Comparison between Single-Shot Diffusion Weighted Methodologies at 3 and 7 Tesla on Brain Volunteers

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Introduction: Research and clinical applications at ≥ 7 T fields require concurrent developments of suitable imaging technologies and methodologies [1,2]. Brain MRI at high magnetic fields could provide advantages over lower field counterparts, including increased contrast and better signal-to-noise ratios (SNR) enabling higher imaging resolution. At the same time, considerable challenges emerge upon scanning at high fields, including RF and static B_0 field inhomogeneities that can result in poor anatomical images. These drawbacks may be particularly harmful when considering single-shot experiments like spin-echo echo-planar-imaging (SE-EPI), endowed with a low-bandwidth dimension prone to artifacts. Still, reliance on fast acquisition methods is essential in various clinical and research applications including functional and diffusion-weighted brain studies. Spatio-temporal ENcoding (SPEN) is an alternative single-shot technique based on the use of frequency-swept RF pulses, which is capable of delivering arbitrary MR spectra or images in sub-second timescales. When considered in an MRI setting, it has been shown that SPEN provides significantly higher immunity to B_0 inhomogeneities and chemical shift offsets than SE-EPI counterparts [3]. This study explores whether these performance improvements, which have been mostly demonstrated in preclinical rodent studies, are maintained at 7 T whole body scanners. Toward this end DW imaging scans based on single-shot SE-EPI and SPEN sequences were compared among volunteers, examined on both clinical 3T and 7T MRI machines.

Methods: Brain MRI scans were conducted on 3 T and 7 T Siemens Trio TIM scanners (Erlangen, Germany) using either a 24-channel head coil (7T) or a 6-channel head coil (3T). T_2 turbo spin echo scans were recorded as anatomical references with a spatial resolution of 0.7×0.7×3.0 mm. Coronal magnitude images were acquired using single-shot 2D SPEN and 2D SE-EPI with a spatial resolution of 2.3×2.3×3.0 mm. Axial magnitude images were also collected, using single-shot multi-slice 2D SPEN and 2D SE-EPI acquired with spatial resolutions of 1.6×1.6×3.0 mm. All single-shot methods were collected with the low-bandwidth directions running form R >> L; in the 7 T scanner, technical complications prevented the use of fat suppression. All DW MRI experiments were monitored using six b-values (0, 100, 200, 400, 600, 800 sec/mm^2) applied along three orthogonal directions; the data were then processed to obtain the geometric mean ADCs using a $\boldsymbol{\delta}$=20 ms and Δ=30-35 ms. Cross-terms between the imaging and DW gradients were accounted as described in Ref. [4].

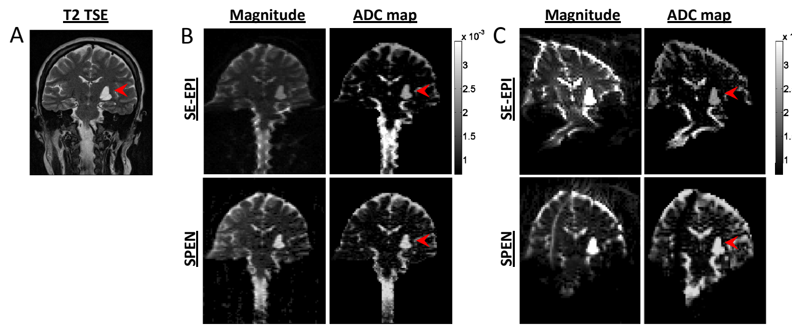

Figure 1. Representative comparison between coronal b-zero magnitude images and ADC maps derived from SE-EPI and SPEN of a volunteer with brain cyst (red arrow) on 3T (B) and 7T (C) scanners. (A) presents a reference anatomical image scanned with a T2-weighted turbo spin-echo image. Since technical (SAR-related) reasons prevented the use of fat suppression at 7T, residual artifacts arising from the fat surrounding the skull are visible in panel C for both methods.

Results and Discussion: Figure 1 presents representative coronal slices of a healthy volunteer exhibiting a benign brain cyst, visible in a multi-shot TSE scan (panel A). Panels B and C present SE-EPI and SPEN imaging data collected at both 3 and 7 Tesla, respectively. These panels display the b-zero magnitude diffusion weighted images of the two methods, together with ADC maps that arose upon processing multi-b image sets for each sequence. Among the main features revealed by these experiments count (1) the clearly susceptibility-driven distortions that arise upon going to higher fields; (2) SPEN's more faithful capability to deliver undistorted images, certainly at 7 T but also for certain interphase regions also at the lower field; (3) the subtle but consistent differences in ADC values that can be observed for the maps retrieved at the two fields. Figure 2 presents a representative axial brain images, from a healthy volunteer at 7T. Once again, the overall brain shape is substantially less distorted in SPEN than in SE-EPI; also the susceptibility distortions arising from air/fat/tissue interfaces in the brain periphery are less marked in the SPEN images. Overall, however, the ADC maps arising from both methods are in good agreement.

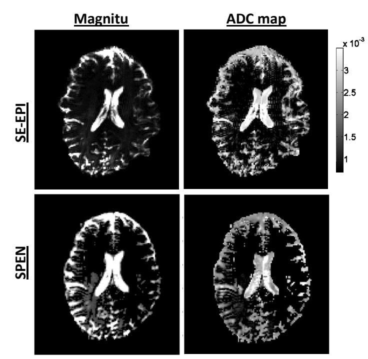

Figure 2. Axial b-zero images and ADC maps derived at 7T for a healthy volunteer from SPEN and SE-EPI.

Conclusion: In this study we perform an anatomical and diffusion imaging comparison between two single-shot acquisition methodologies on two MRI scanners with different magnetic fields (3T vs 7T). Our results show SPEN's capability to obtain reliable brain anatomical images and ADC maps in high magnetic field while showing significant advantages in terms of robust reduction of artifacts.

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