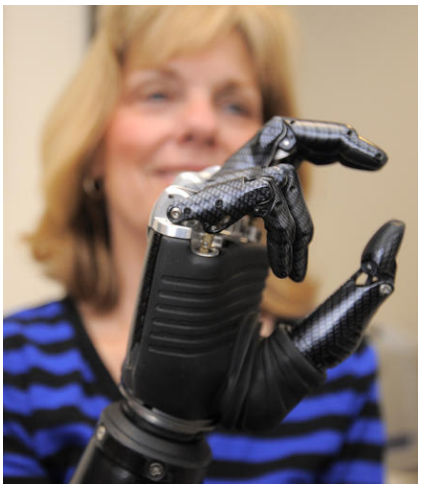
The next moment, though, the bionic hand doesn't know what to make of slight muscle movements in Mekalian's forearm, interpreted through a set of electrodes touching the skin on the rounded remnant limb that extends just below her elbow. Instead of pinching a red clothespin, the robotic hand spins like Linda Blair's head in "The Exorcist."

"This is why it's experimental, right?" Mekalian, of Joppatowne, joked to a group of scientists who had gathered in an office at Johns Hopkins Hospital to watch her as part of clinical trials of advanced prosthetics.

Despite occasional setbacks — and, perhaps, because of them — the technology is advancing quickly. Over the past several months, Mekalian and two other amputees working with a Johns Hopkins Hospital surgeon and local company have been among the first in the nation to take home thought-controlled robotic arms designed for wounded veterans.
While the devices haven't been perfect replacements for limbs lost, they have brought a glimpse of what patients took for granted before being struck by infection, cancer or violence. Trial and error applying the technology to their daily lives — putting on makeup, cooking, carrying a laundry basket — is leading to refinements. The scientists say the technology could be available within a couple of years to countless others commercially, with plans for U.S. Food and Drug Administration review next year.

Before that can happen, the scientists are learning all they can through the 67-year-old Mekalian and the others.

"We're almost inventing a new field of medicine," said Dr. Albert Chi, a Johns Hopkins trauma surgeon working with the patients. "We're kind of learning as we go. There's no textbooks out there."



For the past two years, Chi has worked with Baltimore's Infinite Biomedical Technologies and Advanced Arm Dynamics, a Texas-based developer of prosthetics, to blaze the trail, starting with Johnny Matheny, a West Virginian who lost his left arm to cancer in 2008. Dana Burke, a Pennsylvania woman who lost her right arm about five inches below her shoulder after a shooting 15 years ago, came next.

Efforts to develop the device began in 2006, under a program of the U.S. military's Defense Advanced Research Projects Agency. The Johns Hopkins Applied Physics Laboratory, hired for $35 million in 2010, was responsible for developing the technology for soldiers returning from the wars in Iraq and Afghanistan with amputations. Research on the technology is also occurring at institutions including the University of Chicago and the California Institute of Technology.

Anne Mekalian trains the prosthetic limb. Assisting her are, left to right, James Vandersea, an Advanced Arm Dynamics prosthetist, Rahul Kaliki, CEO, Infinite Biomedical Technologies (IBT), and Megan Hodgson, IBT research engineer.

Now Mekalian has joined Matheny and Burke in various successes and frustrations as they serve as guinea pigs for, they hope, many amputees to follow.

Just two years ago, it wasn't a position the third-grade teacher at School of the Cathedral of Mary Our Queen in North Baltimore expected to be in. But then her health took a sudden, disastrous turn.

"I had a cough and a cold like teachers often have," Mekalian said. "In about four days I was at the emergency room."

The ailment ended up being an infection of Group A streptococcus bacteria that caused pneumonia in both of Mekalian's lungs and put her body into sepsis, an immune response that triggers full-body inflammation. Her extremities began to blacken with gangrene, a condition in which infection begins to kill body tissue.

She recovered from the ordeal, in which she spent six weeks in the hospital, but as a result of the gangrene had to undergo quadruple amputation, below the knees and elbows. She remains on medical leave from the school.

As she began rehabilitation, she read a Baltimore Sun article about Burke and saw a "60 Minutes" piece featuring Matheny, who were both working with Chi and the prosthetics companies. She wondered if she might be able to use the technology, too.

Within days of a call to the Hopkins physics laboratory, she was connected with Chi and was soon in his office, amazing the surgeon with the potential she showed when hooked up to prosthetic simulation software.

"She could literally play the piano in the virtual system," Chi recalls.

The high-tech prosthetics are the closest thing to a flesh-and-bone arm for amputees like Mekalian, and yet they aren't any more invasive than traditional devices that are known as "body-powered." With those prosthetics, amputees might activate a pincer hand by using their opposite shoulder to pull a cable within the device.

But to control Mekalian's prosthetic arm, down to each individual robotic finger, she does little more than think — just as she did before her amputation.

It starts with a firing in the brain that activates nerves connecting to muscles, a process that occurs in a split-second and generates a small jolt of electrical activity within the body, explained Rahul Kaliki, CEO of Infinite Biomedical Technologies. Eight tiny metal domes on the inside of the socket that surrounds a patient's remnant limb detect that activity, anywhere from 30 to 500 hertz.

Kaliki's company has made the sophisticated motion of the prosthetics possible through what it does with that electrical noise — data Chi calls "a symphony of information." The company's software figures out how to classify that information into a complex set of motions, whether stretching the palm, bending the thumb and forefinger or rotating the wrist. Meanwhile, it filters out electrical noise that surrounds us, radiating from devices plugged in to the 60-hertz wall sockets used in the United States.

If it sounds complicated, that's because it is. The patients and their arms undergo daily "training" to teach the software algorithm what various patterns of electrical activity mean. But the scientists are learning that variations in a patient's posture can keep the algorithm from recognizing which motion is intended.

While Mekalian's prosthetic responds accurately when she tries to pinch a plastic cone while seated, for example, it gets confused when she tries to do the same, standing with arm outstretched, with the clothespins. The nuances mean extra training to "teach" the algorithm more electrical patterns and the corresponding motions.

"It's kind of like teaching someone how to play a musical instrument," Kaliki said. "When I started playing the guitar, my fingers would hit multiple guitar strings, so that would be a mess. It's just like in this case, we're trying to make sure they precisely hit the right string at the right time."

Anne Mekalian works with Megan Hodgson, IBT research engineer, to train the prosthetic limb.

Dana Burke, a Pennsylvania woman who was shot in the arm 14 years ago, smiles before beginning another day of testing a thought-controlled prosthetic arm.

For the patients, there is a learning curve, too. It is steep, said Matheny, who was able to use his arm for a month without having to use the software to retrain it. He has been so successful that scientists are preparing to upgrade him with a robotic hand with more dexterity and complex motion.

“I just looked at myself like a newborn child,” Matheny said, recalling the time when he began using the arm. But he has progressed more quickly, partly because of the technology and partly because of extra motivation, he said. “It’s how hungry you are to wanting your life back the way it was versus you’re just satisfied with having something that’s going to be useful as a tool.”

Burke’s trials have been more challenging. In her first day or two with the arm, she was able to crush a soda can in her hand, carry a laundry basket with ease and open a bag of candy for her two children. She was ambitious enough to give two-handed driving a try, but that didn’t go as well — her hand fell off.

The device has since been in for repairs for several weeks, frustrating Burke but also leaving her excitedly anticipating its return.

“I feel balanced. There’s weight over there again. That’s a sensation I haven’t felt for 15 years,” Burke said. “That little tease of what I could do extra has left me hungry for more.”

As researchers continue to interview patients to test the technology, Mekalian is ready to regain her independence. Last month, she took home a customized Subaru station wagon and expects to soon be driving again. Her former students at Cathedral School raised $33,000 to pay for the vehicle and adjustments, and they are eager to see her behind the wheel.

“I think it’s just wonderful to see her progress in her independence,” said 12-year-old Casey Brown, a Cathedral sixth-grader who organized the fundraisers. “I think she’s just very inspirational.”

sdance@baltsun.com