Miniature implanted devices could treat epilepsy, glaucoma

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Pedro Irazoqui, an assistant professor of biomedical engineering at Purdue, uses a "radio frequency probe station" to test tiny circuits in a new miniature device designed to be implanted in the brain to predict epileptic seizures. The research focuses on a transmitter three times the width of a human hair to be implanted below the scalp to detect the signs of a seizure before it occurs. The system will record neural signals relayed by electrodes in various points in the brain. Credit: Purdue News Service photo/David Umberger

Purdue University researchers have developed new miniature devices designed to be implanted in the brain to predict and prevent epileptic seizures and a nanotech sensor for implantation in the eye to treat glaucoma.

Findings will be detailed in three research papers being presented at the Engineering in Medicine and Biology Society's Sciences and Technologies for Health conference from Aug. 23-26 in Lyon, France.

One research project focuses on a tiny transmitter three times the width of a human hair to be implanted below the scalp to detect the signs of an epileptic seizure before it occurs. The system will record neural signals relayed by electrodes in various points in the brain, said Pedro Irazoqui (pronounced Ear-a-THOkee), an assistant professor of biomedical engineering.

"When epileptics have a seizure, a particular part of the brain starts firing in a way that is abnormal," Irazoqui said. "Being able to record signals from several parts of the brain at the same time enables you to predict when a seizure is about to start, and then you can take steps to prevent it."

Data from the implanted transmitter will be picked up by an external receiver, also being developed by the Purdue researchers.

The most critical aspect of the research is creating a device that transmits a large amount of data at low power. The transmitter consumes 8.8 milliwatts, or about one-third as much power as other implantable transmitters while transmitting 10 times more data. Another key advantage is that the transmitter has the capacity to collect data specifically related to epileptic seizures from 1,000 channels, or locations in the brain, Irazoqui said.

"The fact that this circuit can deliver such a vast amount of data and, at the same time, be less power hungry than anything else that's out there is what makes this important," he said.

A paper about that work will be presented during the conference on Aug. 26. The paper was written by doctoral student Eric Chow, undergraduate student Adam Kahn and Irazoqui, all in the Weldon School of Biomedical Engineering.

While the transmitter and its battery are to be implanted below the scalp, the electrodes that pick up data will be inserted directly in the brain through holes in the skull and then connected to the transmitter by wires.

A commercial implantable device developed by other researchers for epilepsy currently is in clinical trials at several sites, including the Indiana University School of Medicine.

"That device can record from eight channels to collect epilepsy data, compared to a thousand channels for our system," Irazoqui said. "The more parts of the brain that you can look at simultaneously, the better you are able to predict the seizure onset, so the number of channels has a direct correlation with how well the device works."

The research has been funded by Chicago-based Citizens United for Research in Epilepsy, known as CURE. Irazoqui's research group also recently received a two-year grant from the Wallace H. Coulter Foundation to further develop the technology.

"We are planning on doing human testing in two years," Irazoqui said. "Epilepsy affects about 1 percent of the global population, and of that 1 percent, 30 percent don't respond to any drugs. There is no cure or treatment for those 30 percent."

New technologies being developed aim to change that by predicting the onset of seizures and immediately dispensing a chemical called a neurotransmitter directly to the area of the brain where the seizure is starting.

The Purdue researchers will work with Dr. Robert Worth, a neurosurgeon at the IU School of Medicine.

The system's high performance is made possible by simultaneously

reducing power consumption and electronic interference. The researchers also calculated how well the signals are transmitted through tissue.

"We looked at the equivalent of the amount of skin that you have on your scalp, which is about 2 or 3 millimeters," Irazoqui said. "We have demonstrated that the transmitter does penetrate the thickness of tissue that would be required for this application."

The smaller the power consumption, the smaller the battery, which is critical for implantable devices. The battery in the Purdue device is about the size of a nickel. The signals are amplified, digitized and transmitted to the external receiver.

The research represents half of a larger collaboration at Purdue focusing on creating a neuroprosthesis that dispenses a neurotransmitter called GABA and calms the brain once the onset of a seizure is detected. This work is a collaboration between Irazoqui and Jenna Rickus, an assistant professor of biomedical engineering.

The technology is designed to prevent an epileptic "focal seizure," which starts in a specific area of the brain but can then quickly spread to the rest of the brain "like a brush fire," Irazoqui said.

"Once you find out where that focal area is, if you know the seizure is about to start you can suppress the seizure," he said.

Rickus has developed a "living electrode" coated with specially engineered neurons that, when stimulated, releases the neurotransmitter to inhibit the seizure. The engineered neurons are living tissue stimulated with a microchip.

Rickus and Irazoqui have shown that a certain amount of electrical

current causes the neurons to release specific and controllable quantities of neurotransmitter.

"The idea is that by using an engineered cell to release a neurotransmitter, we have a drug pump, in essence, that automatically refills itself and that only impacts the part of the brain where the living electrode is implanted: the epileptic focus," Irazoqui said. "So you are not going to get the side effects that you get by washing the entire body in a particular pharmaceutical."

A paper about that research will be presented on Aug. 24. The paper was written by doctoral students Travis J. Hassell and Sabrina S. Jedlicka, Rickus and Irazoqui.

Another biomedical engineering project to be discussed during the conference involves the development of a sensor to be implanted in the eye to monitor glaucoma by measuring pressure in the eye's interior.

"Glaucoma is one of the big two irreversible, but preventable, causes of blindness," Irazoqui said.

The disease causes blindness from a buildup of fluid pressure in the interior chamber of the eye, killing fibers in the optic nerve. Glaucoma patients go to the doctor periodically to have their eye pressure checked. If it is high, the doctor prescribes medication or performs surgery.

"The problem is that your interocular pressure spikes over hours, sometimes minutes," Irazoqui said. "So you can be fine today and fine in six months and spend three months in the middle where it's very high, killing your optic nerve. What you really need to do is check it often, every couple of minutes, but you can't go to the doctor every couple of minutes for the rest or your life. So what you need is a device that measures your eye pressure continuously."

The research is sponsored by SOLX Inc. in Waltham, Mass.

Collaborating on the research is Babak Ziaie, an associate professor of electrical and computer engineering, working at the Birck Nanotechnology Center in Purdue's Discovery Park.

The pressure sensor, which is placed between two layers of tissue in the eye, measures the interocular pressure and transmits the information to an external receiver so pressure can be continuously monitored, Irazoqui said.

A paper about that research will be presented on Aug. 25. The paper was written by doctoral student Russell P. Dresher and Irazoqui. The research paper describes the workings of a "nanoamplifier" needed to boost the signal from the low-power device.

"This device uses less than a microwatt," Irazoqui said. "It uses nanowatts."

The Purdue researchers are planning to conduct animal trials by December and human trials within 18 months. The device is fully implantable and includes a battery.

Source: Purdue University