2D CONTINUOUS SIMULTANEOUS MULTI-SLICE (CSMS) MR IMAGING TO QUANTIFY CARDIAC PERFUSION

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Introduction

MRI (Magnetic Resonance Imaging) is fast becoming an essential tool in cardiac disease diagnosis and research. Some individuals suffer from ischemia (lack of adequate blood flow to the heart muscle) due to coronary artery disease (blockages of the coronary artery). High quality MR images can be used to diagnose these diseases by quantifying the flow of blood into the heart (Fig 1). A gadolinium contrast agent was used to measure blood flow (perfusion) to the heart muscle itself. The 2d cSMS imaging sequence used in this project is a new method to increase imaging speed while maintaining or even improving image quality.
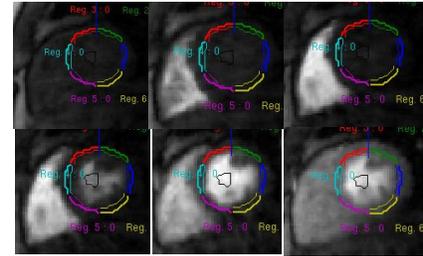
Figure 1 Depiction of cardiac perfusion at different time points after gadolinium administration. Blood flowing into the ventricles of the heart and into myocardium.

Methods

We used 3 slices of 2D MR images collected continuously in each heartbeat and excited simultaneously. After gathering the MR images an ECG was used to identify the phases of the heart cycle and our images were separated into systolic (heart muscle contracting) and diastolic (heart muscle relaxing) MR images. In some patients, images of cardiac perfusion at rest as well as at stress (increased vasodilation) were collected. Prior to gadolinium injection, 3 slices were acquired with a proton density weighting that are used to help convert the signal into gadolinium concentration. The first $\sim$20 readouts of the readouts at each heartbeat were used to estimate the AIF (arterial input function). The AIF is used as a standard to compare the signal intensity of the image to the concentration of gadolinium which is essential in quantification. The raw data from the MRI was reconstructed and then processed. The patients breathed freely throughout the imaging process. To compensate for respiratory movement rigid shift registration of the image as well as deformable registration were applied. Contour lines were drawn around the myocardium using a software program known as mpi2d (matlab based) and the lines were drawn and adjusted manually (Fig 2).
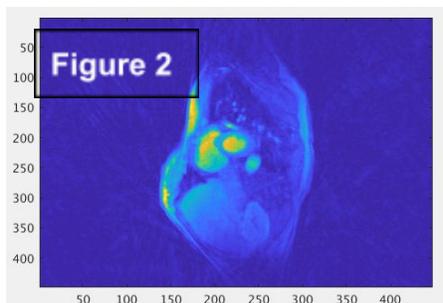
The next step after registration of the images was processing (Fig 3). Within mpi2d are other programs which allow for quantification of the gadolinium in cardiac perfusion. Contour lines were drawn around the myocardium on the MR images. Than the change in signal intensity is observed and quantified going from the blood pool in the ventricle into the myocardium. This signal intensity is converted to gadolinium concentration using the AIF which is a representation of the blood pool in the ventricle. A two compartment (blood pool and tissue) model was used to find the flow rates. The change in Tissue blood concentration can be expressed as $\frac{dTis}{dt} = k1 \cdot AIF - k2 \cdot Tis$ where k1 is rate constant into the myocardium, k2 is rate constant out of the myocardium and the AIF is the blood pool concentration. Solving this differential equation yields the equation $Tis = AIF \otimes k1 \cdot e^{-k2 \cdot t}$. This can then be used to find the change in concentration in the myocardium for the given time. This gives the flow rate of blood into the myocardium.
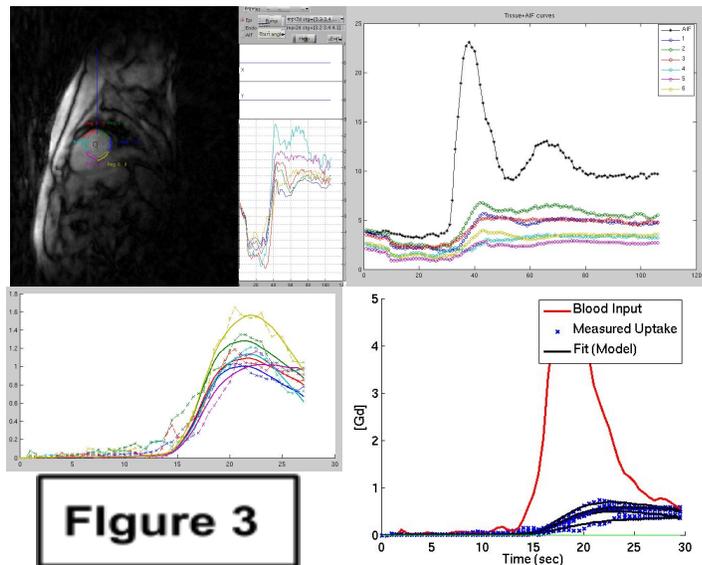
Figure 3

Results

The full set of data is still being processed. But from collected data thus far we have found that typical cardiac perfusion at rest is around .85 ml/min/g for diastolic and .96 ml/min/g for systolic. While at stress, systolic cardiac perfusion is around 2.77 and diastolic is 2.65 ml/min/g. This displays that, as to be expected, the cardiac perfusion rate of a patient at rest is almost half of that under stress. Also of note is that diastolic and systolic flow rates are relatively close to one another which is to be expected.

Conclusion

The purpose was to quantify values for cardiac perfusion using MR imaging from a 2d cSMS sequence. The collected values thus far are not far off from other accepted values for cardiac perfusion. It appears that the cSMS sequence is a useful means of quantifying and obtaining cardiac perfusion data. MRI's in general can become a useful means of diagnosing individuals with coronary artery disease. Considering that MRI does not use radiation like SPECT/CT scans (the more conventional form of obtaining cardiac perfusion images) but uses magnetic fields MRI seems like a better alternative and safer diagnostic tool. More information regarding values of healthy and sick patients will be necessary to effectively analyze obtained data completely and the rest of the data must be processed in order to draw definitive conclusions.