Single Heart Beat Coronary Artery Imaging Provides Direct Assessment of Respiratory Motion Compensation Methods

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Introduction: We have developed a very fast radial coronary artery imaging method providing 1.8 x 1.8 mm resolution in a single heart-beat (150 ms window). Our goal was to use this technique to evaluate the position of the coronary artery during each mid-diastolic rest-period, during navigator-gating and tracking. We analyzed real-time targeted right coronary artery (RCA) images acquired in single heart-beats during free-breathing and calculated the subpixel translational in-plane shifts of the cross-sectional LAD, and the in-plane RCA. The resulting movies and measurements reveal the residual respiratory motion extant using a standard navigator-gating and tracking scheme. 3D coronary artery imaging using navigator approaches has shown great promise (1,2,3). To improve the navigator-gating method, investigators have introduced real-time slice tracking (4), studied the importance of temporal proximity of the navigator to the acquisition window (5), studied inter-subject variability of the tracking ratio (6), employed direct monitoring of the heart with navigators (7,8), even demonstrated the possibility of Affine motion models (9). A typical navigator protocol uses a pencil-beam excitation on the right hemi-diaphragm to monitor respiratory position. A 5mm acceptance window is used, with real-time adaptive slice-tracking, using a 0.6 ratio between the motion of the heart and the diaphragm (10). While this is among the most common approaches, motion artifact persists. Previous comparisons of respiratory motion compensation schemes relied on comparison of 3D coronary images, acquired over multiple cardiac and respiratory cycles (5, 6, 9). We present a more direct approach, by imaging the coronaries in a single heart-beat.

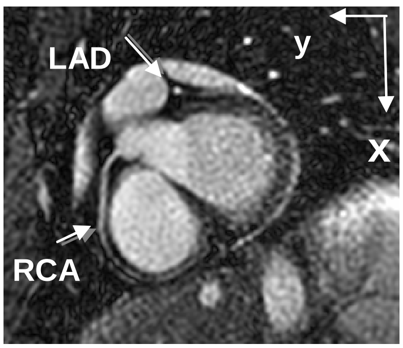

Figure 1: This 2D image of the RCA was acquired during 150 ms of a single heart beat, with 1.8 x 1.8 x 8 mm resolution.

Methods: Scanning was performed on Philips 1.5T Gyroscan ACS-NT (Philips Medical Systems, Best, NL). The real-time sequence was a 2D radial SSFP acquisition with 192 readout points, 36 cm FOV, and 48 projections. The TR/TE/θ= 3.2ms/1.6ms/90º. Spatial resolution was 1.8 x 1.8 x 8 mm, zero-filled to a pixel size of 1.4 x 1.4 mm x 8mm. The diaphragmatic positions measured by the navigator were logged. In order to create contrast between coronaries and the surrounding tissues, fat suppression and T2prep pulses were applied before the mid-diastolic acquisition window. From 30 to 100 frames of the RCA were acquired during navigator-gating and tracking, using a navigator to accept all diaphragmatic positions (i.e. a 100 mm acceptance window), with a 0.6 slice-tracking ratio. By acquiring images at all diaphragmatic positions, the motion for any navigator-acceptance window can be determined. Seven healthy subjects were imaged during free-breathing, and during 20 second breath-holds. Using Matlab, the single-beat RCA images were processed to obtain the in-plane shifts, in pixels. Shifts were calculated using cross-correlation methods similar to (11), with small ROIs around the left anterior descending (LAD) and RCA coronary artery.

Results: Figure 1 shows a single-beat coronary image, showing excellent visualization of the RCA and cross-sectional LAD. The presence of residual motion of the coronaries is visually very clear in each volunteer by viewing the cine loop. Figure 2 shows LAD measured translations in "x" (foot-head direction, see Fig. 1) for 3 subjects (color-coded), plotted against diaphragm position which was logged for each frame. Measured RCA translations were of similar magnitude. The average translational shift is 0.65 mm over the typical 5mm acceptance window, compared to average 0.15 mm measured by our technique for subjects during breath-holding (or see Ref. 12).

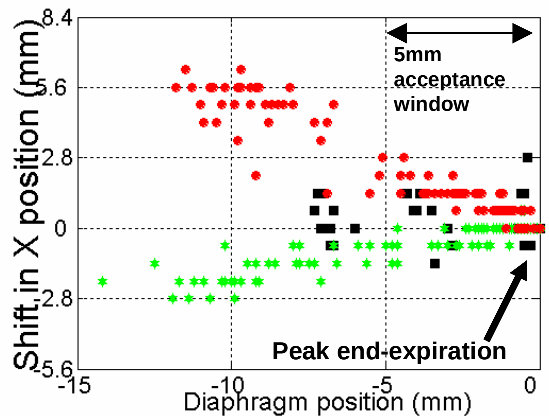

Figure 2: Measured translation of the LAD (x-direction) vs. diaphragmatic position, during free breathing and navigator gating and slice-tracking. Results from 3 subjects (color coded) are shown.

Conclusions: This novel coronary artery imaging protocol allows assessment of residual coronary artery motion and thus provides a test for navigator accuracy. Further investigation is necessary to determine whether small residual motion shown in Fig. 2 impacts 3D coronary artery image quality, and how it compares quantitatively to motion incurred during breath-holding, or the residual cardiac motion due to a finite acquisition window. This approach may allow determination of patient specific tracking factors in an additional short preparation phase.

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