Embracing Respiration-Induced Motion in Cardiovascular MRI

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Abstract

Respiratory motion is a well-known complicating factor in Magnetic Resonance Imaging (MRI), especially when imaging elements of the cardiovascular system. Periodic motion of the lungs during the respiratory cycle affects the torso and abdomen, which impacts imaging of the heart, aorta, liver, and other organs and vessels. The resulting motion artifacts, which appear in traditional Cartesian imaging as distinct replicas in the phase-encoding direction, negatively impact the quality of diagnostic information that can be gleaned from MR images. One common way to mitigate motion artifacts in clinical imaging is to instruct subjects to hold their breath for the duration of the acquisition. However, breath-holds can be infeasible for long acquisitions or for subjects who have difficulty holding their breaths. Alternatively, the acquisition can be gated such that data are only acquired during a single phase of respiration, but this can lead to considerable reductions in scan efficiency. Additionally, respiration has important physiological consequences, and there is merit to exploring the impacts of respiration and respiration-induced motion on the cardiovascular system.

In this thesis, I seek to implement and optimize methods for not only mitigating the effects of respiration in cardiovascular MRI, thereby enabling otherwise impossible imaging, but also to utilize information from the respiratory cycle to improve data efficiency, reduce scan time, and extract valuable diagnostic information. This will be performed in three different scientific contexts, each focusing on a different anatomical region: (1) validation and improvement of radial 2D Phase Contrast (2DPC) MRI for measuring pulse wave velocity in the aorta with sequential and simultaneous multi-slice acquisitions; (2) acceleration of the acquisition of radial, free-breathing 4D flow MRI in the portal venous system; and (3) implementation of a 5D MRI approach for resolving cardiac and respiratory motion of the heart in radiation therapy treatment planning.