Respiratory motion of the heart: Implications for magnetic resonance coronary angiography

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Magnetic resonance (MR) coronary imaging is susceptible to artifacts caused by motion of the heart. The purpose of this thesis was to study the respiratory motion of the coronary arteries and to use the results to develop strategies for improved MR imaging. The first section of the thesis describes a MR motion correction technique for objects undergoing a 3D affine transformation. The remainder of the thesis focuses on measuring the respiratory motion of the heart from free breathing x-ray angiograms. Stereo reconstruction methods are used to generate 3D models of the arteries from biplane angiograms. A method for tracking the motion of the arteries in a sequence of biplane images is presented next. The algorithm uses 3D regularizing constraints on the length changes of the arteries and on the spatial regularity of their motion. The algorithm was validated using a deforming vascular phantom. RMS 3D distance errors were measured between centerline models tracked in the x-ray images and gold-standard models derived from a gated 3D MR acquisition. The mean error was 0.69 ± 0.06 mm for four different orientations of the x-ray system. The motion field recovered from free breathing angiograms is a combination of the cardiac contraction and respiratory motion of the heart. A cardiac respiratory parametric model is formulated to decompose the field into independent cardiac and respiratory components. Results are presented for ten patients imaged during spontaneous tidal breathing. For all patients, the heart translated caudally (mean, 4.9 ± 1.9 mm) and rotated in a cranio-dorsal direction (mean, $1.5° \pm 0.9°$) during inspiration. In eight patients, the heart also translated anteriorly (mean, 1.3 ± 1.8 mm) and rotated in a caudo-dextral direction (mean, $1.2° \pm 1.3°$). Anatomic landmarks were used to compare results across patients. Three dimensional displacements and velocities were compared, and quiescent periods in the respiratory and cardiac cycles were measured. Finally, respiratory motion was analyzed using three linear motion models that correspond to available MR motion correction techniques: translation, rigid body, and affine. Calculations indicate that a two-to-four-fold increase in scan efficiency is attainable, resulting in reduced scan times while maintaining image quality.