A Model-Independent Technique for Eigenvalue Identification and Its Application in Predicting Cardiac Alternans

Xiaopeng Zhao[1]*, David G. Schaeffer[2], Wanda Krassowska[1], and Daniel J. Gauthier[1,3]
Department of Biomedical Engineering[1], Mathematics[2], and Physics[3]
and Center for Nonlinear and Complex Systems
Duke University, Durham, NC 27708

Abstract

Cardiac alternans is a precursor of ventricular fibrillation, a heart rhythm disorder that kills hundreds of thousands of people in the US each year. Predicting alternans is a crucial step for detection and prevention of fatal cardiac arrhythmias. According to the theory of dynamical systems, cardiac alternans is mediated by a period-doubling bifurcation, which is associated with variations in a characteristic eigenvalue of the system's Jacobian. Thus, knowing eigenvalues of a system would allow one to predict the onset of alternans. The existing criteria of alternans either adopt unrealistically simple assumptions and thus produce erroneous predictions or rely on complicated intrinsic functions, which are not possible to measure in *in vitro* experiments. In this work, we present a model-independent technique to estimate a system's eigenvalues without the knowledge of the underlying dynamic model. Using the so-called delay-coordinate vectors, we construct a pseudo-state space of the system, which allows one to compute the eigenvalues using the time history of a single measurable variable, such as the commonly measured transmembrane voltage or the intracellular calcium concentration in the cardiac experiments. Thus, it provides a promising tool for predicting alternans in real-time experiments. The technique has been verified in simulation of alternans using the model of Shiferaw *et al.* [Biophys. J., **85**:3666-3686, 2003].

*Corresponding author: xzhao@duke.edu.