Contrast Enhanced Coronary Artery Imaging in a Breath-hold at 3 Tesla using 3D Segmented EPI: A Feasibility Study

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Introduction: Contrast enhanced coronary artery magnetic resonance angiography (CMRA) at 3T has recently shown very promising results [1]. Imaging time on the order of five minutes was reported for a whole heart acquisition. Drifts in diaphragm position over this relatively long acquisition time could lead to inconsistencies in navigator gating. The long acquisition time also translates into a slower infusion rate of the contrast agent, resulting in lower signal. Further reduction of the imaging time is required to make CMRA more robust and clinically applicable. Segmented EPI is a method which can be exploited to provide a significant speed gain for CMRA and has previously been reported at 1.5T [2-3] using both contrast enhanced and non contrast methods. The purpose of this work was to evaluate the feasibility of high resolution segmented EPI acquisition for first pass contrast enhanced CMRA in a breath hold at 3T.

Methods: A 3D segmented EPI FLASH sequence (Fig 1) was implemented on a clinical 3T scanner (MAGNETOM Trio, A Tim System, Siemens Medical Solutions, Germany). Three echoes were collected after each RF pulse, with a TR of 5.5 msec (echo spacing = 1.83 msec). A reference scan was acquired during the first heartbeat for first order phase correction. The FOV and matrix were 330 x 258 x 24 and 256 x 180 x 9, leading to an acquired resolution of 1.3 x 1.4 x 2.7 mm^3, which was interpolated to 0.65 x 0.7 x 1.5 mm^3. Other scan parameters: flip angle = 12°, spectral selective fat saturation pulse, bandwidth = 1302 Hz/pixel, breath-hold duration = 30 heartbeats. Contrast enhanced CMRA was performed during first pass (0.1 mmol/kg body weight) at a rate of 1cc/sec. The flip angle was increased to 18° and an inversion pulse with an inversion time (TI) of 280 ms was used. The rest of the scan parameters were identical to the precontrast scan. A test bolus was run to match the data acquisition with the first pass of the contrast agent.

Reordering Scheme: In order to minimize ghosting artifacts, the three echoes after each RF pulse filled *k*-space in an interleaved fashion [4]. However, interleaving introduces discontinuities in *k*-space. The application of pre pulses or variable flip angle excitation has been proposed to minimize these discontinuities [4]. For contrast enhanced CMRA, variable flip angle series is difficult since the T1 of blood is variable and pre pulses are not practical, since they will reduce the effectiveness of fat saturation. To circumvent this problem, the partition encoding gradient was incremented for every other RF pulse [5], such that all the partitions were covered in one heart beat in a center out fashion. This removed the discontinuities from the phase encoding direction and converted them into smooth variations in the partition encoding direction. The *k*-space reordering in the phase encoding direction was similar to that used in [6]. In this approach, all the central *k*-space lines have the same readout direction and are acquired as the 1st echo after the RF pulse. This minimizes the phase errors and T2* effects in the central *k*-space region. As shown in Fig 2 the upper half of each partition was encoded during the 1st RF and the lower half during the 2nd RF pulse. The trajectory begins at the edges of *k*-space and progresses inwards in successive heart beats. This hybrid trajectory minimized the in plane and out of plane amplitude modulations in *k*-space due to the segmented and interleaved EPI acquisition. It also provided the optimal fat and myocardium suppression and SNR.

Results and Discussion: Fig 3 shows a single partition (3a: precontrast, 3b: contrast enhanced) from a double oblique slab showing the left circumflex artery (LCX). The LCX (white arrow) is much better delineated during the contrast injection. Compared to precontrast images, SNR was improved by 51% (precontrast/contrast enhanced: 24.3 / 36.5) and CNR was increased by 368% (precontrast/contrast enhanced: 7.19 / 33.7), with contrast agent. Fig 4 shows a maximum intensity projection (MIP) from the same dataset (4a: precontrast, 4b: contrast enhanced). Both the right coronary artery (RCA) and LCX (white arrows) are clearly visualized during contrast injection. Targeted acquisitions were used in this feasibility study to test the efficacy of high resolution contrast enhanced segmented EPI at 3T. Segmented EPI could potentially be used in combination with parallel imaging techniques, to provide wider coverage in the heart with very short acquisition times. The reduced imaging time will potentially allow for higher injection rate and increased SNR and CNR as compared with conventional methods.

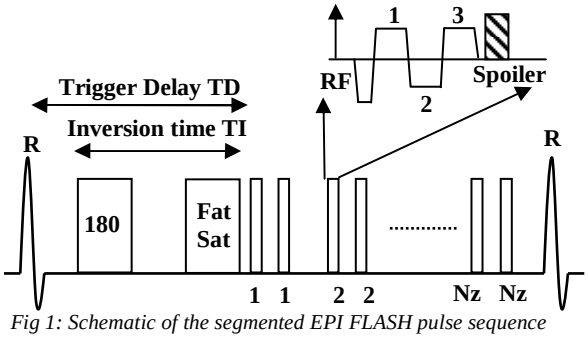

Fig 1: Schematic of the segmented EPI FLASH pulse sequence

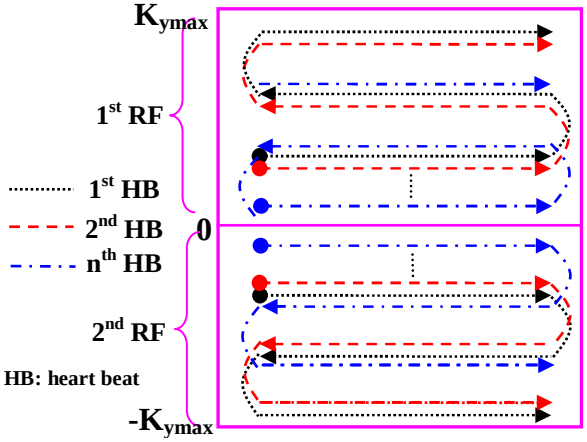

Fig 2: The inplane k-space trajectory used for segmented EPI

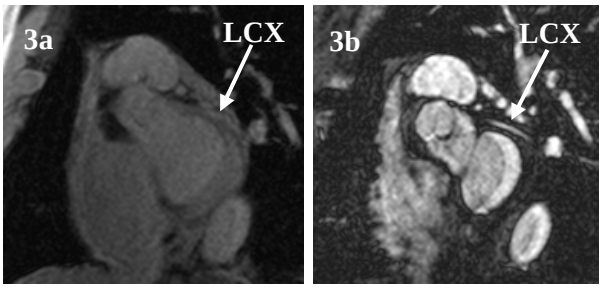

Fig 3: Images showing the LCX (3a: precontrast, 3b: contrast enhanced

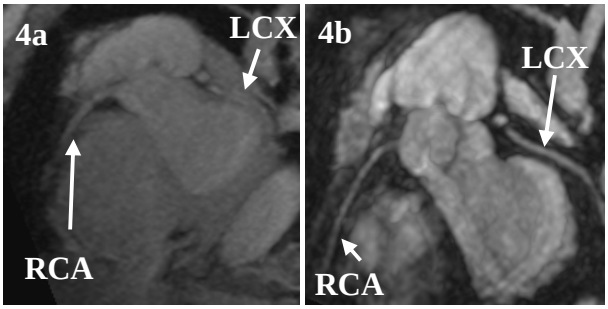

Fig 4: MIP showing the RCA & LCX (4a: precontrast, 4b: contrast enhanced)

Conclusion: The feasibility of 3D segmented EPI for high resolution CMRA at 3T has been shown. Contrast enhanced CMRA at 3T is likely to benefit from the speed of segmented EPI. In conclusion 3D segmented EPI is a promising technique for contrast enhanced coronary artery imaging at 3T.

References: [1] Bi et al. MRM 58: 1-7, 2007. [2] Deshpande et al. JMRI 13: 676-81, 2001. [3] Botnar et al. JMRI 10: 821-25, 1999. [4] Mc Kinnon MRM 30: 609-16, 1993. [5] Wielopolski et al. JMRI 4: 403- 09, 1995. [6] Epstein et al. MRM 39: 514-19, 1998.