Accurate Quantitative Myocardial Perfusion using Single Cycle T1 Mapping

David Chen[1], Behzad Sharif[1], and Debiao Li[1]
[1]*Cedars Sinai Medical Center, Los Angeles, CA, United States*

Target Audience: Researchers investing myocardial ischemia

Purpose: Quantitative myocardial perfusion MRI depends on accurate determination of the arterial input function (AIF). Unfortunately, typical doses of contrast agent (CA) cause saturation in the AIF signal intensity at peak contrast concentrations. Methods using dual boluses [1] or dual sequences [2] have been proposed to correct for this effect; however, they require additional data acquisition which complicates the imaging procedure.

By calculating blood and myocardial T1 values during the first pass, CA concentration can be estimated accurately, overcoming the signal saturation problem [3,4]. This work builds on the work started in [4] which proposes a saturation correction method using fast radial imaging for single cardiac cycle T1 mapping. This method requires only a single scan which minimizes both scan time and setup time. High resolution images also reduces partial volume effect. This method was performed in vivo and compared to the dual sequence method [2].

Methods: Radial AIF correction was performed using the method described in [4]. T1 relaxation following an SR magnetization preparation and FLASH acquisition can be theoretically modeled by Eq. 1 (3).

$$S = \rho\left[\left(1 - e^{-TI/T1}\right)(E\cos(\alpha))^{n-1} + (1-E)\frac{1-(E\cos(\alpha))^{n-1}}{1-E\cos(\alpha)}\right] \qquad (1)$$

with ρ = proton density, T_2^* relaxation, and coil sensitivity variations, $E = e^{-TR/T1}$, α = flip angle, n = lines to k-space center, TI = delay time, TR = echo spacing. By acquiring multiple images after a single SR and using the acquisition parameters, pixelwise T1 can be found by solving a simple non-linear data fitting exercise. The T1 can then be converted to Gd concentration using the known relaxivity of Gd CA [6]. The baseline T1 can be found using pre-contrast images.

Ten healthy volunteers underwent perfusion MRI studies on a Siemens 3T Verio system with IRB approval and written consent. Two first pass perfusion scans were performed at rest using a radial acquisition for T1 mapping and a dual resolution Cartesian acquisition. Subjects were given separate injections of 0.1 mmol/kg Gd-DTPA with 10 min interval between doses to allow residual Gd to wash out. Imaging parameters for the Cartesian scan include: FOV = 300 mm; bandwidth = 651 Hz/pixel; flip angle = 10°; TR = 2.5 ms; TI = 120 ms; matrix size = 160x120; and TGRAPPA = 2. The short TI scan is centrically encoded with a TI of 28 ms.

The multi-shot radial scan used the following parameters: FOV = 270 mm; BW = 744 Hz/pixel; flip angle = 10°; TR = 2.5 ms; 3 images per SR with TI = 50, 94, and 138 ms respectively; resolution 1.7x1.7mm^2; 160 readouts x 128 projections, 8 shot interleaved. Three images were collected at the same slice position during diastolic phase. Total acquisition time per cardiac cycle is 148 ms. Reconstruction of multi-shot radial data was performed using a compressed sensing based method with a HYPR based composite reference constraint [3]. The AIF was measured in a manually drawn ROI in the LV blood pool. Myocardial blood flows was calculated using a model-independent deconvolution [7]. The Cartesian AIF was corrected by scaling the short TI AIF to the long TI AIF by matching the upslopes of the AIF.

Results: Raw Cartesian and radial perfusion signal intensity curves showed higher than expected rest MBF. Using the proposed method, the Gd concentration of the AIF was found. Fig. 1 shows signal curves comparing uncorrected radial and corrected. The uncorrected radial AIF show truncation due to signal saturation. Using the proposed T1 mapping technique allows for correction of the radial AIF ('SI Curve'). The MBF using the corrected AIF compared favorably with MBFs found using the AIF from the dual sequence, as presented in Table 1.

	Cartesian	Radial	P-Value
Uncorrected	1.96±0.45	1.88±0.41	P<0.33
Corrected	1.34±0.41	1.35±0.27	P<0.23

Table 1: Comparisons of MBF (ml/min/g) measurements using Cartesian and radial techniques. There is no significant difference between radially acquired and Cartesian MBFs.

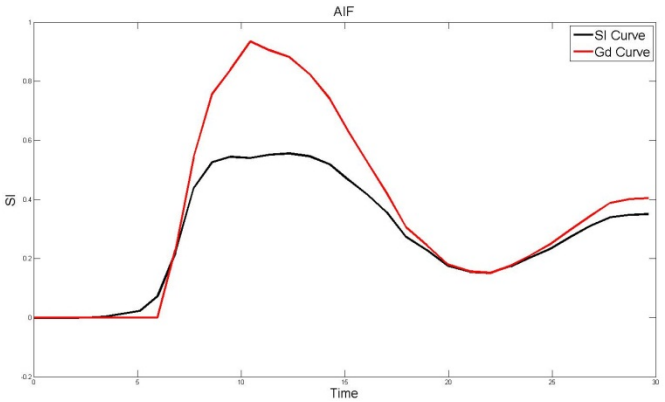

Figure 1: AIF Curves produced from the radial scan. The black curve shows the AIF derived from raw SI. The red curve shows the AIF taken from Gd concentrations produced from the described method. The peak signal amplitude is recovered by finding the Gd concentration.

Discussion: Myocardial perfusion measurement using radial T1-mapping eliminates the need to acquire two datasets to produce an unsaturated AIF with the dual sequence approach, making it more practical for clinical use. The method produces similar MBF measurements. The major problem with the dual sequence method is it produces AIF of different signal intensity scale due to different T1 weighting. The AIF needs to be scaled properly with respect to myocardial tissue function for accurate MBF measurements. The proposed method allows the myocardial tissue signal and AIF to be extracted using the same set of the images, thus eliminating a potential source of error.

References:

1) Christian, Arai. Rad 2004: 677-84. 2) Kim, Axel. JMRI 2006: 81-6. 3) Kholmovski, DiBella. MRM 2007:821-7. 4) Chen, Li. Proc Int MRM. 2012. 5) Ge, Li. MRM 2009: 835-9. 6) Hanicke, Chien. Med Phys 1990:1004-10. 7) Zierler. Circ 1962. 393-407.