Motion Reduction Algorithm Applied to Fluorescent Signals from Rat Hearts using Multilevel Wavelet Analysis

Huda Asfour1, Luther Swift2, Milos Doroslovacki1, Matthew Kay1,2
1Department of Electrical and Computer Engineering, 2Department of Pharmacology and Physiology, The George Washington University, Washington DC, USA.

Background

Over the past 30 years, fast fluorescence imaging of transmembrane potential has been shown to be a powerful tool for studying cardiac electrophysiology and arrhythmias [1]. It has been used to study patterns of electrical activation within cells, cell monolayers, and intact hearts [2]. It provides a number of advantages over traditional electrical mapping techniques such as higher spatial resolution, the ability to analyze action potential waveforms, and signals can be acquired without contamination of pacing spikes or defibrillation shocks. Fast potentiometric probes that span the cell membrane are used to transduce transmembrane potentials into fluorescent light (shown below).

A limitation of fast fluorescence imaging is that during contraction swelling of the heart results in a large motion artifact in the fluorescence signals.

Conventional Cardiac Fluorescence Imaging

Raw fluorescence with motion artifact
![Image]

Raw fluorescence with blebbistatin
![Image]

Blebbistatin dF/dt
![Image]

Effect of blebbistatin on metabolism
![Image]

NADH fluorescence imaging during ischemia reveals a higher slope of increase in NADH fluorescence when the heart is contracting. The kinetics of NADH fluorescence before and after introducing blebbistatin is shown.

Theoretical basis

The wavelet expansion series of a function $x(t)$ can be expressed as [4]:

$$x(t) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} a_{mn} \phi_{mn}(t) + \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} d_{mn} \psi_{mn}(t)$$

where $m$ = scale, $n$ = shift, $M$ = Maximum scale $a_{mn}$ = approximation coefficients $d_{mn}$ = detail coefficients $\phi_{mn}$ and $\psi_{mn}$ are scaling and wavelet functions.

Image Processing of Cardiac Fluorescence Imaging

Signal decomposition using wavelet

![Image]

Fluorescence Signal

No Blebb

Blebb

Amplitude

Frequency

Motion

Motion Reduction Algorithm Applied to Fluorescent Signals from Rat Hearts

Raw signal

Wavelet Analysis

Motion reduction (using of wavelet coefficients)

Wavelet Decomposition

Reconstruction (from higher level approximation)

Reconstruction (from lower level details)

APD (msec, ratiometry or optical ratiometric approach for estimating the time to 75% repolarization)

Reconstruction

Action potentials

Image Reconstruction

Motion

Motion Reduction

APD (msec, wavelet analysis)

Comparative Analysis of APDs

Optical ratiometric approach for reducing motion artifact [5]

Frequency content of reconstructed signals

APD (msec, wavelet analysis)

Motion

References


Acknowledgements

This work was supported by a grant from the American Heart Association (to M.W. Kay) and a grant from the NIH (R01-HL078722) to N.A. Sarvazyan. We thank N. Asfour for very helpful discussions.