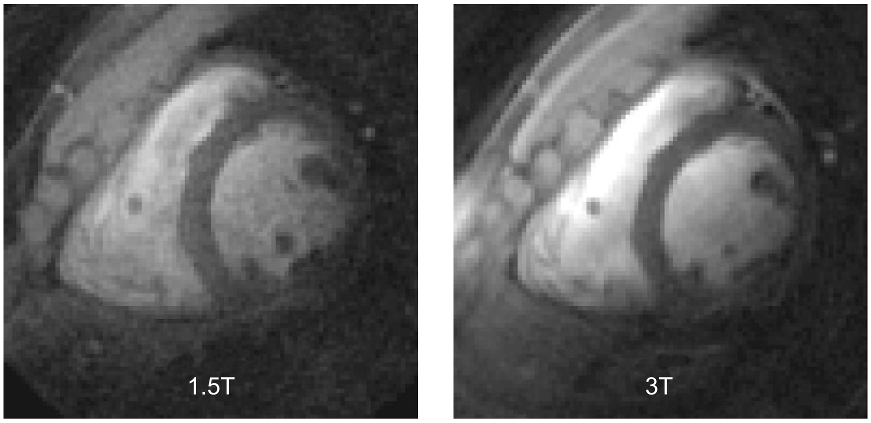
Image Comparison:



3T real-time coronary images:

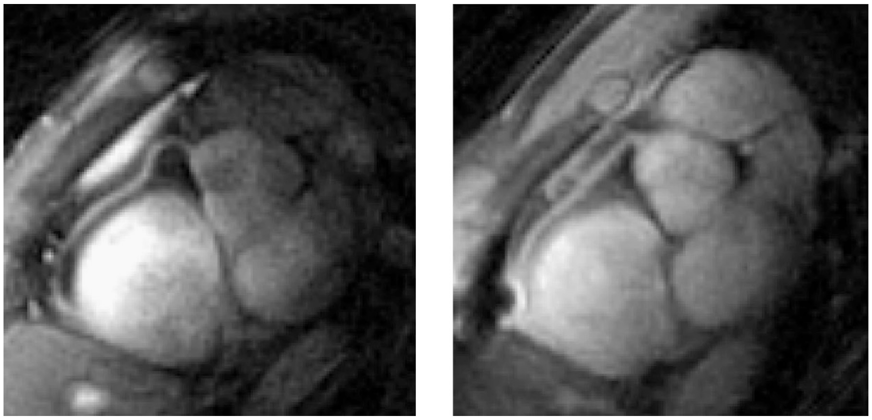


Figure 1.

3T is feasible, and is advantageous due to the increased SNR and increased blood-myocardium contrast.

548. Respiratory Motion of the Heart: Translation, Rigid Body, Affine, or More?

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Introduction: Three dimensional MR coronary imaging requires scan times longer than possible breath-hold durations. Respiratory motion compensation can be used to increase scan efficiency, reduce exam duration, and improve image quality. Previous studies of respiratory motion of the heart using MRI have been limited by the use of breath-holding, the use of 2D imaging for real-time acquisitions, or data averaging over multiple breathing and cardiac cycles for 3D free breathing studies (Danias, 1999; Manke, 2002; McLeish, 2002; Wang, 1995).

Purpose: To characterize the motion and deformation modes of the coronaries during spontaneous tidal breathing. X-ray imaging provides the high temporal and spatial resolution images necessary for this study. The motion is analyzed in the context of three 3D MR motion correction techniques: 1) translation; 2) rigid body (translation+rotation); and 3) affine (rigid body+shear+scale).

Methods: Biplane x-ray coronary angiograms were obtained in nine patients. We captured natural respiratory motion by not giving patients any breathing instructions. A three dimensional+time model of the coronary arteries was generated from the cine-angiograms using stereo reconstruction and automatic motion tracking techniques (Shechter, 2003).

Diastasis images nearest to end-inspiration (EI) and end-expiration (EE) were identified in each

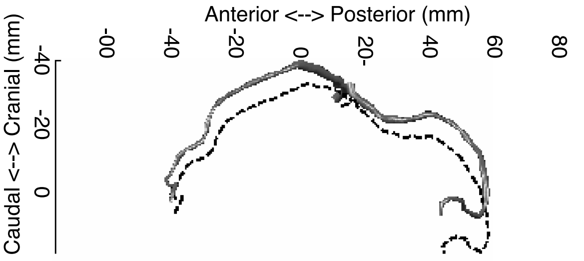

Figure 1. Position of the left coronary tree at EE (solid model) and EI (dotted lines) for patient P2. (*View this art in color at www.dekker.com.*)

dataset. Displacement of the diaphragm as seen in the images provided a measure of respiratory phase. To quantify the magnitude of the respiratory motion, a 3D RMS distance (e_{3D}) was computed between the EI and EE coronary models for each patient.

The two trees were registered to each other using each of the 3D motion models and residual errors (e_T, e_R, e_A) were computed. The residual errors are the e_{3D} between the two coronary models after optimal registration.

Results: The left coronary tree was studied in nine patients. The mean length of the reconstructed left coronary tree was 26±6 cm. The selected images spanned 56–99% (mean = 82%) of the respiratory cycle. The maximum difference in cardiac phase between an EE–EI image pair was 2.2% (22 ms for a heart rate of 60 beats/minute). This suggests that the motion we measured is not due to the cardiac contraction (Figure 1).

The mean e_{3D} was 6.1±1.8 mm (range = 3.8–9.7 mm). 3D translation accounted for 66±19% of the motion (range = 33–83%); the rigid body transformation for 81±15% (range = 46–93%) of the motion; and the affine deformation for 86±14% (range = 51–94%) of the motion (Table 1).

Table 1. Results for the left coronary tree.

Patient	Percent of respiratory cycle (%)	e_{3D} (mm)	e_T (mm)	e_R (mm)	e_A (mm)
P1	78	4.7	0.8	0.7	0.4
P2	56	6.2	4.1	1.9	1.4
P3	63	5.7	3.6	3.1	2.8
P4	84	7.7	3.1	1.0	0.6
P5	80	3.8	1.1	0.4	0.3
P6	93	9.7	1.7	1.1	0.7
P7	90	4.6	1.3	1.0	0.6
P8	97	6.9	1.2	0.5	0.4
P9	99	5.2	1.2	0.6	0.4

The majority of the tidal respiratory motion can be explained by a 3D translation. However, correcting the translation alone reduced $e_{3D} \leq 1$ mm in only 1/9 patients. Using a rigid body transformation, $e_{3D} \leq 1$ mm in 6/9 patients. Affine correction provided $e_{3D} \leq 1$ mm in 7/9 patients.

The respiratory motion of the left coronary tree in two patients demonstrated significant local deformations, such that none of the tested motion models was able to reduce $e_{3D} \leq 1$ mm.

Conclusions: Tidal respiratory motion of the coronary arteries was measured from x-ray angiograms. In 6 of 9 patients, a rigid body transformation was sufficient for explaining the motion of the coronary tree (3D RMS error ≤ 1 mm) over a significant portion (mean = 82%) of the tidal respiratory cycle. The more complex affine deformation model adds one more patient to this group.

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549. Validation of a Single Breath Hold Three-Dimensional Projection Reconstruction Steady-State Free Precession Magnetic Resonance Imaging Method for Cardiac Function Evaluation

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Introduction: Steady-state free precession (SSFP) imaging has emerged as the clinical magnetic resonance (MR) standard for characterizing cardiac function. Most techniques use two-dimensional (2D) Cartesian encoding and require repeated breathholds for full cardiac coverage, resulting in ~7–12 minute exam