Acoustic Emission Cascade Predicting Progression to Failure of Rock and Bone: A Journey from Hydraulic Fracturing to Neurosurgery

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Thursday, October 16, 2025, 9 a.m. Central Time

Andrew Bunger is a Professor in the University of Pittsburgh's Department of Civil and Environmental Engineering. Dr. Bunger will speak on Thursday, October 16, 2025. The seminar will be at 9:00 Central Time. The topic is "*Acoustic Emission Cascade Predicting Progression to Failure of Rock and Bone: A Journey from Hydraulic Fracturing to Neurosurgery.*" This presentation is in collaboration with Michael McDowell, MD, FAANS, Department of Neurological Surgery, Penn State Health, Hershey, PA, USA.

Abstract

For the roughly 1 million patients who undergo skull-based neurosurgical procedures each year, secure fixation of the head is essential to safety. Fixation almost always uses a clamp that pushes three pins into the skull and that, in turn, can be affixed to the surgical table. Safe pinning balances using too much force and inducing skull fracture against pinning with too little force and risking scalp lacerations and other injuries resulting from head slippage. While slippage can be problematic for patients of all ages, the most significant challenge is for pediatric patients, where the immature skull can leave a very narrow window of pinning forces that are sufficient to avoid slippage while not inducing skull fractures.

Against this backdrop, I will present a journey from hydraulic fracturing to neurosurgery. I will begin with a problem from multistage hydraulic

fracturing that motivates analysis of Acoustic Emission (AE) data in the lead up to failure of rocks using a rate dependent failure model. This model is inspired by catastrophe predictions that invoke evacuations ahead of landslides, volcanic eruptions, and rockbursts in mines. The demonstrated ability of this model to predict time to failure for granite beams under constant bending loads over the final half of their lifetimes - ranging from 35 seconds to two days - becomes the inspiration for a novel detection system to monitor AE generated by the skull due to both fracture and pin slippage. Experiments on human cadaver skulls show striking and useful similarities between failure in bone and rock. Specifically, failure in both materials is time dependent and entails divergence of the AE energy rate towards infinity as the material progresses to collapse through AE generated during microcrack coalescence. The way the AE energy rate diverges is shown to enable accurate prediction of time to failure. For fracture and pin slippage in neurosurgical settings, these predictions are the foundation for a novel warning system that can anticipate failure. In cadaver studies, the system is shown to give 40-60 seconds warning, which is sufficient for a surgical team to prevent patient injury.

Biography

Andrew Bunger is a Professor in the University of Pittsburgh's Department of Civil and Environmental Engineering. He joined the University of Pittsburgh in 2013 after spending 10 years in Melbourne, Australia working in the Geomechanics Group within the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Prior to that, he received his PhD in Geological Engineering from the University of Minnesota. His research interests include the mechanics of hydraulic fractures, characterization of stresses within the Earth, time-dependent failure of materials ranging from rock to human bone, and application of Large Language Models in engineering and beyond. He served as President of the American Rock Mechanics Association from 2023 to 2025.