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By Mike Martin

Brain quakes

Two decades ago, neurologist Ivan Osorio realized that he and his peers were stuck. Specifically, they were "making little progress" understanding "one of medicine's most intriguing intellectual challenges" - sudden, often debilitating surges of brain electrical activity known as epileptic seizures.

So Osorio decided to look outside clinical medicine. He discovered that seizures share similarities with a much larger phenomenon: earthquakes. He reasoned that laws describing earthquake behavior could, when applied to the brain, reveal new clues about what happens during epileptic seizures.

What can earthquakes tell us about seizures?

Osorio, who directs the Comprehensive Epilepsy Center at the University of Kansas Medical Center in Kansas City, made the connection between seizures and earthquakes in a sort of roundabout way. The world's most prevalent neurological disorder, epilepsy affects some 60 million people worldwide. To understand the relationship between abnormal brain wave activity and full-blown seizures, Osorio reviewed a 1967 *Nature* paper (214:1020-1) by psychologist Graham Goddard, which described a phenomenon called "kindling."

Repeatedly stimulating rat brains with low electrical voltages, Goddard discovered that, once he induced a seizure, he needed less and less electrical stimulation to induce a subsequent seizure relative to the first applied voltage. He called the phenomenon "kindling" because it reminded him of adding kindling, stick by stick, to build a blazing fire. "Kindling is the slow accumulation of energy," Osorio says. "Those microcurrents in the rat brains were microseizures, gradually building toward a violent discharge."

Complex-systems theory calls kindling behavior "relaxation." When energy accumulates at a much slower pace than it takes to discharge, opening the relief valve is called a "relaxation event." Because so much time occurs between relaxation events, the amount of energy ultimately discharged is so great it can have cataclysmic consequences.

Could seizures qualify as a relaxation event? Osorio and University of Kansas mathematician Mark Frei presented the idea at several conferences, including one attended three years ago by John Milton, a computational neuroscience professor at the Claremont Colleges in Claremont, Calif. Intrigued, Milton suggested that they compare seizures to other well-described relaxation events, including earthquakes. The idea was simple: Use the laws of one phenomenon to resolve the mysteries of another.

Last year, Milton introduced Frei and Osorio to UCLA geophysicist Didier Sornette, a complex systems researcher known as the "master of disaster" for using physics to predict all manner of calamities, from earthquakes to stock market crashes.

In an ArXiv.org paper (http://arxiv.org/abs/0712.3929v1, archived by Cornell), the four researchers compared 16,032 epileptic seizures to 307,019 earthquakes. They discovered different versions of the same universal phenomenon: the sudden relaxation of a tense and complex system with often devastating consequences.

The researchers found that three well-tested earthquake laws apply to epileptic seizures: Earthquakes (and seizures) beget more earthquakes (and seizures); small earthquakes/seizures can trigger larger ones; and the longer it has been since the last earthquake (or seizure) the longer it will be before the next one, regardless of size or intensity.

The findings overturn the conventional thinking that aberrant, subclinical brain wave activity in an epileptic patient isn't important. Just as no seismologist would ignore blips on a seismograph near the San Andreas Fault, no neurologist should ignore minor oscillations on an epileptic's EEG, says Osorio.

"The idea that earthquakes and seizures share so many mathematical similarities is indeed intriguing," says epilepsy specialist Carl Bazil, an associate professor of neurology at the Columbia University College of Physicians and Surgeons in New York City.

But he says the comparison is "incomplete" because subclinical brain wave activity - electrical oscillations on an EEG - can't accurately or consistently characterize seizures. "Many forms of brain oscillation are not seizures, and there are also oscillations that look like seizures but are completely normal," says Bazil. In other words, he argues, EEG interpretation is not an exact enough science to distinguish a subclinical epileptic seizure from other forms of abnormal brain wave activity.

Osorio says Bazil's concerns arise from "studying seizures entirely at the level of neurons." Instead, he insists that seizures are complex systems involving not only neurons, but cortical columns, lobes, hemispheres, and even the skull. Oscillations might be "so localized they don't involve a large enough part of the brain to affect its functionality. But that is not the same as saying they are not part of the complex process called a seizure."