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

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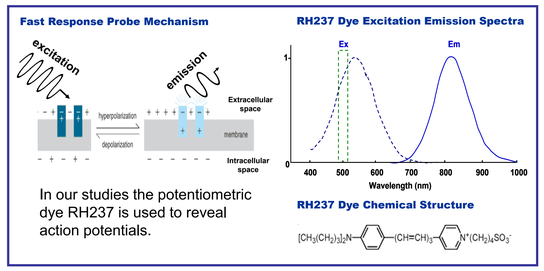
Background

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 fluoresced light (shown below).

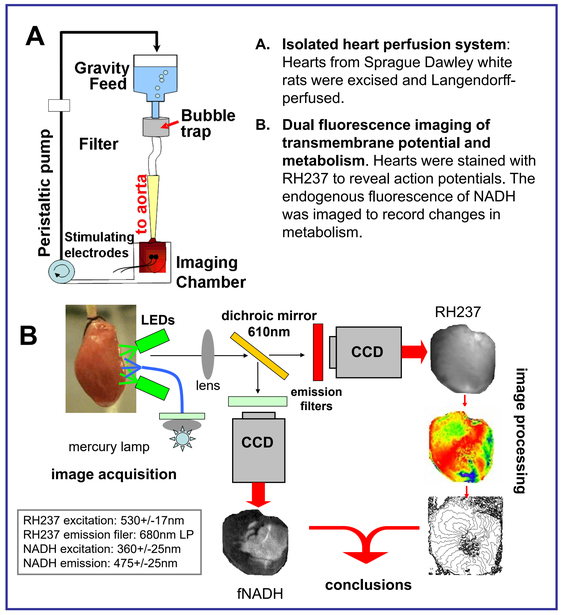


In our studies the potentiometric dye RH237 is used to reveal action potentials.

A limitation of fast fluorescence imaging is that during contraction registration between the imaging device and the heart is lost. This results in a large motion artifact in the fluorescence signals. This artifact can be eliminated using pharmacological agents such as **blebbistatin,** which blocks cross-bridge cycling to inhibit contraction without interfering with electrical activity [3]. However, a goal of our current work is to study the interaction between metabolism and electrical activity.

Contraction and metabolism are intimately linked so our objective has been to develop an approach for applying fast fluorescence imaging to study arrhythmias in contracting hearts.

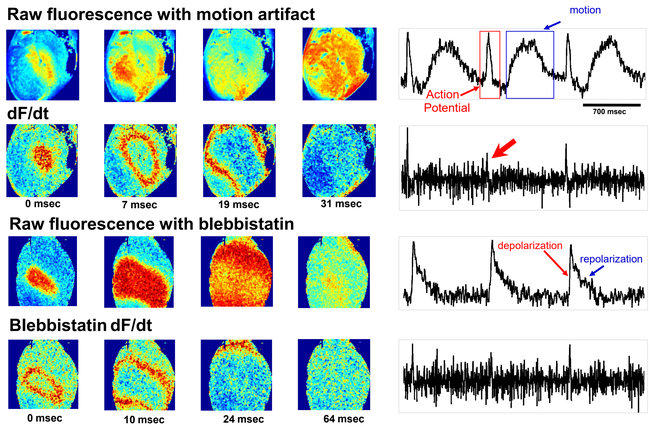
Experimental Setup

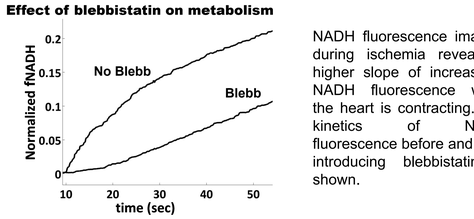


A. **Isolated heart perfusion system**: Hearts from Sprague Dawley white rats were excised and Langendorff-perfused.

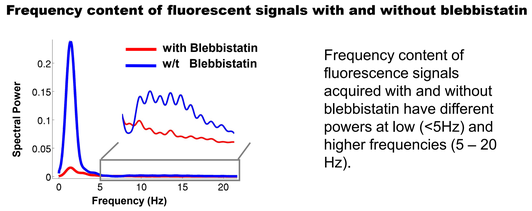
B. **Dual fluorescence imaging of transmembrane potential and metabolism**. Hearts were stained with RH237 to reveal action potentials. The endogenous fluorescence of NADH was imaged to record changes in metabolism.

Conventional Cardiac Fluorescence Imaging





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.



Frequency content of fluorescence signals acquired with and without blebbistatin have different powers at low (<5Hz) and higher frequencies (5 – 20 Hz).

Wavelet Analysis Approach Applied to Cardiac Fluorescence Imaging

Theoretical basis

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

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

$$a_{Mn} = \langle \phi_{Mn}, x \rangle = \int_{-\infty}^{\infty} \phi_{Mn}(t)x(t)dt$$

and

$$d_{mn} = \langle \psi_{mn}, x \rangle = \int_{-\infty}^{\infty} \psi_{mn}(t)x(t)dt$$

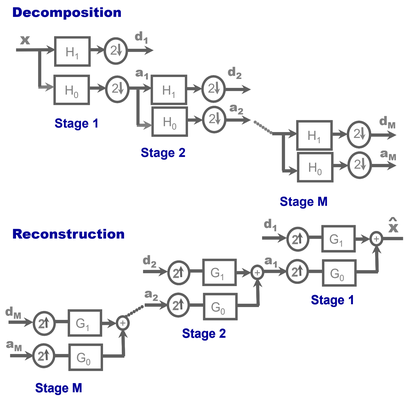
where m: scale, n: shift, M: Maximum scale

a_{Mn} :approximation coefficients

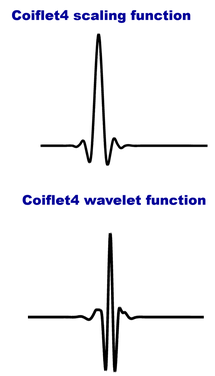
d_{mn}: detail coefficients

ϕ_{Mn} and ψ_{mn} are scaling and wavelet functions.

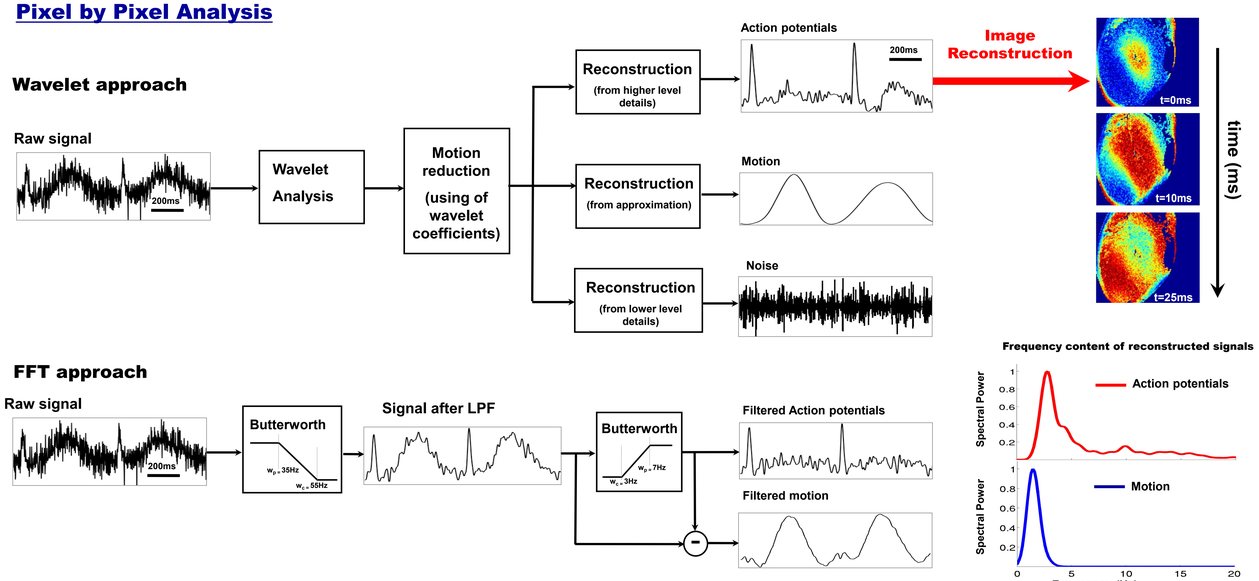
Numerical implementation



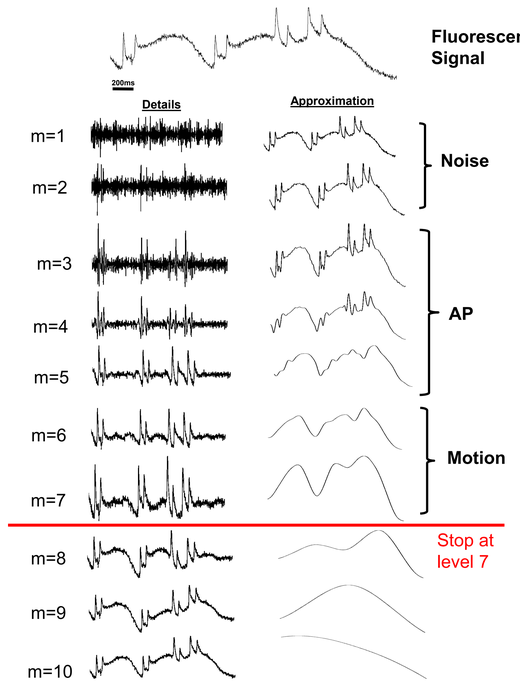
The Coiflet Wavelet



Pixel by Pixel Analysis

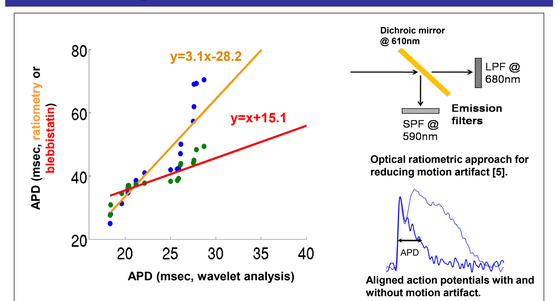


Signal decomposition using wavelet



Fluorescence signals were decomposed at each level (m). Analysis was implemented using the MATLAB Wavelets toolbox™. **Left**: Signal reconstructed using all details d_{1n} to d_{mn}. **Right**: Signal reconstructed using all approximation coefficients at level m (i.e. a_{Mn}).

Comparative Analysis of APDs



Action Potential Durations (**APDs**) are an important parameter in electrical propagation speed and propagation block.

References

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