# Reduced Field of View Imaging for Twice-Refocused Diffusion EPI using a Perpendicular Refocusing Slab

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**Introduction:** Imaging with a reduced field of view (rFOV) is a way to reduce distortion in EPI by acquiring fewer phase-encode lines. However in cases in which regions of signal lie outside the phase field of view, aliasing will occur. This problem has been addressed by suppressing the volume outside the reduced field of view [1] and also by 2D selective excitation [2]. The latter is limited by the number of slices that can be used and both methods require lengthy preparation periods. Another approach is ZOOM-EPI [3,4] which uses a tilted refocusing slice, however this requires a large gap between slices. The approach presented here is similar to ZOOM-EPI, however the 180-degree pulses are titled by 90 degrees, which assures a very sharp profile of the selected band.

**Methods:** *MRI:* Single-shot twice-refocused diffusion-tensor (DTI) EPI was performed on a volunteer using a 1.5T scanner (Signa HDX, GE Healthcare) with a 4-channel spine coil. Three b=0 s/mm$^2$ images and 60 isotropically distributed diffusion-weighted (DW) directions with b = 500 s/mm$^2$ were collected on 7 slices with a 4 mm slice thickness and no gap between slices, TR/TE = 3000/72ms, for a total scan time of 3:12 min. The preparation period of the pulse sequence is shown in Fig 1a without diffusion pulses. A 90-degree slice selective spectral-spatial excitation is performed on the z-axis while the 180-degree refocusing pulses are performed on y. The resulting excitation pattern is described in Fig 1b where the intersection of the 2 rectangular slabs is the rFOV area. Here, the second 180 pulse ensures that inverted spins outside the desired slice are reset. For the thoracic spine scans the rFOV = 30 x 10 cm with a 180x54 image matrix (partial fourier with 12 overscans). The phase encoding direction was A/P. An FSE was acquired for comparison. For the cervical spine the same parameters as above were used with a FOV = 26cm x 7.8cm. Full FOV images were acquired to compare the distortion reduction (TR/TE = 3000/105ms).

*Data Processing:* Isotropic DW images were calculated by complex averaging the phase-corrected images from all diffusion directions. Color fractional anisotropy (FA) maps were also calculated. SNR was assessed in an ROI placed in the thoracic spinal cord by using the 3 T2-weighted images acquired [5]. For comparison the relative SNR was calculated by normalizing by the square root of the readout time.

**Results and Discussion**: The SNR of the rFOV implementation was approximately 67% of the SNR in the full FOV implementation, however the relative SNR was 12% higher in the rFOV image due to a lower achievable echo time. Images acquired with the rFOV method (Fig 2c,e,g) had far less distortion than the full FOV images (Fig 2b,e,f). The distortion in the full FOV images (Fig 1b,d,f) caused the spinal cord to have a serpentine appearance. The rFOV images (Fig 1c,e,g) are much straighter and more accurately represent the actual shape of the spine depicted in the FSE image (Fig 2a). To show that signal is maintained over multiple slices, the T2-weighted images of 3 adjacent slices from the rFOV scan (Fig 3a) are compared to the same slices from the full FOV scan (Fig 3b). The reduction of distortion in the rFOV scan over the full FOV scan is apparent in each image. Images of the cervical spine with the rFOV technique (Fig 4) were of similar quality to those acquired on the thoracic spine.

**Conclusion:** An rFOV method for DTI EPI was presented that had significant reduction in distortion compared to full FOV EPI at the cost of modest reduction in SNR. Compared to other approaches, this approach is of particular interest as it requires just a few simple modifications to the twice-refocused DTI sequence.

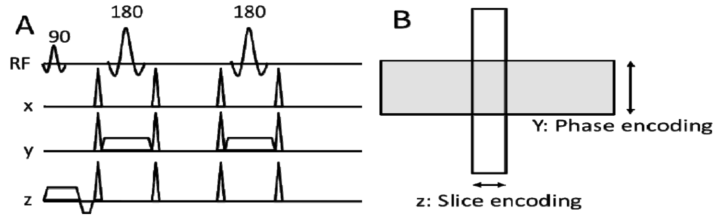


**Figure 1:** The preparation portion of the pulse sequence (a) shown without the diffusion gradients. The 90-degree pulse excites the slice (b, white rectangle) while the 180s refocus spins in the area intersecting the perpendicular slab (b, grey rectangle).

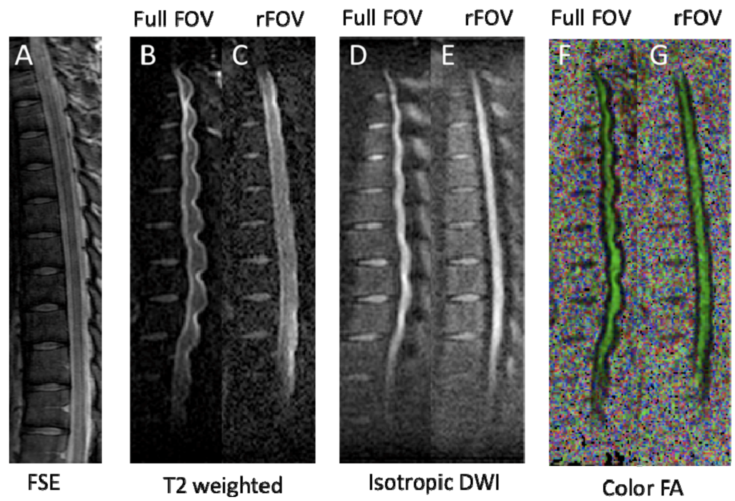


**Figure 2:** Thoracic spine images compared. The FSE (a) is shown for anatomical reference. The full FOV T2-weighted image (b) has much more distortion than the rFOV image (c). The DWI (d,e) and color FA (f,g)images show a similar effect .

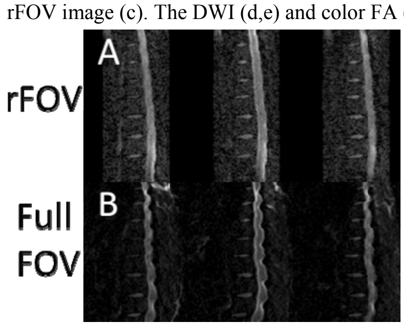


**Figure 3:** T2-weighted images from 3 of the 7 acquired slices in the rFOV exam (a) are compared with the same slices of the full FOV exam (b).

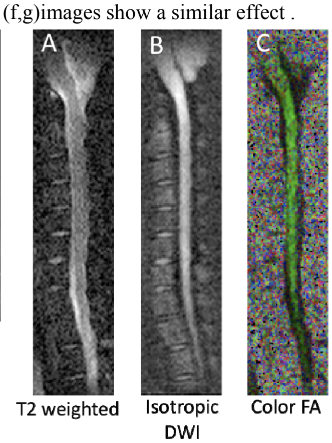


**Figure 4:** rFOV images from a single central slice of the of the cervical spine exam.

**References:** [1] Wilm et al. MRM 2007. [2] Saritas et al MRM 2008. [3] Mansfield Phys. E: Sci. Instrum. 1988 [4] Symms M. ISMRM 2000;160. [5] Reeder et al. MRM 2005.

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