Optimal selection of the subject-specific data acquisition window for coronary MRA

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Introduction Coronary motion during a cardiac cycle varies substantially from subject to subject (1). Empirical formulas were previously proposed to calculate the optimal trigger delay time (TD) for coronary MRA (2). Single-slice cine scan was also employed to determine the quiescent period of the heart (3, 4). The selection of optimal TD for data readout requires substantial user interactions and experience. Empirical formulas may not apply in every subject, and cine images from a single slice may not be adequate to reveal the 3D cardiac motion. In this study, we propose to use a motion curve calculated from biplane cine scans to identify the subject-specific time window for coronary MRA. The method provides an objective way to identify the quiescent phase in a cardiac cycle with minimal user dependency.

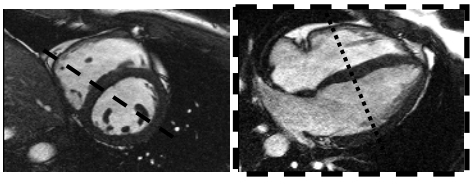

Figure 1. One of the 40 phases of biplane cine images acquired with reduced FOV within one breath-hold. Imaging planes were planned as indicated by dashed and dotted lines.

Method Retrospectively gated cine images were acquired from orthogonal biplanes (four-chamber and short-axis views). The cine images had reduced FOVs to minimize non-cardiac related signals and oversampling was used to avoid aliasing (Figure 1). A "motion" curve tracking the cardiac motion from each view was derived by calculating the sum-of-square of the pixel-by-pixel signal intensity difference in two adjacent phases. Multiplication of the two curves (each normalized to its own maximum values) from the two cine views provides a global index of the heart motion: the smaller the index, the more stationary is the heart at that cardiac phase. All calculations were performed offline using Matlab. No image cropping or segmentation (5) was involved. The minima towards the end of the cardiac cycle represent the diastolic phase of the cardiac cycle (e.g., time window b in the left image of Figure 2).

Validation: The proposed method was validated by retrospectively correlating the quality of coronary artery images acquired at various TDs to the motion curve derived from the cine scans. Four healthy volunteers were scanned on a 1.5T Siemens whole-body scanner. For each subject, retrospectively gated cines (40 phases) were acquired from the short-axis and 4-chamber views within one breath-hold. Typical imaging parameters for cine acquisition were 144×200 mm^2 FOV, spatial resolution = 1×1×6 mm^3, 60° flip angle, parallel imaging (GRAPPA) factor = 2. The right coronary artery was imaged multiple times with TDs gradually increased from about 50% of the R-R interval to the maximum possible value within the cardiac cycle with a 50 msec step size. The image quality was blindly graded by a reviewer on a scale of 1 to 4 (1 = best, 4 = worst). An ECG-triggered, navigator-gated, T2-prepared, segmented SSFP sequence was used for coronary MRA with 1×1×1 mm^3 spatial resolution. Other parameters included: TR/TE = 4.1/1.7 msec, 21 lines/heart beat, centric phase-encoding, flip angle = 90°.

Results Figure 2 illustrates a typical motion curve and coronary artery images acquired at various time windows of the curve. The RCA is best depicted in image b, corresponding to the minimum motion in the motion curve (time window b). Image quality of the coronary arteries is well correlated to the motion curve, as shown in Figure 3. Minimal motion and the best image quality were observed around 75% of the R-R interval for these four volunteers. Exemplary coronary images acquired from the subject-specific optimal data acquisition window (determined from corresponding motion curves in Figure 3) are illustrated in Figure 4. The RCA is well depicted for each of these subjects. The distal portion and small branches are clearly visible as indicated by arrows in the figure.

Discussion The results showed that the optimal timing for coronary MRA can be predicted by a motion curve derived from a biplane cine scan in healthy volunteers. The need for visual assessment of cine images is eliminated, which minimizes user-dependence. This method provides an objective way to accurately identify the diastolic phases of a cardiac cycle needed for coronary MRA. Implementation of online processing software for the cines will allow automatic generation of the motion curve and determination of optimal trigger delay.

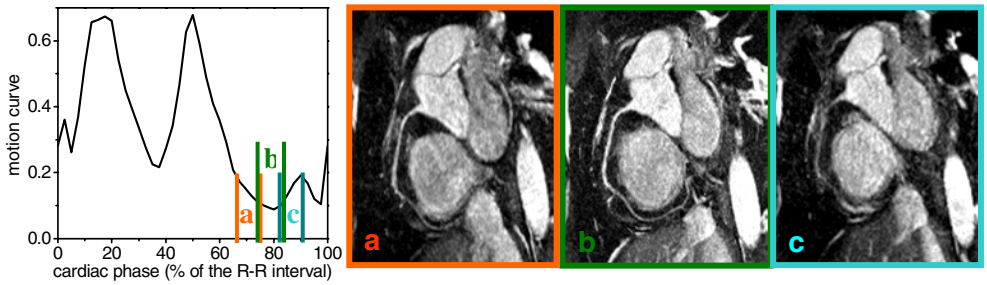

Figure 2. Motion curve of a volunteer indicates that minimal 3D cardiac motion is expected around 78% of the R-R interval. RCA image acquired in this time period (b) shows the best quality as compared to images (a) and (c), acquired before and after this time window, respectively, as indicated in the motion curve.

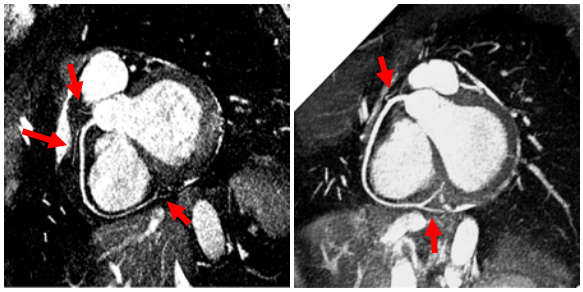

Figure 4. RCA images of two subjects acquired from the optimal time windows determined from Fig. 3. Note that the RCA is well depicted for each subject, with distal portion and small branches visible as indicated by the red arrows.

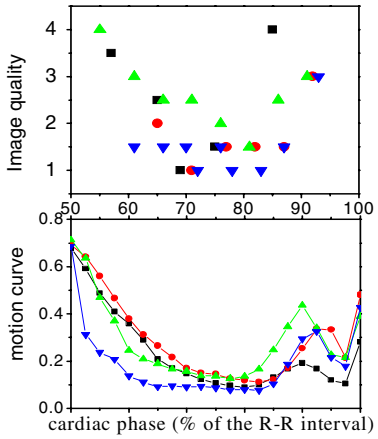

Figure 3. Image quality (1 = best, 4 = worst) from four volunteers shows close correlation to the corresponding motion curves. Best image quality and cardiac motion are observed around 75% of the R-R interval for these four volunteers.

References 1. Wang Y. et. al. Radiology 213: 751-758, 1999. 2. Stuber M. et. al. Radiology 212: 579-587, 1999. 3. Hofman MBM. et. al. JMRI 8: 568-576, 1998. 4. Weber OM. et. al. MRM 50: 1223-1228, 2003. 5. Lorenz CH. et. al. Proc. 13th ISMRM, p. 2170, 2005.