Dynamic Contrast Enhanced IDEAL with Parallel Imaging

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Introduction: High quality, homogeneous fat suppression is critical for dynamic T1-weighted spoiled gradient recalled echo (SPGR) acquisitions following injection of contrast. Fat-suppression approaches for SPGR include spectrally selective fat-saturation RF pulses and water-selective RF pulses. Unfortunately these methods are sensitive to both B0 and B1 inhomogeneities. Iterative 'Dixon' water-fat separation with Echo Asymmetry and Least-squares estimation (IDEAL) (1) provides excellent separation of fat and water signals despite the presence of B0 and B1inhomogeneities. However, application of this technique to dynamic contrast enhanced imaging has been limited by the requirement that three images must be collected with different fat-water phase shifts, tripling acquisition time relative to equivalent non-IDEAL acquisitions. The increased time, coupled with the necessity in dynamic imaging to acquire data during a narrow time window, restricts the spatial resolution and/or anatomic coverage achievable with IDEAL.

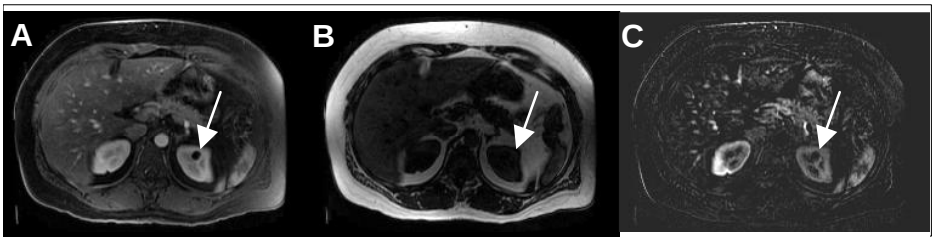
Parallel MRI (2, 3) and IDEAL are complementary methods. IDEAL imaging has high inherent SNR (equivalent to a 3 average scan) (1), sufficient to compensate the majority of the SNR loss incurred when using a parallel MRI acceleration of three. Thus IDEAL images acquired with an acceleration of three have no SNR or scan time penalty, relative to the equivalent non-IDEAL image. IDEAL also preserves the information on fat content, a desirable secondary feature that may be clinically relevant for characterization of fat containing lesions.

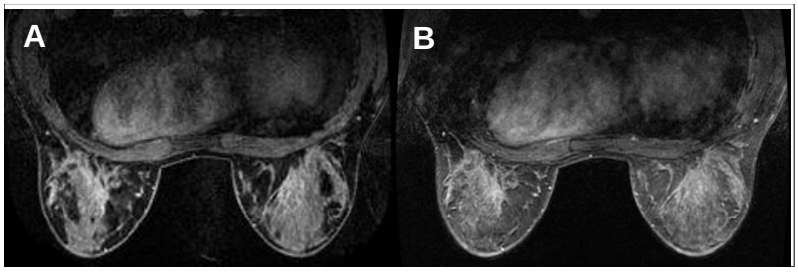
In this work we combine IDEAL, Spoiled Gradient Recalled Echo (SPGR) imaging, and parallel MRI to obtain dynamic T1 weighted images in the abdomen and breast following intravenous injection of a contrast agent.

Methods: We obtained dynamic contrast enhanced images of the abdomen (n=4) or breast (n=4) from asymptomatic adult volunteers. The study was approved by the site IRB and written consent was obtained from all volunteers. We performed all scans on a GE 1.5T Twin-Speed MR system (GE Healthcare, Milwaukee, WI, USA) using an 8element body array or a 4 element breast coil.

We acquired 3D-IDEAL-SPGR images from axial volumes through the liver and kidneys (TR=6.9 ms, TE=1.9,3.5,5.4 ms, BW=±90 kHz, flip=20°, 6 mm slice, 32 cm FOV, 256×160 matrix, 32 slices, 24 s breath hold) or breast (TR=8.5ms, TE=2.0,3.6,5.2ms, flip=10°, BW= ± 62kHz, 256x256, 3mm slice, 30-36cm FOV, 120s acquisition). Images were accelerated twofold in the abdomen and threefold in the breast. Parallel MRI reconstructions were performed using ASSET (Array Spatial Sensitivity Encoding Technique). In the abdomen, images were acquired prior to contrast injection and during the arterial, and portal venous phases after intravenous bolus injection of 0.1 mM/kg of Magnevist (Berlex Laboratories, Wayne, NJ). To facilitate comparison, fat saturated SPGR (fs-SPGR, TR=4.9 ms, TE=2.3 ms, BW=±42 kHz, flip angle=15°, other parameters same as IDEAL-SPGR) images were acquired immediately before the precontrast IDEAL image and immediately after the venous IDEAL image. In the breast, images were acquired pre-contrast and at 1,3,5,7 and 9 minutes following bolus injection of 0.1 mM/kg of Magnevist. Comparison was made with fat saturated SPGR images (TR/TE/flip=7.4ms/4.2 ms/10°, BW= ± 31kHz, 256x256, 3mm axial slice, 30-36cm FOV, 120s acquisition) that were acquired immediately before and after IDEAL imaging.

Results: Figure 1 shows examples of IDEAL abdominal images. The lesion seen in the kidney (arrow) has low signal in both water and fat images, does not enhance, and can be confidently diagnosed as a simple renal cyst. This lesion could be diagnosed as a cyst without having a T2 weighted image, demonstrating the utility of preserving the fat information in the dynamic SPGR imaging. In the fat image, there is also signal in the liver, indicating mild fatty infiltration of the liver. This too would have required an additional scan, such as an in+out of phase gradient echo imaging. Fig. 2 shows examples of dynamic breast imaging. Fig. 2A shows a peak contrast water only image and Fig. 2B shows the corresponding fs-SPGR image. The tissue-fat contrast of the IDEAL-SPGR water image is superior to the fs-SPGR due to robust fat-suppression with IDEAL-SPGR. This was typical of IDEAL vs. fs-SPGR comparisons.





Discussion: We have demonstrated the feasibility of combining self-calibrated parallel imaging with IDEAL water-fat separation. SNR losses from the parallel reconstruction are mitigated by SNR gains from the efficient IDEAL acquisition. This makes the two methods complementary and allows the final accelerated IDEAL images to be of high quality.

Conclusion: The combination of IDEAL fat-water separation and parallel imaging (R=3) produces dynamic contrast-enhanced water images with no time penalty and improved water-fat contrast compared to fat suppressed methods. In addition, the method simultaneously produces fat images that can provide additional clinical information and potentially eliminate the need for other scans in the imaging protocol.

References: 1. Reeder et al, MRM, 2004, 51:35-45. 2. Sodickson McKenzie. Med Phys 2001;28:1629-1643. 3 Pruessmann et al, MRM 1999 42:952-62.