High field steady state MR imaging: Advanced acquisition & reconstruction methods

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Fully refocused steady state MR imaging is primarily used in protocols requiring high signal and acquisition speed, but only modest resolution. This work aims to exploit the high signal-to-noise (SNR) of these methods for applications that require high resolution. The combination of the Steady State Free Precession (SSFP) method with a rapid 3D radial trajectory to accelerate acquisition and reduce susceptibility artifacts has been the anchor of this work. Three acquisition strategies have been developed, incorporating both fat-suppression and fat/water separation variations on the SSFP method, to simultaneously acquire data and eliminate fat signal for improved image contrast. The bulk of this work has been performed with the Linear Combination SSFP (LC-SSFP) fat/water separation method. This sequence has been clinically evaluated for whole knee joint assessment at 1.5T relative to conventional MR sequences in more than 3000 patients, with arthroscopic correlation for 100 patients. At 3.0T, additional evaluation relative to emerging and conventional MR sequences as well as the current MR knee cartilage protocol has been performed in more than 300 patients. In each study, the sequence was found to perform at least as well as, and in most cases better than, the emerging and conventional MR sequences and protocols all while providing an accelerated acquisition. These studies indicate that with the use of 3D radial LC-SSFP, the standard 25 minute knee exam may be reduced to just 5 minutes, allowing time for scans that are sensitive to cartilage changes prior to volume loss.

The resultant high quality knee joint images feature isotropic resolution as high as 0.47-mm at 1.5T and 0.33-mm at 3.0T. More recently the Fat-Suppressed and Multi-Acquisition Fat/Water Separation Alternating TR (ATR) SSFP methods have been developed to advance work at 3.0T to achieve knee joint images with 0.29-mm isotropic resolution and consistent fat suppression across relevant structures.

Finally, application of the 3D radial LC-SSFP sequence at 1.5T has been extended beyond musculoskeletal applications to Non-Contrast Enhanced MR Angiography (NCE MRA) in the abdomen, specifically to renal and thoracic vasculature, through the addition of a novel real-time adaptive respiratory-gated method.