3D Multiphase Coronary Artery Imaging in a Single Breath-hold using Undersampled Projection Reconstruction

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Introduction Coronary artery imaging remains a challenge for MR imaging because cardiac and respiratory motions impose special constraints on conventional acquisitions. Previously our group has shown that undersampled projection reconstruction techniques can break the link between imaging time and resolution in contrast-enhanced MR angiography but introduces artifacts that are usually acceptable [1]. In this work we investigate the artifacts that occur when using undersampled PR to image an oblique 3D volume containing the coronary artery. This high-resolution acquisition was completed in a single breath-hold using a Gd-based contrast agent. We have found that the artifacts are not limiting and believe there are several key elements of the technique that help overcome the limited SNR that is achievable in short scan times at high resolutions.

First, the scan is completed in a single breath-hold. This minimizes blurring from respiratory motion that can decrease the image resolution. Because the duration of the scan is roughly 30 seconds, clinically available first-pass Gd-based agents can be used. Second, the three-dimensional nature of the scan allows for viewing the coronary artery from multiple angles. A stenosis that might not be visible from one angle could be visible from a different projection. In addition the 3D acquisition increases SNR and avoids the slice discontinuities of multiple slice 2D. Third, multiple cardiac phases of true 60ms duration are reconstructed (30 ms with view sharing). This minimizes motion artifacts and allows for a dynamic display to aid *.V.* in the visualization of the coronaries. The availability of many time frames during the cardiac cycle allows for the possibility of combining multiple interleaved projection sets to increase SNR. An additional benefit of the continuous RF required to image multiple cardiac phases is that myocardium and fat are very well suppressed and allow for imaging of the true lumen of the coronary artery.

While the SNR is still limiting due to the constraints of a breath-hold cardiac study, the high resolution, multiple phase, and three-dimensional aspects of the acquisition are promising for visualization of the coronary arteries. It remains to be investigated whether further refinements can increase the usefulness of the technique.

Methods Projections were acquired as fractional echoes in the kx-ky plane through a range of angles spanning 180 degrees and Fourier encoding was used in the kz direction. For image reconstruction the acquired data was regridded onto a Cartesian grid and then fast Fourier transformed into image space. During one heart beat interval, a single projection angle was acquired at multiple time frames. At each time frame all of the slice encode values for the projection were collected, thus determining the duration of the time frame. The starting projection angle for each time frame was fractionally incremented to achieve interleaving (Figure 1). Data collection was continuous until a trigger was detected, at which time the projection angle was incremented and the sequence started again with the next projection. The number of projections determined the scan time.

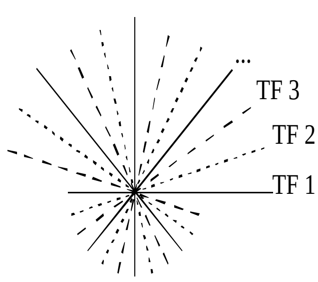

Figure 1. Starting angles of three time frames (TF).

The sequence was implemented on a Signa Horizon CardioVascular scanner (GE Medical Systems, Milwaukee, WI) with peak gradient amplitudes of 40 mT/m and maximum slew rate of 150 mT/m/ms. Healthy human volunteers were imaged using the phased array cardiac coil. A single oblique volume was prescribed to provide an in-volume view of the right coronary artery (Fig. 2). The dose of Gd-based contrast agent administered was 15 cc at 0.8 cc/s and the injection rate was calculated to deliver the dose over the duration of the scan. Forty-eight projections were acquired with a 256 readout matrix (fractional echo – 160 points) at a bandwidth of 64 kHz and a FOV of 28 cm. Fourteen slice encode values were acquired at a resolution of 3 mm and were zero-filled to 28 slices during reconstruction. The TR of the sequence was 4.1 ms and the TE was 1.2 resulting in a time resolution of 57 ms. The scan time for the volunteer (heart rate of 90 bpm) was 32 s.

Results Figure 2 shows images acquired during the breath-hold scan. Images a, b, and c show limited slice MIPs at end diastole (a) and early systole (b and c). The image in Figure 3 shows the result of adding frames b and c to increase SNR. The myocardium and epicardial fat is very well suppressed in all the images. The projection streak artifacts appear to be minimal and do not interfere with visualization of the artery.

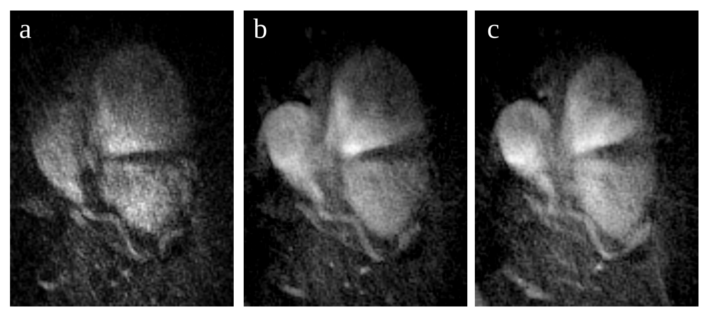

Figure 2. Images a, b, and c are limited slice MIPs of the right coronary artery in multiple cardiac phases.

Conclusions In this preliminary work we have shown that undersampled projection reconstruction can be applied to coronary imaging with acceptable artifacts. The technique allows for high-resolution images in a single breath-hold. The multiphase nature of the scan has many potential advantages, including multiple time frame averaging during diastole and dynamic display of the coronary arteries, which remain to be investigated.

Figure 3.

References

[1] D. Peters, et al. Undersampled projection reconstruction applied to MR angiography. MRM; 43 (2000).

Acknowledgments

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