

TMCNET

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Reaching for the next generation of prosthetic arms

(New Scientist Via Thomson Dialog NewsEdge)WHEN US forces went into Fallujah in November 2004 in a bid to flush out Iraqi insurgents, Brian Neuman's team was in the thick of the action.

On the fourth day of the assault, a rocket-propelled grenade slammed into the Bradley Fighting Vehicle he was in, which exploded in a maelstrom of light, heat and dust. "It took about a minute to realise what had happened," Neuman recalls. Gobs of molten metal were searing his legs, but the main problem was his left arm. "Initially, it felt like it was twisted behind my back and broken. But when the dust cleared, I could see it was completely severed. I had about 7 or 8 inches left." Today, after four operations and extensive rehabilitation, Neuman works for the Wounded Warrior Project, a charity that helps injured veterans. He meets many with injuries worse than his own.

Advances in body armour and battlefield surgery mean that soldiers in Iraq and Afghanistan are surviving blasts that would have killed earlier combatants, but many are being horribly maimed by rocket-propelled grenades and improvised bombs. The US Department of Veterans Affairs (VA) has treated more than 400 amputees from the two conflicts, many of whom have lost more than one limb.

This gruesome toll has prompted a surge in funding for prosthetics research, spearheaded by the VA and the Defense Advanced

Research Projects Agency (DARPA). In 2006 the VA plans to spend \$11 million on developing advanced prosthetics, a budget that has been rising by about 20 per cent a year since the invasion of Afghanistan. DARPA has launched two projects to develop new prosthetic arms, at an expected cost of \$73 million by 2009. The research looks set to transform the lives of injured veterans, as well as people who lose limbs in accidents or terrorist attacks.

For soldiers who lose a leg, reasonably good prosthetics are already available. The VA provides computerised "C-Legs", which have a knee joint that senses variations in gait and terrain and adapts accordingly, allowing more-or-less normal movement. Still, the agency is striving to improve the prospects for leg amputees, some of whom have injuries that make it difficult for them to use existing devices.

Today's prosthetic arms, however, leave much to be desired. After his wounds healed, Neuman was fitted with a myoelectric arm. These pick up electrical signals from the contraction of remaining muscles, which drive motors in the prosthesis. Today's models perform only three movements flexing the elbow, rotating the wrist, and grasping with a crude hand and then only one action at a time. The muscles that control the device are different from those that moved the lost arm, so people must learn how to control their prosthesis from scratch.

Neuman never learned to control his device effectively, and would often drop what he was holding in his hand as he tried to bend the elbow. Now he uses a cruder mechanical arm, operated by cables controlled by body movements.

This is where the DARPA projects come in. Over the next two years, DEKA, an R&D firm in Manchester, New Hampshire, will develop a myoelectric arm that is capable of up to nine distinct movements. By 2009, a team led by Johns Hopkins University's Applied Physics Laboratory (APL) in Laurel, Maryland, aims to build a device that will move like a real human arm. Both teams report to Geoff Ling, a colonel in the US Army Medical Corps now seconded to DARPA, who was appalled by the injuries he witnessed while serving in Afghanistan and Iraq.

The APL-led team, under Stuart Harshbarger, is working on a prosthetic arm that will perform 22 distinct movements in a coordinated fashion, even down to fingers that can tap the keys on a computer keyboard. The basic engineering should be relatively straightforward; the main difficulty is how to imbue a prosthetic arm with the same strength as flesh and bone when electric motors only give about one-fifth as much power, by weight, as muscle.

Michael Goldfarb, a mechanical engineer at Vanderbilt University in Nashville, Tennessee, may have the answer. His team has designed powerful pneumatic actuators that work by passing hydrogen peroxide

into a reaction chamber the diameter of a pencil, filled with granules of iridium. The metal catalyses a reaction that produces steam and oxygen, which can be fed through tubes to power the limb's joints. Although the reaction reaches 230 C, heat dissipates quickly, and water vapour condenses in similar quantities to natural sweat. "You can put your hand at the exhaust," says Goldfarb. The main challenge is developing valves to control the flow of gas.

Even more challenging is how to integrate the limb with patients' nervous systems, so that they can control their prosthesis as they did their missing arm, without first having to adapt other nerves and muscles for the task. This would have been unthinkable until a few years ago, but advances in neuroscience have brought the goal within reach (New Scientist , 28 February 2004, p 26)

Harshbarger's team will attack the problem on three fronts. Their first is a modification to myoelectric technology pioneered by Todd Kuiken of the Rehabilitation Institute of Chicago. Kuiken, who is also working on the DEKA project, operates on amputees to transplant nerves that once fed into the arm into muscles in their chest. The prosthesis is then controlled by sensing contractions of these muscles. Patients find they can move their prosthetic arm merely by thinking about moving their missing limb.

Nevertheless, myoelectric signals may not be able to adequately control an arm with 22 distinct movements, and feeding information back to the brain from sensors in the hand and arm is hard if you don't connect directly to the nervous system. This information is

thought to be vital for achieving fine control, so researchers led by Greg Clark at the University of Utah in Salt Lake City are using arrays of 100 electrodes that can be implanted into the nerves that feed the arm, where they can both record and transmit electrical signals. The first task is to decode the bursts of neural signals that direct normal arm movements. "We're basically wire tappers," says Clark.

Finally, three teams are working with arrays of electrodes that can record signals directly from the brain's cortex. Richard Andersen's team at the **California Institute of Technology** in Pasadena is studying the signals that control the action of reaching for an object; Jiping He's group at Arizona State University in Tempe is working out how to adjust this reaching action during the movement, as well as hand shaping; while Marc Schieber and his colleagues at the University of Rochester in New York are recording the cortical signals that control fine finger movements.

By the end of next year, Harshbarger and colleagues will decide which approach has come up with the best signals with which to control the new prosthesis. "We may need a hybrid approach," says Andersen. It's a daunting task, but team members are confident of approaching the function of a real arm.

For those maimed in Iraq and Afghanistan, not to mention civilian amputees, DARPA's device cannot come a moment too soon.

Down to the bonePeter Aldhous For some amputees, prosthetic legs are too uncomfortable to wear. Although they are designed to be strapped onto the stump so that a

cup on the end fits snugly around the soft tissue, this can rub.

"In some patients, that irritation is very serious and prevents them using the prosthesis," explains Roy Aaron, who heads the Department of Veterans Affairs' Center for Restorative and Regenerative Medicine in Providence, Rhode Island.

This is why researchers at Aaron's centre are working on ways to implant a titanium rod into the femur that will extend out through the skin, so the prosthesis can be bolted on, holding it clear of sensitive tissue. This should also provide a more natural feel as the stump would bear the body's weight through the bone. The hard part will be to get the skin to heal around an exposed metal rod, sealing up the leg against infection. Metallurgists at the Providence centre are experimenting with building prosthetic legs from titanium with different-sized pores, to see which size best encourages skin to grow into the surface of the metal.

Another problem is that some amputees have stumps that are too short to readily take a prosthetic limb. So Aaron's centre is also working on adapting the bone-lengthening techniques used to treat children who grow with one leg shorter than the other. This involves cutting the bone, which is then slowly pulled apart using a frame and pins to "stretch out" the healing process.

For adult amputees, says Aaron, it may be necessary to add biochemical growth factors to stimulate the formation of bone and blood vessels.