Journal of Cardiovascular Magnetic Resonance

Poster presentation

Open Access

Automated detection and quantification of microcirculatory oxygenation changes in the heart

Sotirios A Tsaftaris*[1], Xiangzhi Zhou[2], Richard Tang[2], Aggelos Katsaggelos[1], Debiao Li[2] and Rohan Dharmakumar[2]

Address: [1]Northwestern University, Evanston, IL, USA and [2]Northwestern University, Chicago, IL, USA
* Corresponding author

from 13th Annual SCMR Scientific Sessions
Phoenix, AZ, USA. 21-24 January 2010

Published: 21 January 2010

Journal of Cardiovascular Magnetic Resonance 2010, **12**(Suppl 1):P216 doi:10.1186/1532-429X-12-S1-P216

This abstract is available from: http://jcmr-online.com/content/12/S1/P216

Introduction

Blood-oxygen-level dependent (BOLD) MRI may be used for detecting myocardial oxygenation (MO) changes secondary to coronary artery stenosis (CAS). Under pharmacological stress, the myocardial territory affected by CAS appears hypointense relative to healthy regions in BOLD images.

Purpose

To test a method for automatic quantification of myocardial signal changes reflecting the regional variations in oxygenation against true microsphere flow measurements obtained from controlled canine studies.

Methods

Data Acquisition: Short-axis 2D cine SSFP-based myocardial BOLD images were acquired in 7 dogs under adenosine stress with and without hydraulically-controlled left-circumflex CAS in a Siemens 1.5 T scanner. Scan parameters: resolution = 1.2 × 1.2 × 6 mm^3; flip-angle = 90°; and TR/TE = 5.7/2.9 ms. Fluorescent microspheres were infused to measure true myocardial perfusion. Following imaging studies dogs were euthanized and the myocardial tissue was processed to ascertain perfusion. The flow within each segment was summed to obtain total flow μ_F for each slice. Image Processing: End-systolic images were identified and segmented. Baseline images (BA) were used as reference, while stress without (AD) or with various levels of CAS (SS) were used as targets (TRG). BA myocardial intensities were collected and the mean (μ), variance (σ), and degrees-of-freedom of a Student's t-distribution were found. C_M, defined as the size of the largest contiguous hypointense region (pixel intensity below μ-σ) divided by the number of pixels in the myocardium, was computed.

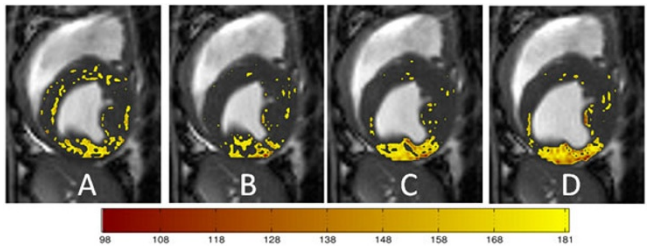

Figure 1
Color-coded end-systolic basline image (A); adenosine induced stress image (B); adenosine induced stress image with moderate LcX stenosis (C); and with severe stenosis (D). Only hypointense regions of the myocardium were color coded. Yellow hues correspond to values close to *m*-s as described in text, while red is for darker values. The small and minimally contiguous regions of hypointensity (yellow coded) in th BA and AD images may be attributed to signal inhomogeneties due to physiological nose, coil bias, or limitations in shimming. However, regions of hypointensity are significantly larger under stenosis (C and D). The premise of usin baseline images is to isolate the BOLD signal from background deviations. The C_M values for the imges A to D are 0.05, 0.02, 0.13, and 0.14, respectively.Total microsphere flow for each case is 19.82, 53.41, 34.67, and 30.44, resppectively.

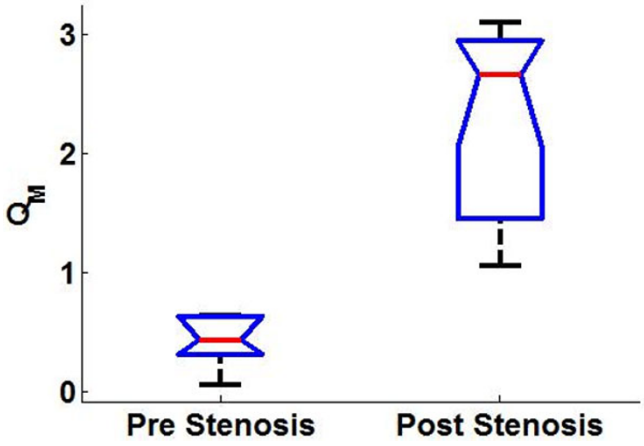

Figure 2
A box-plot Q_M values derived when comparing baseline with adenosine stress images pre and post stnosis. Median is shown in red and notches demonstrate 95% confidence intervals. A non-parametric t-test (Wilcoxon rank-sum test) illustrates a significant difference among the two medians (P = 0.001).

C_M ratios between BA and TRG images, Q_MTRG, BA) = C_M(TRG)/C_M(BA), were also calculated. Statistical tests were used to show that Q_M(AD, BA)<Q_M(SS, BA). Finally, Q_M was correlated against the ratio of microsphere flow ρ = μ_F(TRG)/μ_F(BA).

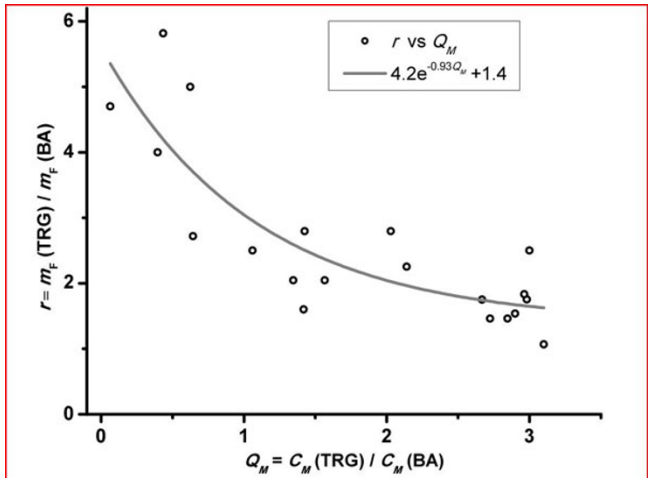

Figure 3
A scatter plot between Q_M (ration of the image-derived metric) and *r* (the ration of the flow). $Q_M = Q_c$ (TRG)/C_M (BA), where BA is without stenosis. Observe that when Q_M < 1, the ration of the flow is high indicating no apparent stenosis. However, when Q_M >1, the flow ratio drops significatly. When an exponential decaying function is fit through the data, an R2 of 0.68 is achieved and the regression is deemed significant (P < 0.001) with a power or 0.99.

Results

Representative end-systolic images with hypointense regions automatically detected are color coded and shown in Fig. 1. Fig. 2 shows a box-plot demonstrating the change in Q_M pre- and post-stenosis. Fig. 3 illustrates a scatter plot between Q_M and ρ, and a non-linear fit with power of 0.99.

Conclusion

The method is capable of automatically delineating the perfusion deficit territories (Fig. 1). Observe that C_M increases as the total flow decreases, establishing the foundation for utilizing the ratio of C_M between rest and stress studies as an image-based metric for detecting microcirculatory oxygenation changes. Fig. 2 supports the fact that Q_M provides adequate power (0.8) in detecting CAS. The exponential relationship (Fig. 3) between microsphere flow and Q_M has 0.99 statistical power. The work forms an initial step in the development of an objective and automated analysis of BOLD MR images and a metric for quantifying microcirculatory oxygen changes in the heart.