Comparison of Reduced-FOV Single-Shot EPI Methods for DWI: ZOOM-EPI vs. 2D Echo-Planar RF Excitation

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Introduction: Single-shot EPI (ss-EPI) is widely used for diffusion-weighted imaging (DWI), due to its robustness against motion-induced phase perturbations. However, it is challenging to produce high-resolution DWI images with ss-EPI. Several reduced-FOV methods have recently been proposed to overcome this challenge [1-4]. In this work, we thoroughly compare two of these methods, ZOOM-EPI [1] and reduced-FOV with 2D echo-planar RF (2D-EPRF) excitation [2], by presenting sagittal and axial DWI of the spinal cord using both techniques.

Methods: Figure 1 shows the excitation schemes for the aforementioned reduced-FOV methods. The first method, ZOOM-EPI (Fig. 1.a), uses a 90° slice-selective pulse (a spectral-spatial RF pulse that also suppresses the signal from fat), followed by a 180° refocusing RF pulse applied obliquely at an angle θ. The intersection of the resulting profiles is a parallelogram-shaped inner volume (light blue section in Fig. 1.a) that will be used for reduced-FOV imaging. This technique performs better if a slice skip is allowed between two adjacent slices, using an interleaved multiple-acquisition scheme (slice skip = $N_{acq}\times$ {slice thickness + slice spacing}). The parallelogram becomes more slanted for smaller slice skips, yielding an undesirably wide transition band (TB).

The second method (Fig. 1.b) uses a 90° 2D-EPRF excitation, with periodic sidelobes located $\Delta d_{replica}$ distance apart in the slice-select (SS) direction. A refocusing 180° RF pulse is then applied to select only the main lobe of this excitation (light blue section in Fig. 1.b). The long duration of the 2D-EPRF pulse allows this excitation scheme to simultaneously suppress the fat signal (see [1] for details). Because the adjacent slices are not excited with this method, there is no need for a slice skip. However, the number of slices that can be imaged in a single TR is limited: $\max(N_{slices})=\Delta d_{replica}/\Delta d_{SS}$, where Δd_{SS} is the slice thickness. To increase the number of slices, a longer RF pulse is needed, which increases the echo time (TE).

In this work, we incorporated these reduced-FOV methods into the same pulse sequence to ensure that the only difference is on the excitation side. *In vivo* cervical spine scans of healthy subjects were acquired on a 1.5T GE Excite scanner (40 mT/m gradients with 150 mT/m/ms slew rates) using an 8-channel CTL coil. For the sagittal comparison, 6 slices were acquired in a single acquisition (i.e., no slice skip). Meanwhile, two acquisitions were performed for the axial comparison, producing 24 slices for ZOOM-EPI and 16 slices for the 2D-EPRF method. We used a 62.5% partial k-space coverage, TR=3.6 s and ±62.5 kHz bandwidth for the ss-EPI readout. Other imaging parameters are listed in Figures 2-3.

Multiple NEX images were combined with a refocusing reconstruction [5], where the central 12.5% of each single-shot data was used for phase correction. Partial k-space homodyne reconstruction [6] was then performed on the combined data.

Results: DWI images acquired with ZOOM-EPI and 2D-EPRF methods in the sagittal and axial planes are shown in Figures 2 and 3, respectively. Since a single acquisition is used in the sagittal plane, the parallelogram-shaped slice profile of ZOOM-EPI is quite slanted. This results in a signal dropout towards the edges in the PE direction. When multiple acquisitions are allowed as in the axial comparison, 2D-EPRF cannot image as many slices as ZOOM-EPI, due to the previously mentioned limit on the number of slices.

Conclusion: A thorough comparison is presented between two reduced-FOV methods, namely ZOOM-EPI and 2D-EPRF. 2D-EPRF is better suited when a single-acquisition is sufficient to cover the region of interest, as in sagittal imaging of the spine. In contrast, ZOOM-EPI performs better when many slices are needed, as in axial imaging of the spine. Therefore, these two sequences can be used complementarily, depending on the application's specific needs.

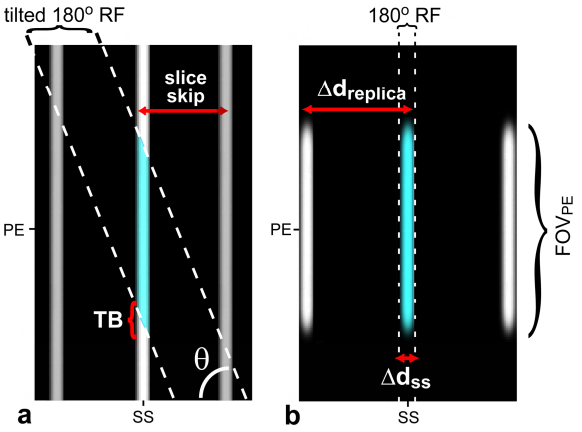

Figure 1. *Excitation profiles:* ***(a)*** *ZOOM-EPI method, with regular 90° excitation and a tilted 180° RF pulse, creating a parallelogram-shaped inner volume.* ***(b)*** *The 2D-EPRF pulse and a 180° RF pulse that refocuses only the excitation in the main lobe. Light blue denotes the final profiles.*

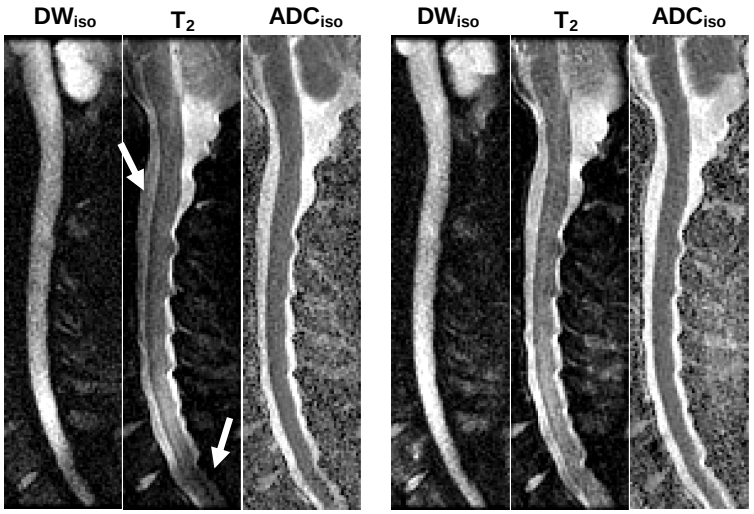

Figure 2. *Sagittal comparison of* ***(a)*** *ZOOM-EPI and* ***(b)*** *2D-EPRF. Note the shading in the ZOOM-EPI images (the white arrows) close to the edges in the PE direction, due to the parallelogram-shaped profile (Fig. 1.a). 6 slices are acquired for both techniques (only 1 shown), with 4 mm slice thickness, 0.4 mm slice spacing, 0.94 × 0.94 mm² in-plane resolution, 18 × 4.5 cm² FOV, b = 500 s/mm², TE = 64ms, NEX = 10, total scan time = 2:24s.*

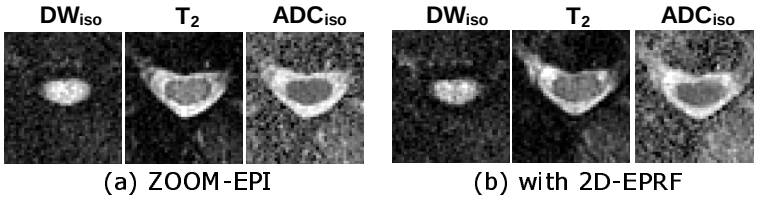

Figure 3. *Axial comparison:* ***(a)*** *24 slices with ZOOM-EPI and* ***(b)*** *16 slices with 2D-EPRF are acquired in 2 acquisitions (only 1 slice shown). Note that the images with 2D-EPRF have slightly lower SNR due to a slightly longer TE (57 ms vs. 61 ms), and a narrower 180° RF profile. 5 mm slice thickness, 0.5mm slice spacing, 0.83 × 0.83 mm² in-plane resolution, 8 × 4 cm² FOV, b = 500 s/mm², NEX = 10, scan time = 4:48s.*

References: 1. Wheeler-Kingshott, Neuroimage 16:93-102, 2002. 2. Saritas, MRM 60:468-473, 2008. 3. Jeong, MRM 54:1575–1579, 2005. 4. Wilm, MRM 57:625-630, 2007. 5. Miller, MRM 50:343:353, 2003. 6. Noll, IEEE TMI 10:154-163, 1991.