# Contrast-Kinetics-Resolved Whole-Heart Coronary MRA Using 3DPR

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## Introduction:

In contrast-enhanced coronary MR angiography (CE-CMRA), the transit time of the contrast agent from injection to peak arterial enhancement is dependent on both the injection scheme and the blood circulation of the individual subject. A test bolus is usually performed to synchronize central k-space acquisition with the period of the highest blood signal, necessitating an additional scan and subjective assessment. However, optimal timing of data acquisition often remains elusive due to variations of heart rates and respiratory gating efficiency as well as simultaneous myocardial enhancement. Improper timing may result in suboptimal SNR and CNR. This work aimed to investigate the feasibility of contrast-kinetics-resolved CMRA using 3DPR which can eliminate the tedious planning task and enables automatic retrospective selection of the optimal coronary artery visualization from time-resolved image series covering the entire heart.

## Methods:

A navigator(NAV)-gated, ECG-triggered 3DPR FLASH sequence was implemented for this study. 5 healthy volunteers were scanned on a 1.5T Siemens Avanto system. Gd-BOPTA (0.2 mmol/kg) was slowly infused at a rate of 0.3ml/sec [1]. A whole-heart slab was scanned using the following parameters: 175×175×175 $mm^3$ FOV, 160 readout points; 1.1×1.1×1.1 $mm^3$ isotropic resolution (interpolated into 0.55×0.55×0.55 $mm^3$); 8400 projections; 42 lines/segment; 20° flip angle; TR/TE = 3.3/1.78ms; TI = 110ms. The scan time for one measurement during free-breathing was approximately 6 minutes. Data acquisition started simultaneously with contrast injection and was repeated within 10 minutes to cover the arterial phase of contrast kinetics. Self-calibrated GRAPPA (acceleration factor = 3) was used to reduce undersampling streaking artifacts [2].

As shown in Fig.1, tornado filtering [3], including all outer-k-space (Kr,max) samples but partial center-k-space (Kr,min) samples within a small temporal aperture (10 NAV-accepted heartbeats) for image reconstruction, was used to increase temporal resolution and therefore resolve contrast kinetics. Different time frames were reconstructed by sliding the Kr,max window and the Kr,min aperture in the temporal direction. The k-space center, depicting the total signal in the imaging volume and repeatedly visited in each k-space line, was used to automatically select optimal time frames for coronary artery visualization. First, the signal intensity variation as a function of the heartbeat number was derived by summing the magnitude of all centre k-space samples acquired in each heartbeat and then low-pass filtered to suppress respiratory and cardiac motion. Due to high blood-background contrast in CE-CMRA, this signal intensity variation is highly correlated with cardiac-blood-signal enhancement during the scan, which approximates coronary-blood-signal enhancement with slow infusion. Next, by sliding the kr,max window in time, signal integration over the window was calculated in different window positions (Fig.1). The position corresponding to the max integration value was selected as the optimal Kr,max window position. Similarly, the integration signal over different Kr,min apertures could be calculated. The first-pass of the contrast agent was found by identifying the moments when the integration signal starts to rise and reaches the peak. For image reconstruction, Kr,max window was fixed in the optimal position. A few time frames were reconstructed during the first-pass period at an interval of 30 sec by sliding the Kr,min aperture to obtain different blood signal and blood-myocardium contrast.

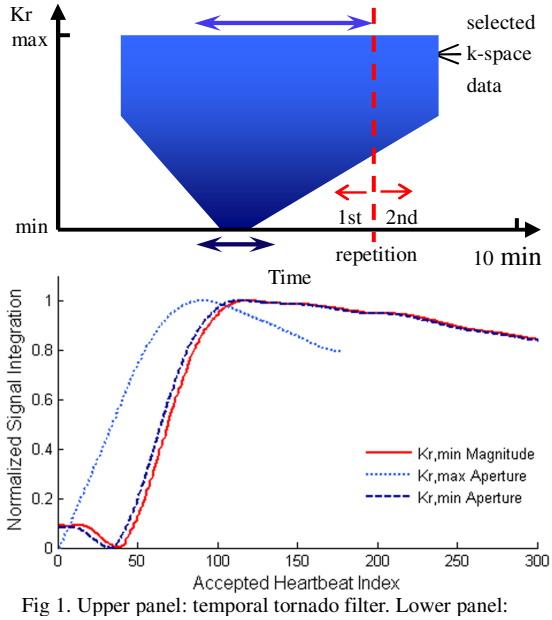


Fig 1. Upper panel: temporal tornado filter. Lower panel: selection of the optimal Kr,max and Kr,min aperture positions.

## Results:

On all 5 volunteers, time-resolved CMRA images could be reconstructed capturing the contrast kinetics of the entire coronary artery tree. An example is shown in Fig.2 and 3. Fig.2 shows the derived Kr,min integration signal. The signal intensity starts to increase 68 sec after contrast injection and reaches the peak at 167 sec. In 9 time frames, intensities of aorta blood, myocardium and epicardium fat were measured. Clearly, both blood and myocardium signals increase after contrast injection, while myocardium is enhanced relatively later. In comparison, fat signal remains relatively constant during the scan. In the 9 sampled time points, the highest blood signal and blood-myocardium contrast are achieved at 137 and 108 sec, respectively. Fig.3 shows 4 frames during the first-pass period as well as a pre-enhancement and two post-peak frames. Coronary arteries are invisible before contrast arrival in the 1st frame and enhance between 78 sec and 167 sec and then gradually decay afterwards. RCA, residing in a lipid environment, is best depicted in the highest-blood-signal frame at 137 sec, while LAD, clinging to myocardium, is best visualized in the maximum-contrast frame at 78 sec.

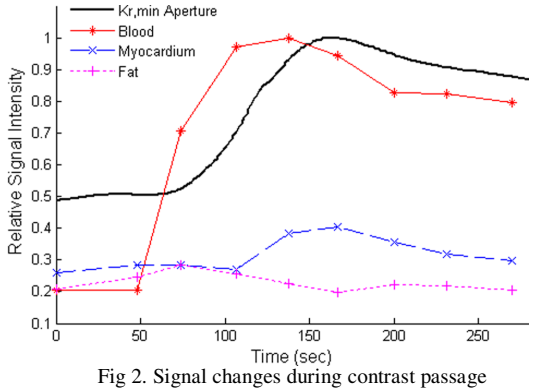


Fig 2. Signal changes during contrast passage

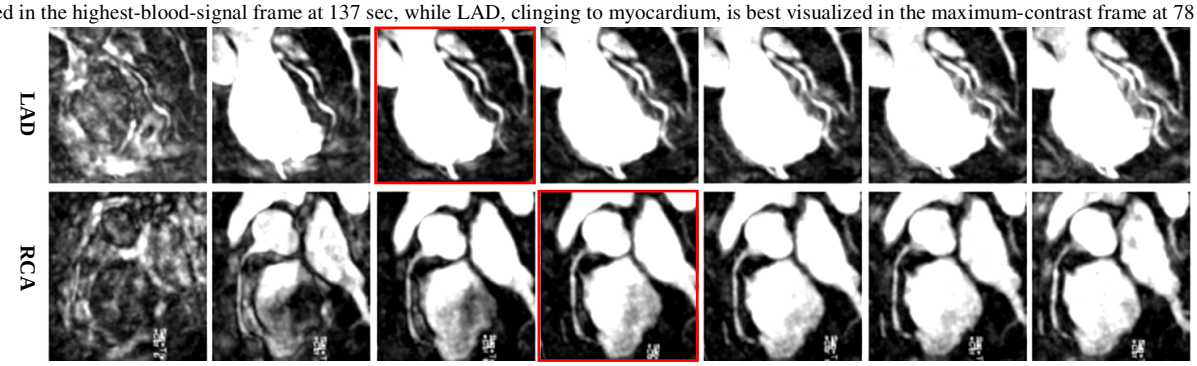


Fig 2. Left to right: coronary artery images (LAD:1st row; RCA: 2nd row) at 0, 78, 108, 137, 167, 200, 270 sec after contrast injection, respectively.

## Discussions:

The proposed technique is capable of time-resolved CMRA capturing the contrast kinetics in the entire coronary artery system. No bolus scan is needed. The variation of center-k-space magnitude can be exploited to estimate cardiac-blood-signal enhancement during the scan. Multiple time frames during the first pass of the contrast agent can be reconstructed, allowing retrospective selection of the best vessel delineation for each coronary artery segment.

**References:** [1] Bi X et al, MRM, 2007; 58:1-7; [2] Huang F et al, MRM, 2007;57:1075-85; [3] Barger AV et al, MRM, 2002;48:297-305