Neuroimaging with INSIDIR: Integrated Single Inversion and Double Inversion Recovery

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TARGET AUDIENCE: Physicists interested in T1-weighted imaging methods, and researchers and clinicians interested in studies of gray matter.

PURPOSE: Double inversion recovery (DIR) methods are promising methods to obtain gray matter (GM) only images in the brain by simultaneously nulling white matter (WM) and cerebrospinal fluid (CSF)[1-3]. DIR methods are being used to detect and investigate cortical lesions in multiple sclerosis (MS), and are promising for characterizing subtle cortical and hippocampal GM pathology[4,5]. Unfortunately, the prohibitively long acquisition time and associated cost increase has prevented its routine use in many clinical settings. Finally, the effectiveness of the DIR is also influenced by the T1 of the WM, which is highly sensitive to age, myelination and pathology. *The purpose of this work is to investigate a novel and efficient DIR method INSIDIR (Integrated Single and Double Inversion Recovery) that simultaneously obtains single IR and double IR image images in a single acquisition.*

THEORY: DIR methods work by applying two 180° inversion pulses with timing such that both WM and CSF are simultaneously nulled (1-3). Acquisition of DIR image data occurs after the second inversion pulse (applied ~2200-2600 ms after the first pulse) with the center of k-space being sampled near the double inversion nulling condition (~350-500 ms after the second RF pulse). To improve the efficiency of the acquisition, the INSIDIR method collects image data both before and after the second inversion pulse. Imaging is possible after the first inversion pulse by switching from a fast spin echo (FSE) sequence traditionally used for DIR to a spoiled gradient echo acquisition. Now the longitudinal magnetization after the first inversion recovers with a modified relaxation rate T1*, determined by the identity cos(alpha)*exp(-TR/T1)=exp(-TR/T1*). Imaging during this period may be performed using either MP-RAGE, MP-2RAGE, or the recently introduced MP-nRAGE technique. Images during this period will produce "conventional" T1-weighted (T1w) images where at maximum a single T1 species is nulled, while the data collected after the second inversion pulse provides an image with DIR image contrast. To further increase the efficiency, sensitivity and flexibility of INSIDIR, imaging data in this abstract was collected using 3D radial k-space sampling (VIPR), similar to a previously described single IR MP-nRAGE method[6], which generates a large number of high resolution, volumetric images with different T1w contrasts in a single exam by view sharing along the IR curve.

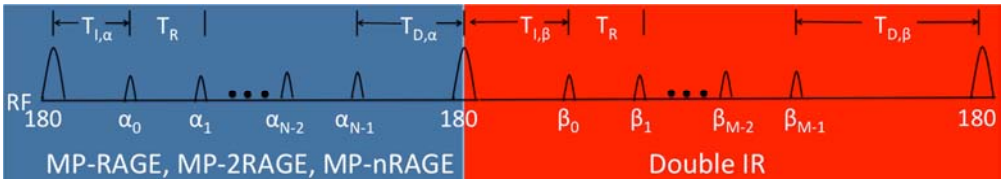

Fig 1. Timing schematic for INSIDIR. The blue region is the single IR portion and red is the double IR.

METHODS: An inversion-recovery spoiled gradient echo acquisition sequence was modified to apply two adiabatic inversion pulses at different rates and to collect data using radial k-space sampling. After the first inversion pulse and a short delay, N radial projections with flip angle α were acquired. After the second inversion pulse, M radial projections with flip angle β were acquired. A delay after the DIR acquisition was added to allow further recovery of the longitudinal magnetization. For both single and double IR acquisitions, angular interleaving was performed so that the projections were roughly uniformly distributed using any subset along the relaxation recovery curve. A sliding window reconstruction was used to combine data across a range of inversion times[6]. The VIPR-INSIDIR method was applied to a 3T brain study of a healthy adult male with informed consent. A 32-channel, receive-only head coil was used.

PARAMETERS for the INSIDIR exam were: FOV=240 mm x 240 mm, slab thickness 160 mm, acquired resolution = 1.0 mm x 1.0 mm x 1.0 mm, SPGR TR = 5.1 ms, and TE = 1.8 ms. 20 ms after the first inversion pulse, SPGR data was collected for 2500ms with N=478 α = 3° pulses. The DIR SPGR data begin 20ms after the second inversion pulse and lasted another 2500 ms with M=478 β = 4° pulses. The entire double acquisition was repeated 3725ms after the second inversion pulse. The total acquisition time was roughly 11.5 minutes.

RESULTS: Select frames as a function of inversion time for the first (single) IR (SIR) portion and the second (double) IR portion are shown in Fig 2. The SIR frames illustrate the broad spectrum of contrasts including frames that correspond to the null pointes of WM, GM, and CSF, as well as intermediate null frames and frames that appear similar to standard T1w MPRAGE. The DIR frame illustrates dual nulling contrast.

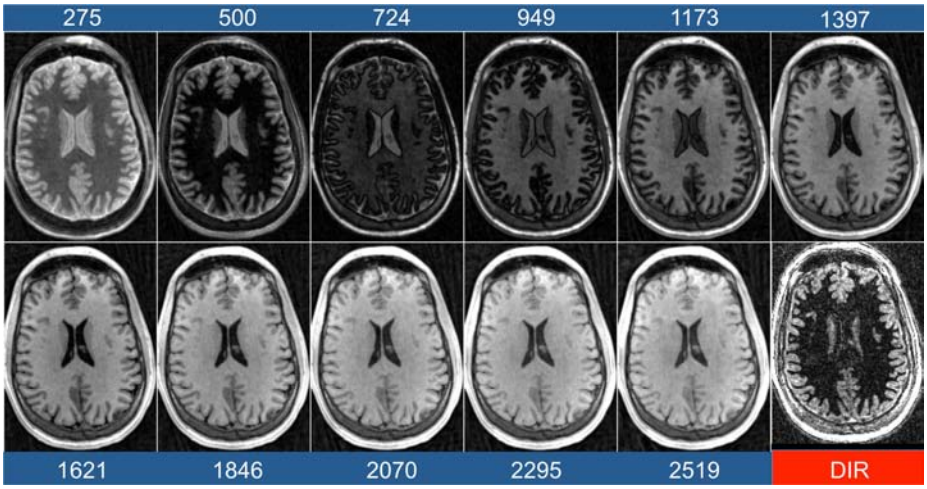

Fig 2. Representative IR=weighted images for SIR and the double IR frame generated from a single 11 minute INSIDIR scan.

DISCUSSION AND CONCLUSION In this preliminary work, we demonstrated a novel method for simultaneous acquisition of single and double inversion recovery contrasts that provide both a spectrum of standard T1w images as well as dual nulled images for gray matter specific imaging. While the 3D radial acquisition has advantages for providing multiple simultaneous T1w contrasts, the method could be easily extended to standard Cartesian imaging to obtain a T1w MPRAGE and a DIR scan in a single acquisition. Parallel imaging may be used to decrease scan times further. Future studies will investigate the application to cortical pathology including MS.

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