Real Time Self Tracking of Contrast Kinetics for Whole Heart Coronary Artery Magnetic Resonance Angiography

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Introduction: Contrast enhanced coronary artery magnetic resonance angiography (CMRA) at 3T with slow infusion of contrast agent has recently shown very promising results [1]. In this method the imaging delay time was empirically determined. The contrast dynamics are however, dependent on parameters like cardiac output, age, heart rate and severity of vascular disease [2], making the optimal delay time highly subject dependent. Methods like MR Smartprep [2] and fluoroscopic triggering [3] have been proposed for real time tracking and detection of contrast agent arrival in the anatomy of interest. These methods, however, require a separate pulse sequence to detect the contrast agent arrival, prior to the high resolution imaging sequence. In this work we propose a new method to track the contrast enhancement for slow infusion of contrast agent in real time. The method is easily embedded into the high resolution imaging sequence and can potentially be used for changing the k-space reordering in real time or to trigger the data acquisition based on the signal enhancement.

Methods: Proposed Method: The hypothesis of this work is that since a relatively low injection rate (0.3cc/sec) is used for the whole heart scan [1], the average signal in the heart can give a good estimate of the blood signal enhancement due to the contrast agent. The average signal in the heart can be measured by collecting a 1D projection of the whole heart (phase and partition encoding gradients turned off). This is called the self tracking (ST) signal. Since the sequence is inversion recovery (IR) prepared (Fig 1), most of the background is suppressed, and the ST line mainly contains signal from the heart. The mean value of the ST signal can thus be used to estimate the contrast enhancement curve. The schematic of the proposed sequence is shown in Fig 1. It is an IR prepared, fat saturated, ECG triggered segmented FLASH sequence as proposed in [1]. In order to track the contrast enhancement curve, the ST line is acquired in each cardiac cycle (CC) after all the segments have been acquired.

Validation: A validation study was performed on 6 healthy volunteers to test whether the contrast enhancement curve predicted by the ST line actually matches the true blood signal changes. A single shot (SS) (1 coronal image in each CC) ECG triggered, inversion recovery (IR) prepared, FLASH sequence was used for the validation (Fig 2). Parameters for the sequence were: TR = 3.5 ms, TE = 1.65 ms, matrix = 90 x 128, GRAPPA acceleration factor = 3, flip angle = 20, slice thickness = 5mm, inversion time (TI) = 200 ms. The SS image was followed by the ST line. For a fair comparison, the ST line was collected after a non selective (NS) excitation in order to get the average signal from the whole heart. Data was acquired in diastole to minimize the effects of cardiac motion. The trigger delay (TD) was set up using a 4-chamber cine acquisition to identify the window of minimal cardiac motion. The above sequence structure (Fig 2) was repeated for 500 cardiac cycles during contrast injection at a rate of 0.3cc/sec. The true contrast curve was obtained by placing an ROI in the aorta (near the root of the coronary arteries) in the coronal image. The estimated contrast curve was obtained from the mean value of the NS-ST line.

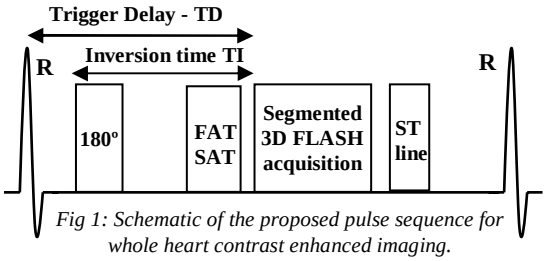

Fig 1: Schematic of the proposed pulse sequence for whole heart contrast enhanced imaging.

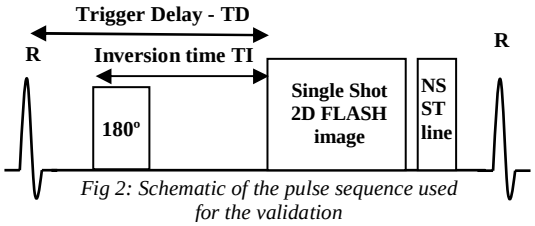

Fig 2: Schematic of the pulse sequence used for the validation

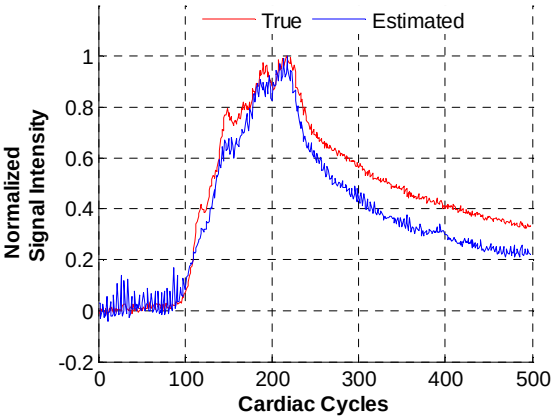

Fig 3: True (red) and estimated (blue) contrast enhancement curves

Results and Discussion: Fig 3 shows the true (red) and estimated (blue) contrast enhancement curves (using normalized signal intensity) in a healthy volunteer. Excellent agreement between the 2 curves can be seen. Fig 4 shows the peak position of the true (red) and estimated (blue) contrast enhancement curves in the 6 volunteers. There was no statistically significant difference between the peak positions given by the true and estimated curves using a paired t-test (p value = 0.23). The mean value of the error between the true and estimated curves was 12.8 %. Based on these results, the ST signal gives an accurate estimate of the contrast enhancement during slow infusion of contrast agent. The main difference of this method from previous methods is that the contrast curve estimation is embedded in the high resolution CMRA sequence. A potential application could be where the reordering is started in a linear fashion and then interactively changed to a center out fashion when the peak of the contrast curve is detected. Another application could be for triggering a center out reordered high resolution CMRA sequence when the peak enhancement is detected. In both these cases the central k-space lines would be acquired during peak contrast enhancement, leading to optimal SNR and CNR. Another application could be for recording the contrast curve during time resolved imaging. The curve could then be used to retrospectively select the appropriate time frame to reconstruct, instead of reconstructing and evaluating all the time frames.

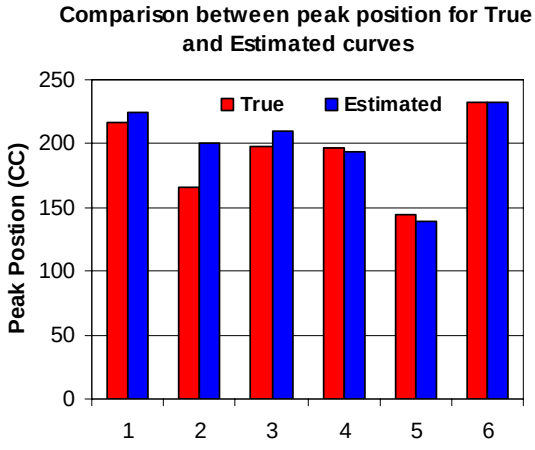

Fig 4: True (red) and estimated (blue) peak positions

Conclusion: In conclusion, a new method for tracking the contrast enhancement during slow infusion of contrast agent is proposed and validated. This method is based on acquiring an extra projection of the heart during imaging and gives an accurate representation of the contrast enhancement. The method is embedded in the high resolution IR-FLASH sequence and has a host of potential applications.

References: [1] Bi et al. MRM 5 8: 1-7, 2007. [2] Foo et al. Radiology 203: 275-80, 1997. [3] Wilman et al. Radiology 205: 137-46, 1997.