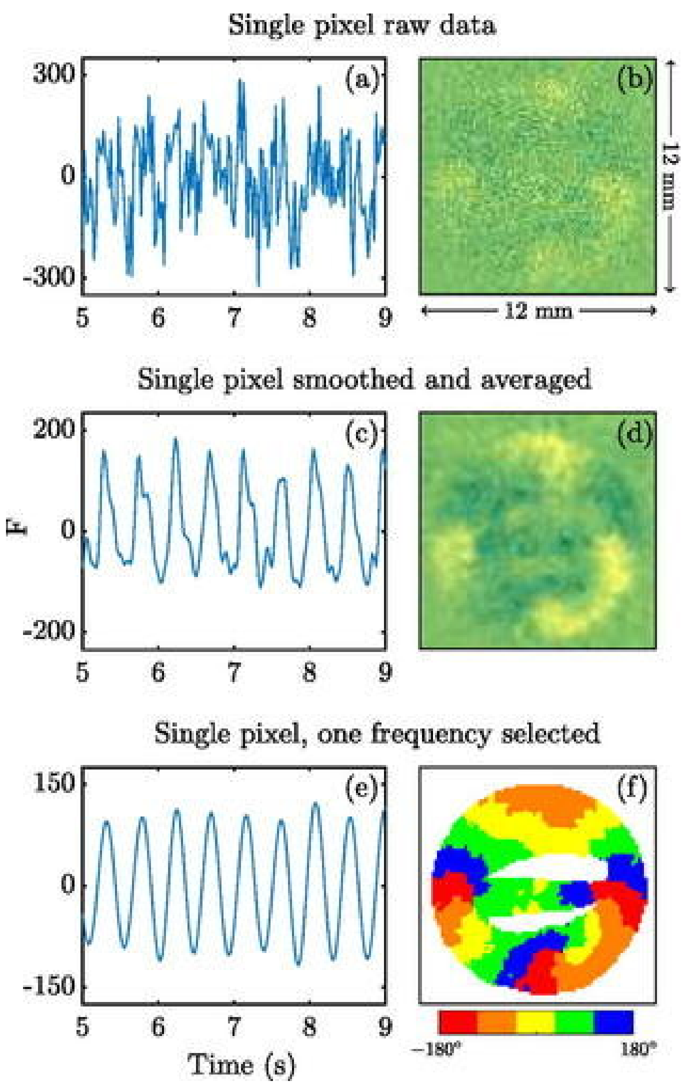
Getting to the heart of mapping arrhythmia-related excitations

September 29 2017



Fluorescent image data processing. (a) Time series of the raw intracellular Calcium-Green-1 fluorescence signal sampled at 40 Hz. (b) Snapshot of raw intracellular calcium fluorescence across a 1-cm diameter monolayer of embryonic chick heart cells. (c) Time series after averaged eight-neighbor pixel smooth and third-order Butterworth bandpass filtering. (d) Snapshot of the monolayer following data smoothing and filtering. (e) Time series after filtering using Fast Fourier Transform followed by Inverse Fast Fourier Transform after selecting frequencies near the peak frequencies. (f) Snapshot of the phase map with phase at each pixel in the monolayer defined by the angular coordinate. Credit: *Chaos: An Interdisciplinary Journal of Nonlinear Science* (2017). DOI: 10.1063/1.5001459

Atrial fibrillation is the most prevalent form of cardiac arrhythmia, affecting up to 6 million people in the U.S. alone. Common treatments for severe forms of the erratic beating phenomenon are controversial, and guided by detection methods that are not yet standardized or fully refined. But new research from a diverse group of cross-disciplinary scientists, published this week in the journal *Chaos*, offers a computational approach to understanding the important factors involved in measuring cardiac excitation waves.

While arrhythmias can be a symptom associated with multiple maladies, their fundamental behavior arises from waves of excitation and how they propagate through cardiac muscle tissue. These waves can take on spiral geometries, called rotors, which are thought to be important for initiating and maintaining atrial fibrillation.

For some severe cases, treatment can include ablating—effectively destroying—localized areas of heart tissue where cardiologists identify presumptive rotors. Although ablation of rotors claims a number of satisfied patients, its overall success is still controversial. This is partially due to disagreements related to diagnostic approaches used to characterize the underlying phenomena and identify rotors.

Leon Glass and Alvin Shrier, both professors of physiology at McGill University in Canada, have been studying rotors in cardiac cells from embryonic chicks. Along with Min Ju You, an undergraduate student at the time, cosmologist Matt Dobbs, and two other researchers, they identified misleading effects arising from the methods used to map the dynamics.

"Cardiologists are measuring local activity in a number of different places and trying to reconstruct what's happening based on that," Glass said. "The question is what are the errors in that procedure. Problems arise because there is not a clear understanding of the measurement analysis process. You'll always have a certain spatial resolution, a certain temporal resolution. ..."

Glass and his team developed an algorithmic technique to map the spiral wave activations measured in 1-centimeter wide monolayer samples of embryonic chick heart cells, tagged with calcium-sensitive fluorescent dyes that make the rotors radiative for direct optical detection.

This simplified model lends to measurements with much higher precision than the catheter-based detection methods used in living (human) patients, but this is actually a factor the research team was trying to highlight. With their algorithm, they were able to show some of the misleading effects of sampling errors and resolution discrepancies.

"When you have a heterogeneous medium, such as the real tissue is, then there can be complications due to multiple velocities of conduction and complicated geometries of propagation of waves from different sources," said Glass. "There may be false positives, you may be seeing something that may not really be there, [or] there may be false negatives, you may fail to detect something that is really there, and for all of those there are data requirements in terms of the spatial resolution that you need in order to detect rotors."

By taking statistical considerations into account, their computational reconstructions provide a number of valuable insights for rotor identification. For simpler dynamics, they show simple adjustments of thresholds based on the detection resolution can prevent false positives.

For more complex dynamics with multiple interacting rotors, they were able to demonstrate when artifacts might be accounting for false positive reads of so-called phase-singularities associated with the origin of a rotor. Because these singularities are often the focus of determining where to target ablation, their findings highlight what might be contributing to much of the uncertainty in the field.

"We feel that in order to try to resolve what's happening in the human heart, that it will be necessary for groups to try to make explicit the techniques that they're using in the data processing," Glass said.

Given that the difficulties in rotor identification from substrate heterogeneities and complex wave geometries is made challenging by low recording resolutions, and that these complications will only be magnified in real-time analyses of diseased human hearts, Glass was echoing a sentiment made in directly the article's conclusion: "We urge the community to develop public algorithms for rotor identification that can be critically evaluated in research as well as clinical contexts."

More information: Min Ju You et al, Demonstration of cardiac rotor and source mapping techniques in embryonic chick monolayers, *Chaos: An Interdisciplinary Journal of Nonlinear Science* (2017). DOI: 10.1063/1.5001459

Provided by American Institute of Physics

Citation: Getting to the heart of mapping arrhythmia-related excitations (2017, September 29)