Tissue Border Enhancement by Inversion Recovery Acquisition

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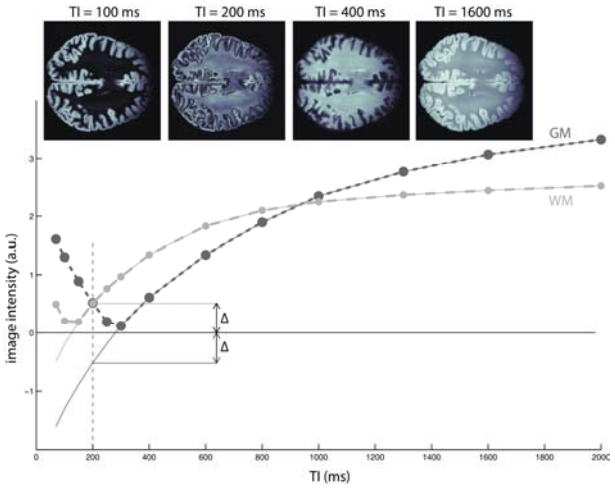
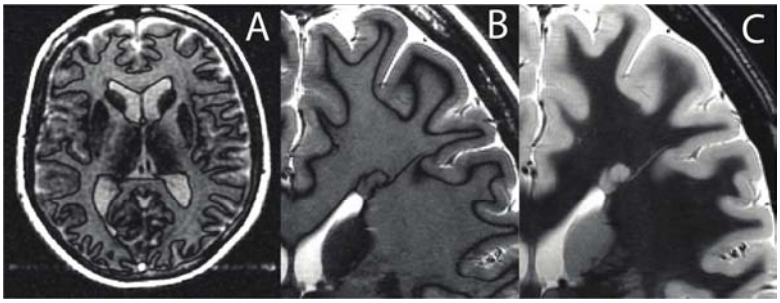
Target Audience: Radiologists and MR-system operators in the clinical practice; researchers interested in morphometry and segmentation techniques.

Purpose: This study presents an Inversion Recovery (IR) technique for immediate, enhanced visualization of borders between two tissues of interest without any additional post-processing.

Methods: Inversion recovery preparation in gradient echo imaging is often used to suppress fat by using a short inversion delay (STIR, [1]) or cerebrospinal fluid by using a long inversion delay (FLAIR, [2]). By varying the inversion time TI, it is possible to obtain images with different contrasts, which depend on the different values of the magnetization of each tissue for that TI, as shown in the four examples depicted below, where the same slice of an ex-vivo human brain was repeatedly acquired by varying the TI and keeping all other parameters constant: Repetition Time (TR) = 3000ms, Echo Time (TE) = 10ms, Bandwidth (BW) = 31.3KHz, Field of View (FOV) = 160x160 mm^2, slice thickness = 2 mm, matrix size = 128x128. Data were acquired with a GE MR950 7.0 T system (GE Healthcare, Milwaukee, WI, USA) equipped with a two-channel transmit/receive birdcage coil (Nova Medical, Wilmington, MA, USA). If the TI is chosen such that two neighboring tissues have longitudinal magnetization with equal magnitude but opposite sign at the time of the excitation pulse, voxels containing an equal mixture of each tissue will have no net signal. In this study we employ **appropriate TI in order to enhance the border between two tissues of interest**, and demonstrate its feasibility on MRI systems at both standard (1.5 T) and ultra-high (7.0 T) static magnetic field. At one specific value of TI (in our example, TI = 200 ms) the border between gray matter (GM) and white matter (GM) results enhanced and clearly represented by a dark line. This phenomenon is explained in the plot to the left, where each dot displays how image intensities for representative voxels GM and WM vary with TI. Data was polarity-restored to represent, in thin lines, the transverse magnetization of the two tissues. At TI = 200 ms the magnetizations of GM and WM have approximately the same magnitude Δ (hence the two tissues possess the same image intensity) however their signs are opposite. This means that, ideally, one voxel that contains 50% of WM and 50% of GM possesses an average magnetization that is approximately zero. If the proportion of the two tissues within the same voxel is not 50%-50%, the signal will be non-zero, yet it will be smaller than that of voxels covering pure GM or WM. As a consequence, the interface between the two adjacent tissues results highlighted by a dark line in the image. We will refer to this phenomenon as Tissue Border Enhancement (TBE), and optimal TI for TBE can be easily calculated as explained above, for each couple of tissues of interest.





Results: TBE images of living human volunteers, as well as ex-vivo samples, were acquired at both ultra-high field (7.0 T, see above) and standard systems (1.5 T, Signa HDxt equipped with a HD 8ch Hi Res Brain Array by Invivo Corporation, Gainesville, FL, USA), and examples are shown to the right. The slice depicted in Panel A was acquired from one healthy volunteer at 1.5 T: all imaging parameters were the same to those employed at 7.0 T, except for TR, which was decreased to 2000ms to reduce scan time, and FOV (20x20 cm^2). For this protocol, optimal TI for TBE between GM and WM was 400 ms. In Panel B is displayed a TBE acquisition obtained using a FSE-IR sequence on the 7.0 T system (TR= 4875 ms, Echo Train Length = 9, TE = 7.9 ms, TI = 700 ms, slice thickness = 2 mm, matrix size = 512x512, FOV = 22x22 mm, pixel size = 0.43x0.43 mm), which shows a periventricular cortical heterotopia: the borders of the gray matter nodule with the respect to the adjacent white matter and frontal horn of the left lateral ventricle, as well as the border between cortical GM and WM, result sharper with respect to Panel C, where a TI = 400 ms was used to suppress the contribution of white matter.

Discussion and Conclusion: This study presents an IR sequence that employs appropriate TI to enhance the border between two tissues of interest, and demonstrates that this technique is feasible on both standard (1.5 T) and ultra-high field (7.0 T) MRI systems. The most obvious advantage of this technique is that it allows for immediate, enhanced visualization of borders between two tissues of interest without any additional post-processing procedure, hence "enhanced" images are immediately visible to the neuroradiologist / MR-system operator in real time. Possible applications in the clinical practice include the use of TBE for contour enhancement of small structures of interest as well as the interface between gray matter and white matter, with potentials of improved detection power in cases of cortical atrophy and cortical malformations / dysplasia. Further, combination of images with TBE at WM-GM interface and images with TBE at GM-Cerebro-Spinal Fluid interface may provide optimal input for new, more robust algorithms for anatomical segmentation, brain morphometry and measurements of cortical thickness.

References:

[1] Bydder GM, Young IR. "MR imaging: clinical use of the inversion recovery sequence", *J Comput Assist Tomogr*, 1985:9:659-675
[2] Hajnal JV, De Coene B, Lewis PD, Baudouin CJ, Cowan FM, Pennock JM, Young IR, Bydder GM. "High signal regions in normal white matter shown by heavily T2-weighted CSF nulled IR sequences", *J Comput Assist Tomogr*. 1992;16:506-513