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Granger causality test can make epilepsy surgery more effective

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A new statistical test that looks at the patterns of high-frequency network activity flow from brain signals can help doctors pinpoint the exact location of seizures occurring in the brain and make surgery more effective, according to researchers at Georgia State University and Emory University School of Medicine. The findings are published in the journal *Epilepsia*.

Emory researchers Dr. Charles Epstein, Dr. Robert Gross and Dr. Jon Willie; Dr. Bhim Adhikari, a post doctoral researcher at Georgia State, and Dr. Mukesh Dhamala, an associate professor of physics and neuroscience at Georgia State, studied two groups of patients suffering from epileptic seizures, two patients who were awaiting surgery and eight who had already undergone surgery to eliminate their seizures.

The statistical test known as Granger causality spectral analysis was installed in a computer program, and the researchers found they were able to pinpoint where seizures were originating in the brain and detect seizures up to 10 seconds earlier than previously possible.

"Because of a serious deficit in our fundamental understanding of seizure sources and propagation pathways in the brain, there's about a 50 percent cure rate," Dhamala said. "Identifying seizure sources is an imperfect process. Currently, there are no universally established criteria to clinically identify the seizure onset zones useful for successful surgery. So we've tried to contribute to identifying where a seizure comes from so that the doctor can target the mostly likely seizure

sources. Without identifying the location, the surgery cannot happen. For the two patients who were going to have surgery, our results helped to identify the locations of their seizures and eliminate some suspected locations for the doctors to operate."

A seizure is an abnormal, uncontrollable electrical discharge in the brain that produces changes in awareness, sensations and motor behaviors. More than 50 million people worldwide and 2.5 million people in the United States suffer from epileptic seizures. Thirty percent of these cases don't respond to medication, making surgery in which a doctor removes the part of the brain where the seizures originate the only option, Dhamala said.

To identify precisely where seizures are coming from, a person is hospitalized, his or her skull is opened and electrodes are implanted in the brain so electrical activity can be monitored when a seizure occurs.

For the two patients in the study awaiting surgery, the researchers used Granger causality analysis to evaluate intracranial EEG (iEEG) recordings of the patients' brains, locate the seizures and determine which parts of the brain are not the sources of the seizures.

For the eight post-surgery patients, this analysis was not applied for surgical decision-making. The researchers analyzed iEEG recordings taken before surgery to determine if the correct part of the brain was removed. Two of the patients suffered relapses and weren't free of seizures, and the research team concluded the part of the brain that was removed during surgery was inconsistent with their statistical findings about which part was causing the seizures. The researchers identified where the seizures were originating, and doctors were able to prescribe medication to manage the seizures. Both patients improved and remain seizure-free one year later.

The team chose to use Granger causality analysis because it can be applied to any network phenomena that have time series recordings from dynamic processes, such as epileptic seizures. A seizure starts in one part of the brain and spreads to other parts. Granger causality can estimate the direction, strength and frequency of information flow among the recording sites.

In the future, the research team would like to make the computer program faster and able to handle larger data sets, which would allow it to assist doctors in real time and be implemented into medical treatment for epileptic patients. They would also like to develop a graphical interface that can show the time series and pattern of causal flow of seizures side by side.

In addition, they would like to understand how high frequency network activity in the brain relates to underlying structural abnormalities. In this study, they showed that high-frequency activity can be detected early and used to predict seizures.

More information: The study, "Application of High-Frequency Granger Causality to Analysis of Epileptic Seizures and Surgical Decision Making," is available online at onlinelibrary.wiley.com/journa … 1111/(ISSN)1528-1167

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