Control of Effective TE for 3D Fast Spin Echo – Image Quality Implications

R. F. Busse[1]

[1]MR Applied Science Lab, GE Healthcare, Madison, WI, United States

Introduction: RARE sequences (e.g. FSE, TSE) acquire multiple echoes per excitation and therefore do not have a single echo time (TE). Contrast is determined by the TE at which the center k-space is acquired, and views are conventionally ordered such that TE is modulated one full period across k-space and therefore may be "scrolled" to control TE_{eff}, the "effective" TE [1]. For 3D-FSE, there is much more freedom to order views along both phase encode directions, however views are conventionally ordered such that a kx-ky or kx-kz plane is acquired in an integer number of echo trains [2]. This causes TE modulation to occur in a single direction and also constrains ky-kz grids to be regular and rectangular. We have developed a new view ordering method that allows TE modulation to be directed along an arbitrary direction (e.g. ky, kz, or kr), and decouples echo train length (ETL) from matrix size and shape, enabling elliptical k-space coverage [3] and partially parallel imaging [4] with a non-separable 2D auto-calibration region. The purpose of this work was to explore several variations of this view ordering technique and to evaluate the impact of view order on image quality.

Methods: *View Ordering Strategies*— Four view ordering strategies were considered. A "Y-Monotonic" strategy (Fig 1a) orders views such that TE is least on one edge of k-space and greatest on the other edge; TE_{eff} may only be controlled by adjusting the ETL. A "Y-Scrolling" strategy (Fig 1b) orders views such that TE varies in the ky direction, but with a full cycle of modulation to allow scrolling of TE_{eff}. An "R-Scrolling" strategy (Fig 1c) orders views so TE variation occurs radially with a full cycle of modulation between the center of k-space and the periphery, also allowing scrolling of TE_{eff}. Finally, an "R-Dithered" strategy (Fig 1d) approaches the center of k-space for some fraction of the echo train, then recedes from the center afterward, with the approaching and receding views dithered; TE_{eff} is controlled by adjusting relative number of views approaching and receding.

Imaging Experiments— The view ordering strategies were implemented for 3D-FSE-Cube with eXtended Echo Train Acquisition (XETA [5,6]). The sequence acquires large 3D matrices in clinically practical scan times using variable flip angle refocusing RF [5-7] and 2D-accelerated autocalibrating parallel imaging (ARC [8]). Human imaging experiments were performed on a GE HDx 3T system. For all acquisitions, TR=2000ms, TE_{eff}=90ms, and matrix=320×320×128. For the Y-Monotonic strategy, only ETL=90 produced the desired TE_{eff}. For the other strategies, images were acquired with three separate ETL values, 60, 90, and 120.

Results and Discussion: Figure 2 compares images acquired with the four techniques using ETL=90. The Y-Monotonic strategy (Fig 2a) produced the highest image quality. Y-Scrolling appeared slightly degraded in comparison (Fig 2b), while R-scrolling exhibited severe ringing artifacts (Fig 2c). The R-dithered strategy had no structured artifacts, but the interleaving of short-TE and long-TE echoes in a dithered, quasi-random fashion, with the TE disparity between neighboring points becoming greater toward the edge of k-space, caused an unstructured, noise-like artifact (Fig 2d). Decreasing the ETL to 60 increased scan time, but did not improve image quality in any of the cases. Increasing the ETL to 120 decreased scan time, but further degraded image quality in all cases.

Conclusion: Although scrolling and dithered view ordering allows TE_{eff} to be controlled independently of ETL, artifacts are lowest and apparent SNR highest with monotonic view ordering. Locking ETL to the input TE_{eff} value, rather than allowing the operator to vary it freely, eliminates a potential source of unintended variation and degradation of image quality.

References: [1] Melki et al JMRI 1991; 1:319-26. [2] Yuan et al JMRI 1993; 3:894-899. [3] Bernstein et al JMRI 2001;14:270-280. [4] Wang et al MRM 2006; 56:1389-1396. [5] Busse et al MRM 2006; 55:1030-7. [6] Busse et al ISMRM 2007 p1702. [7] Mugler et al ISMRM 2000 p687. [8] Beatty et al ISMRM 2007 p1749.

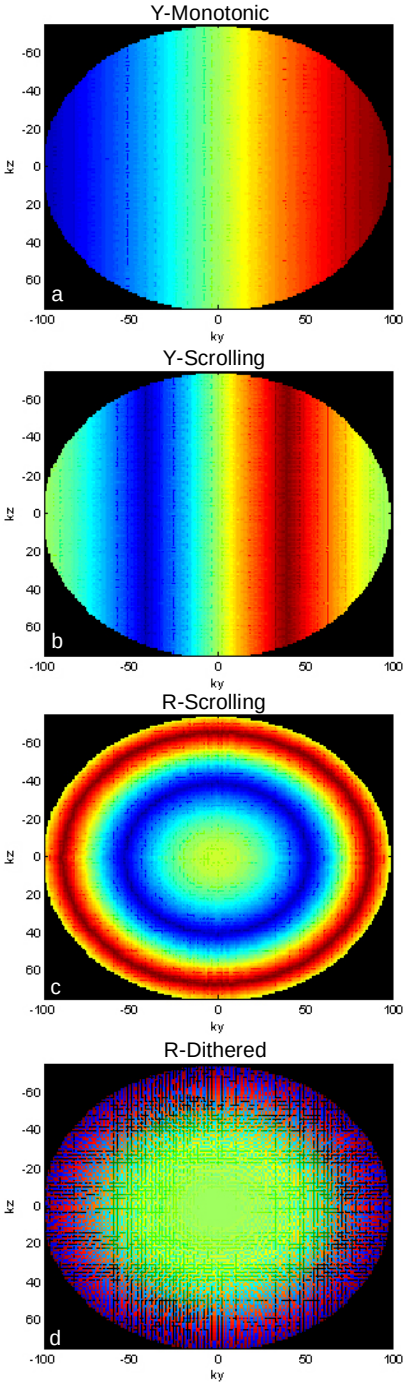

Figure 1: For 3D-FSE sequences, views may be ordered so that TE modulation occurs (a) monotonically in y, (b) full cycle in y, allowing scrolling to adjust TE_{eff}, (c) full cycle in r, or (d) dithered. The earliest echoes are shown in blue and the latest echoes in red.

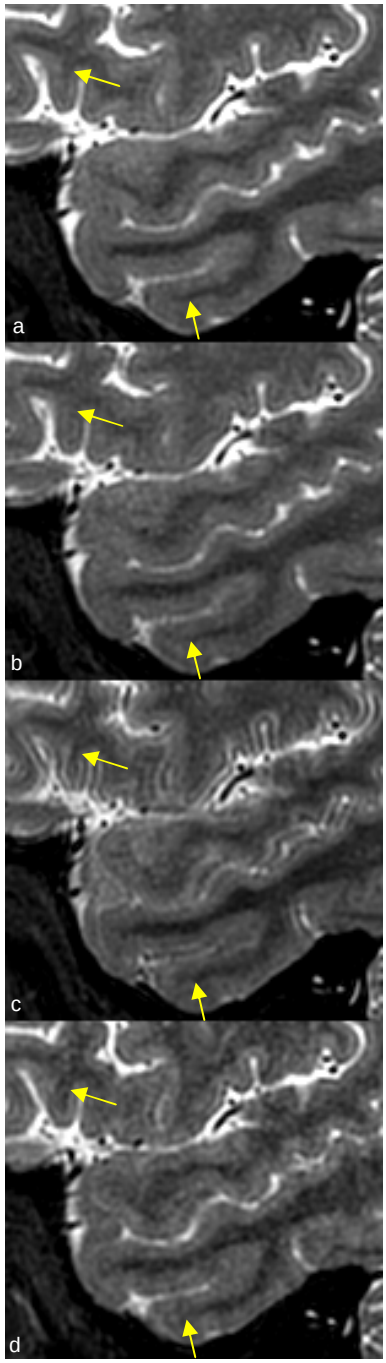

Figure 2: View ordering affects image quality. Highest quality is observed for (a) y-monotonic, compared to (b) y-scrolling, (c) r-scrolling, and (d) r-dithered. Arrows indicate areas were gray-white boundaries are distinct with y-monotonic, but degraded with other strategies.