

Dissolving implantable device relieves pain without drugs

June 30 2022



The soft flexible device bends and stretches with the body, without the need for bulky, rigid hardware. Credit: Northwestern University

A Northwestern University-led team of researchers has developed a small, soft, flexible implant that relieves pain on demand and without the use of drugs. The first-of-its-kind device could provide a much-needed alternative to opioids and other highly addictive medications.

The biocompatible, water-soluble device works by softly wrapping around nerves to deliver precise, targeted cooling, which numbs nerves and blocks pain signals to the brain. An external pump enables the user to remotely activate the device and then increase or decrease its intensity. After the device is no longer needed, it naturally absorbs into the body—bypassing the need for surgical extraction.

The researchers believe the device has the potential to be most valuable for patients who undergo routine surgeries or even amputations that commonly require post-operative medications. Surgeons could implant the device during the procedure to help manage the patient's post-operative pain.

The study will be published in the July 1 issue of the journal *Science*. The paper describes the device's design and demonstrates its efficacy in an animal model.

"Although opioids are extremely effective, they also are extremely addictive," said Northwestern's John A. Rogers, who led the device's development. "As engineers, we are motivated by the idea of treating pain without drugs—in ways that can be turned on and off instantly, with user control over the intensity of relief. The technology reported here exploits mechanisms that have some similarities to those that cause your fingers to feel numb when cold. Our implant allows that effect to be produced in a programmable way, directly and locally to targeted nerves, even those deep within surrounding soft tissues."

A bioelectronics pioneer, Rogers is the Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering and Neurological Surgery in the McCormick School of Engineering and Northwestern University Feinberg School of Medicine. He also is the founding director of the Querrey Simpson Institute for Bioelectronics. Jonathan Reeder, a former Ph.D. candidate in Rogers'

laboratory, is the paper's first author.

How it works

Although the new device might sound like science fiction, it leverages a simple, common concept that everyone knows: evaporation. Similar to how evaporating sweat cools the body, the device contains a liquid coolant that is induced to evaporate at the specific location of a sensory nerve.

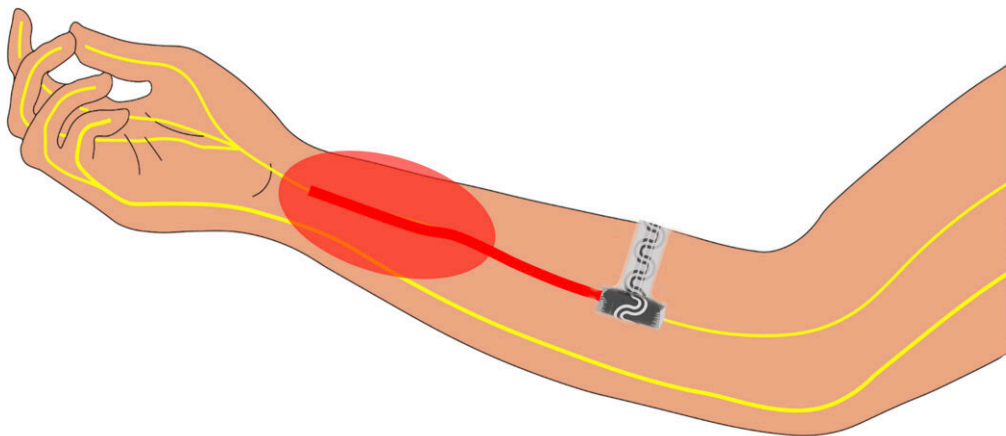


Illustration of the implantable device inside an arm. The red oval indicates pain. The device softly wraps around the peripheral nerve to silence signals to the brain. Credit: Northwestern University

"As you cool down a nerve, the signals that travel through the nerve become slower and slower—eventually stopping completely," said study

coauthor Dr. Matthew MacEwan of Washington University School of Medicine in St. Louis. "We are specifically targeting peripheral nerves, which connect your brain and your spinal cord to the rest of your body. These are the nerves that communicate sensory stimuli, including pain. By delivering a [cooling effect](#) to just one or two targeted nerves, we can effectively modulate pain signals in one specific region of the body."

To induce the cooling effect, the device contains tiny microfluidic channels. One channel contains the liquid coolant (perfluoropentane), which is already clinically approved as an ultrasound contrast agent and for pressurized inhalers. A second channel contains dry nitrogen, an inert gas. When the liquid and gas flow into a shared chamber, a reaction occurs that causes the liquid to promptly evaporate. Simultaneously, a tiny integrated sensor monitors the temperature of the nerve to ensure that it's not getting too cold, which could cause tissue damage.

"Excessive cooling can damage the nerve and the fragile tissues around it," Rogers said. "The duration and temperature of the cooling must therefore be controlled precisely. By monitoring the temperature at the nerve, the flow rates can be adjusted automatically to set a point that blocks pain in a reversible, safe manner. On-going work seeks to define the full set of time and temperature thresholds below which the process remains fully reversible."

Precision power

While other cooling therapies and nerve blockers have been tested experimentally, all have limitations that the new device overcomes. Previously researchers have explored cryotherapies, for example, which are injected with a needle. Instead of targeting specific nerves, these imprecise approaches cool large areas of tissue, potentially leading to unwanted effects such as [tissue damage](#) and inflammation.

At its widest point, Northwestern's tiny device is just 5 millimeters wide. One end is curled into a cuff that softly wraps around a single nerve, bypassing the need for sutures. By precisely targeting only the affected nerve, the device spares surrounding regions from unnecessary cooling, which could lead to side effects.

"You don't want to inadvertently cool other nerves or the tissues that are unrelated to the nerve transmitting the painful stimuli," MacEwan said. "We want to block the pain signals, not the nerves that control motor function and enables you to use your hand, for example."

Previous researchers also have explored nerve blockers that use electrical stimulation to silence painful stimuli. These, too, have limitations.

"You can't shut down a nerve with electrical stimulation without activating it first," MacEwan said. "That can cause additional pain or muscle contractions and is not ideal, from a patient's perspective."

Disappearing act

This new technology is the third example of bioresorbable electronic devices from the Rogers lab, which introduced the concept of transient electronics in 2012, published in *Science*. In 2018, Rogers, MacEwan and colleagues demonstrated the world's first bioresorbable electronic device—a [biodegradable implant](#) that speeds nerve regeneration, published in *Nature Medicine*. Then, in 2021, Rogers and colleagues introduced a [transient pacemaker](#), published in *Nature Biotechnology*.

All components of the devices are biocompatible and naturally absorb into the body's biofluids over the course of days or weeks, without needing surgical extraction. The bioresorbable devices are completely harmless—similar to absorbable stitches.

At the thickness of a sheet of paper, the soft, elastic [nerve](#) cooling device is ideal for treating highly sensitive nerves.

"If you think about [soft tissues](#), fragile nerves and a body that's in constant motion, any interfacing device must have the ability to flex, bend, twist and stretch easily and naturally," Rogers said. "Furthermore, you would like the device to simply disappear after it is no longer needed, to avoid delicate and risky procedures for surgical removal."

The study is titled "Soft, bioresorbable coolers for reversible conduction block of [peripheral nerves](#)."

More information: Jonathan Reeder et al, Soft, bioresorbable coolers for reversible conduction block of peripheral nerves, *Science* (2022).

[DOI: 10.1126/science.abl8532](https://doi.org/10.1126/science.abl8532).

www.science.org/doi/10.1126/science.abl8532

Shan Jiang et al, Cooling the pain, *Science* (2022). DOI: 10.1126/science.abm8159

Provided by Northwestern University

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