Rebuilding spinal cords with an engineer's toolkit

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Credit: New Jersey Institute of Technology

Like an earthquake that ruptures a road, traumatic spinal cord injuries render the body's neural highway impassable. To date, there are neither workable repairs nor detours that will restore signal flow between the brain and limbs, reversing paralysis.

"The problem with spinal cord injuries is that nerve cells do not regenerate," explains Treena Arinzeh, director of NJIT's Tissue Engineering and Applied Biomaterials Lab, who has proposed a solution: a scaffold, made of an energetic polymer, that will coax nerve cells to extend their axons over the spine's damaged section.

Earlier this month, Arinzeh and her lab team, former graduate student, Yee-Shuan Lee, Ph.D. '10, and George Collins, an adjunct professor, won an Edison Patent Award from the New Jersey Research and Development Council for their invention. Their repair strategy combines a piezoelectric scaffold with neural cells to regenerate nerve tissue in spinal cord injuries. Piezoelectric material, which produces an electrical charge in response to a mechanical force, is also used in sonar and sound technologies. The advantage of this "smart" material is that it generates its own charge and does not require an external power source.

"Axons - the fibers that transmit messages - can potentially travel long distances if given the right cues to regrow. We knew that an electrical charge could direct this growth," Arinzeh says, adding, "Some tissues in the body are naturally piezoelectric. What we did was to create a fibrous material that is similar, but with a higher charge to stimulate growth."

Her scaffolds caught the attention of the Department of Defense (DoD), which seeks remedies for traumatic battle injuries. "There is no effective treatment for severe spinal cord injuries, and soldiers can remain completely paralyzed for the rest of their lives," she notes.

With funding from the agency, the technology is being put to the test in preclinical studies at the Miami Project to Cure Paralysis, a Center of Excellence at the University of Miami Miller School of Medicine, where Arinzeh is working with Mary Bunge, a neuroscientist, and her former student. They are testing the efficacy of injecting Schwann cells from the peripheral nervous system, which produce the myelin sheath around nerve axons, in combination with the piezoelectric scaffold, for spinal cord repair. The Schwann cells' job is to restore existing cells by stimulating them to extend their axons.

The Miami Project is currently in phase I clinical trials with humans as well, using Schwann cells for spinal cord repair. By combining those cells with piezoelectric scaffolds, "we hope to improve the cells' survival and their effectiveness when implanted into the spinal cord," Arinzeh says.

"The nice thing about Schwann cells is that they're readily accessible from low-risk sites like limbs. I think of them as 'facilitator cells' because they provide the signals that prompt axons to grow and reach their targets - other neurons," she adds.

In the pre-clinical studies, Arinzeh found that implanted scaffolds with Schwann cells would extend over a five-millimeter gap in the spinal cord. "The cells survived and were getting good growth - wrapping themselves around the growing axons as the axons extend along the scaffold."

The primary conventional remedy to spinal cord trauma is to reduce inflammation with drugs. There have also been regenerative medicine strategies which involve injecting cells with growth factors, or growth factors alone, into the spinal cord in the hopes of stimulating new growth, but they have not been successful. Arinzeh says that engineering approaches are gaining more acceptance.

"No technology has been effective so far, and so we're taking it a step further, introducing biomaterials with an electrical charge. We've known in the biomedical world that electrostimulation can cause nerve cell growth - we've seen this with bone and cartilage tissue - so we set about to identify a polymer with piezoelectric properties. We found it in a material used for sutures, which is biocompatible and promotes nerve growth," she explains. "We're looking for some recovery of function. If we can show that, it would be a significant leap."

Arinzeh has creatively borrowed techniques from other engineering sectors to advance tissue regeneration, including for bone and cartilage repair. The polymer fibers that compose the framework of her scaffolds, for example, are formed by electrospinning, a technique developed by the textile industry.

For the community of scientists, engineers and clinicians determined to treat paralysis, the stakes are high. Success will hinge upon contributions from all of their domains.

"With bone and cartilage, we're relying on the scaffold to stimulate the body's own cells to regrow tissue, but the biological factors driving the formation of neural tissue in the spinal cord appear to be more complex," Arinzeh notes. "To induce nervous tissue to not only regrow across the lesion, but to reconnect with the rest of the spinal cord, may require a combination of scaffolds, cells and growth factors."

Provided by New Jersey Institute of Technology