Simulation of Motion-Induced Dark-Rim Artifacts for Cartesian and Spiral Pulse Sequences

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Introduction: First-pass MR perfusion images may be corrupted by dark-rim artifacts, which are at least in part a consequence of myocardial motion during data acquisition [1]. We have previously shown that the non-linear time-varying displacements of the myocardium resulting from cardiac contraction result in dark-rim artifacts that have a different appearance in images obtained at different phases of the cardiac cycle for Cartesian sampling strategies [2]. We sought evaluate whether spiral trajectories which have a different temporal sampling of k-space data would be more robust to dark-rim artifacts.

Methods: To have a realistic representation of cardiac motion, the radii of the epicardial and endocardial borders were measured from a short axis cine of a healthy volunteer, and fit with one cycle of a cosinusoidal wave as demonstrated previously (Fig 1)[2]. For the simulation, the heart was represented as circles of these radii that varied according to this cosinusoidal model. Data collection was simulated by sampling the k-space representation of these two circles (the sum of two jinc functions) at each k-space location according to the pulse sequence timing. The contrast between the LV and myocardium was 3:1 to simulate signal intensities when dark-rim artifacts frequently occur. The following parameters were used to simulate a typical gradient echo Cartesian pulse sequence: FOV 350x262 cm, MAT 192x91, resolution 1.8x2.9 mm, TR 2.3, parallel imaging with R=2 and 24 phase correction lines (corresponding to 59 PE lines total). The identical model of cardiac motion as above was simulated for an interleaved-spiral acquisition. Pulse sequence parameters included: FOV 320mm x 320mm, resolution 2.18 mm, 8 spiral interleaves, readout duration 8.2 ms per interleaf, TR 13ms, TE 1.8 ms. Images were simulated with acquisitions centered at 150, 200, 250, and 300ms from end diastole. Additionally, images without motion were simulated with radii corresponding to the nominal radius at the specified time points.

Results: Figure 2 demonstrates simulated images obtained with Cartesian sampling without motion (top row) and with motion centered at 150, 200, 250, and 300 ms from end diastole (bottom row). In the images without motion, a dark-rim from Gibbs ringing is evident. In the simulated images with motion, the dark-rim artifact has a different appearance. During systole (150-250 ms) the myocardial border is less distinct, and the dark-rim artifact appears mid-myocardial. In the images near peak systole (300ms) the myocardial border is sharper, but a dark-rim artifact appears at the endocardial border and is more pronounced. Figure 3 demonstrates images obtained with interleaved spiral sampling without motion (top row) and with motion centered at the same time points as for the Cartesian case (bottom row). As in the rectilinear case, when there is no motion, Gibbs ringing results in some dark-rim artifact. In the spiral images modeled with motion, the Gibbs ringing is still apparent, but the simulated images with motion, there is a considerable reduction in motion-induced dark-rim artifact as compared to the Cartesian case.

Conclusions: Simulation of interleaved spiral data acquisition demonstrates reduced sensitivity to motion-induced dark-rim artifacts as compared to conventional Cartesian data acquisition. Thus, spiral data acquisition strategies may be advantageous for first-pass myocardial perfusion imaging.

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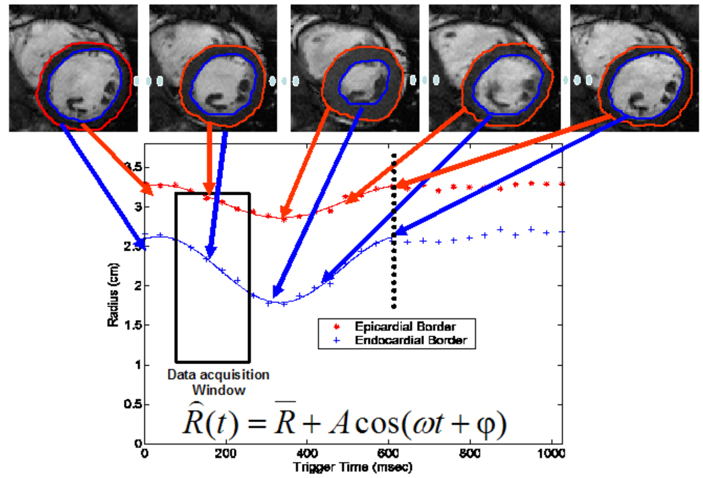

Figure 1: Fitting of LV radius versus time to a cosinusoidal model

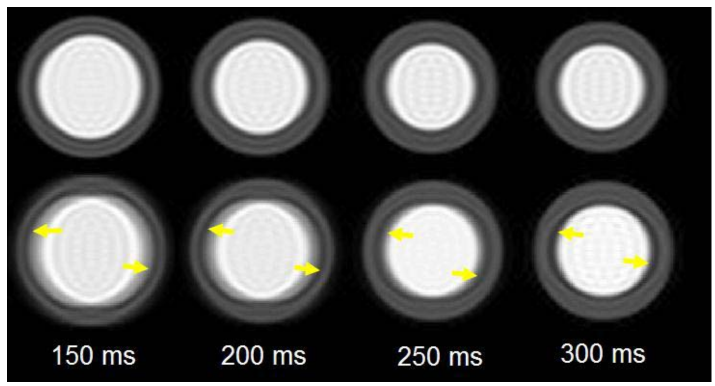

Figure 2: Simulation of LV cavity for Cartesian sampling without (top row) and with (bottom row) motion. A dark-rim artifact is clearly seen in the images with motion (arrows)

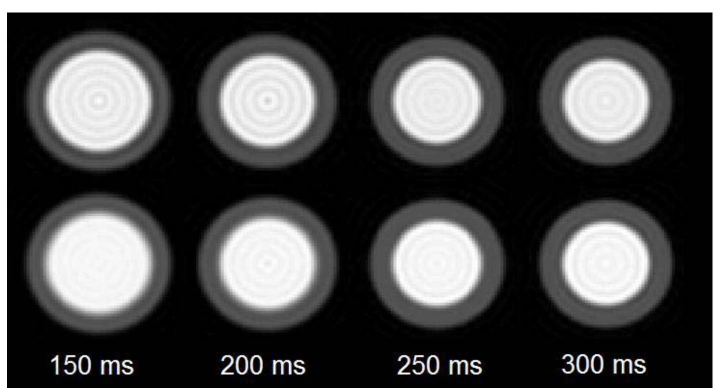

Figure 3: Simulation of LV cavity for Spiral sampling without (top row) and with (bottom row) motion. The dark-rim artifact is less apparent in the images with motion.

References:
1. Story P. et al *Magn Reson Med.* 2002;48(6):1028-1036.
2. Salerno et al. *10th SCMR, 242, 2007*