

Cartesian Undersampling and Two-Point Fat-Water Separation for Dynamic Contrast Enhanced Magnetic Resonance Imaging and Angiography

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High temporal resolution is needed in time-resolved (i.e. dynamic) magnetic resonance imaging (MRI) to depict the rapid movement of blood from arteries to veins and through the capillary beds to the tissues. High spatial resolution is necessary to delineate small arteries and small lesions. However, the inherent compromise between resolution and time in MRI makes satisfaction of both temporal and spatial resolution requirements challenging. The primary purpose of this research is to advance rapid angiography of the lower extremities and perfusion imaging and angiography of the abdominal cavity by developing novel acquisition and reconstruction techniques. In clinical applications, confounding factors including presence of fat, blood flow and patient breathing motion make dynamic imaging problems even more difficult. Of these confounding factors, the relationship between flow and fat-water separation is also studied in detail.

Improvements are presented to help mitigate transient-state imaging artifacts and double the temporal update rate for dynamic Cartesian acquisitions. An imaging protocol using a modified Cartesian IVD subsampling pattern, coupled with constrained reconstruction, was used for performing MRA on a population of patients referred for vascular intervention and the imaging results were compared against the standard-of-care MRA method and the x-ray DSA method. A modified scheme for acquisition of parallel imaging auto-calibration lines was introduced and was used with the IVD undersampling and with real-time triggering, to enable rapid imaging of the liver. It was also shown that accurate contrast bolus timing, near-isotropic spatial resolution and two-point chemical shift fat-water separation can facilitate the acquisition of simultaneous abdominal MRAs without the need for another contrast injection. A new type of flow-induced fat-water misallocation artifact was discovered and was theoretically characterized. The theoretical explanation was tested using phantom experiments and in vivo clinical data. The study was used to show the confounding effects of flow when fat-water-separated methods were used for MRA. In conclusion, the work described in this dissertation has improved the MRI technology for angiography of lower extremities and for dynamic imaging of the abdomen.