Contrast Enhanced Real-Time MRCA

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Introduction: In this work, we describe a new method to evaluate coronary artery disease using real-time MRI. A continuous acquisition is performed in real time without cardiac gating or breath-holding. Small amounts of T1 shortening agent can then be used to increase the blood contrast and to monitor contrast passage through regions where coronary lesions are suspected based on anatomic imaging results. Variable sampling density spirals and constrained coil sensitivity are exploited to achieve one-millimeter resolution in a 75 to 100 ms temporal window.

Methods: An undersampled variable-density spiral k-space trajectory is used to acquire high-resolution images (1 x 1 x 4.5 mm^3) with only three to four 16 ms acquisitions (Fig. 1). A full frame is acquired every 75 ms to 100 ms. The number of interleaves (3 or 4) is selected according to the SNR and heart rate. The images are then reconstructed with a sliding window algorithm at a rate of 40 fps. Acceleration is achieved by a linear decrease in sampling density for high spatial frequencies. Fortunately, the introduced aliasing is mostly translated to noise instead of unwanted structured artifacts [1]. We implemented the proposed pulse sequence in the RTHawk real-time system [2]. This system provides real-time acquisition and reconstruction. It also allows for interactive control of the scan plane location and dynamic adjustment of imaging parameters such as FOV and flip angle. The images are acquired with a GRE sequence and a spectral-spatial excitation to suppress fat signal. A flip angle of 30° is used to maximize SNR and minimize flow saturation artifacts. Once the area of a suspected coronary lesion is localized, the flip angle is increased to 90° to produce saturation of static material. Less than 10 cc of contrast (Gd-DTPA) is then injected to observe the passage through the vessels and increase in SNR.

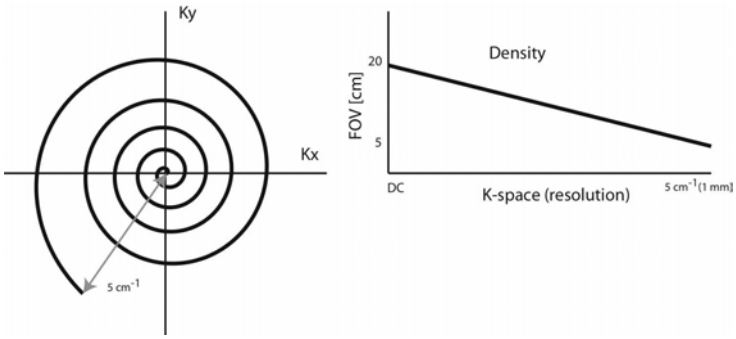

Figure 1: Variable-density spiral k-space trajectory and designed linearly reduced sampling density.

Results: The feasibility of the method was demonstrated on a healthy volunteer on a 1.5T GE Signa scanner (40 mT/m and 150 T/m/s gradient) using a 5" surface coil. Views of both the LAD (Fig. 2a) and RCA (Figs. 2b and 2c) were obtained in real-time. Figure 2b) shows a single frame before injecting contrast while Fig. 2c) shows the first-pass effect after contrast injection. Both frames correspond to the systolic phase of the cardiac cycle. Comparing images 2b) and 2c), it can be clearly observed the improvement in contrast and SNR, especially in the distal portion of the RCA.

Discussion: Good visualization of small vessels can be observed in real time. This provides the potential to obtain dynamic information of coronary lesions by evaluating the contrast passage. Even though SNR is a limiting factor for high resolution imaging, good visualization was possible without external contrast for resolutions of 1x1x4.5 mm^2 and acquisition times of only 75 ms. (Fig. a). After the first-pass images are acquired, it is possible to obtain other coronary segments while T1 remains short. As the available frame rate exceeds the minimum requirements, it is also possible to acquire two slices simultaneously potentially providing first-pass information in both the RCA and LAD. We expect that as little of 5 cc could be used allowing for multiple injections.

References:

[1] Tsai CM, et. al. MRM 43:452-458. 2000.
[2] Santos JM, etc. al. IEEE-EMBS 26th, 1048:1051 (2004).

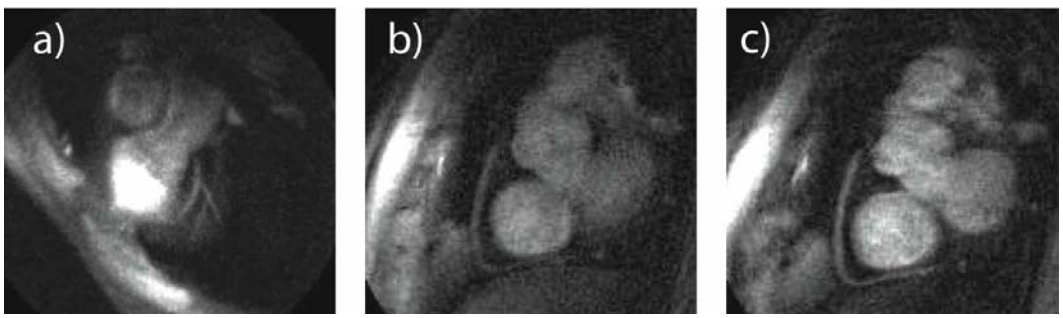

Figure 2: Real-time high-resolution images. . Image a) show the LAD acquired with 3 interleaves in 75 ms. A pre-contrast b) and post-contrast c) (1st pass) frames are shown from a video acquired with four interleaves in 100 ms