ADC Measurement Accuracy in Quantitative Diffusion Phantoms using Reduced Field-Of-View and Multi-Shot Acquisitions

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Target audience: MR physicists and clinicians interested in quantitative diffusion imaging.

Purpose: Diffusion MRI (dMRI) is typically performed using single-shot Echo Planar Imaging (ssEPI). However, the long echo-trains in ssEPI result in significant image distortion in the presence of static B_0 field inhomogeneties. Several techniques have been proposed for reducing the echo-train length in dMRI in order to reduce image distortions compared to ssEPI. Reduced-Field-of-View (rFOV) imaging has been demonstrated in regions such as the spinal cord [1] and pancreas [2]. Multi-shot EPI (msEPI) is based on an interleaved segmented k-space acquisition that enables full FOV dMRI with reduced distortion (upon correction of inter-shot phase inconsistencies) [3]. Both rFOV and msEPI have been shown to provide high quality diffusion weighted images. However, their ability to provide accurate quantitative diffusion measures has not been fully characterized. In this study we extend the work from Banerjee et al [4] by conducting controlled experiments in two recently proposed quantitative diffusion phantoms to compare the apparent diffusion coefficient (ADC) measured from three diffusion sequences: ssEPI, rFOV and msEPI.

Methods: All three sequences were tested on the National Institute of Standards and Technology (NIST) and RSNA-QIBA diffusion phantom [5]. Further, ssEPI and rFOV were tested on a recently proposed diffusion phantom based on acetone-water mixtures with a wider range of ADC values [6]. Both phantoms contain multiple vials with different ADC and were scanned using an ice-water bath for temperature control at 0ºC. Scans were acquired on a 3.0T system (MR 750, GE Healthcare, Waukesha, WI). Because of size differences, the QIBA phantom was images using an 8-channel head coil, while the acetone-water phantom was imaged using a Nova 32-channel coil (Nova Medical, Wilmington, MA). For both phantoms, a full FOV ssEPI sequence was considered the reference. The parameters for ssEPI included: FOV=24x24cm, matrix=128x128, slice thickness=6mm, in-plane: 1.9x1.9mm^2, TR/TE=4000/84, single average, b-values=[50,150,300,500,800,1000] s/mm^2. rFOV scans were acquired with a reduction factor of 60% and 30% using the same b-values, in-plane resolution and slice thickness. In order to test the influence of SNR, two extra acquisitions were performed with two averages and slice thickness=3mm respectively. Finally, msEPI was acquired using the same b-values and slice thickness as ssEPI, with 4 shots and in-plane=1.25x1.25mm^2. Two additional msEPI acquisitions were performed using slice thickness=3mm and in-plane=0.94x0.94mm^2 respectively. For each b-value, three orthogonal diffusion directions were acquired and then averaged in magnitude. From the combined images, ADC maps were computed using non-linear-least-squares fitting to a mono-exponential signal model. From the fitting results, a mean ADC value was obtained from a single slice in each of the vials for each acquisition. Finally, linear regression analysis was performed to compare ADC from rFOV and msEPI to the reference ADC from ssEPI.

Results: In general, measurements from both rFOV (Figure 1.A-B) and msEPI (Figure 1.C) were in very good agreement with the reference ssEPI. For the QIBA phantom, msEPI showed a higher variability in the estimation of the ADC than rFOV. For the acetone-water phantom, rFOV seems to underestimate the ADC for high values.

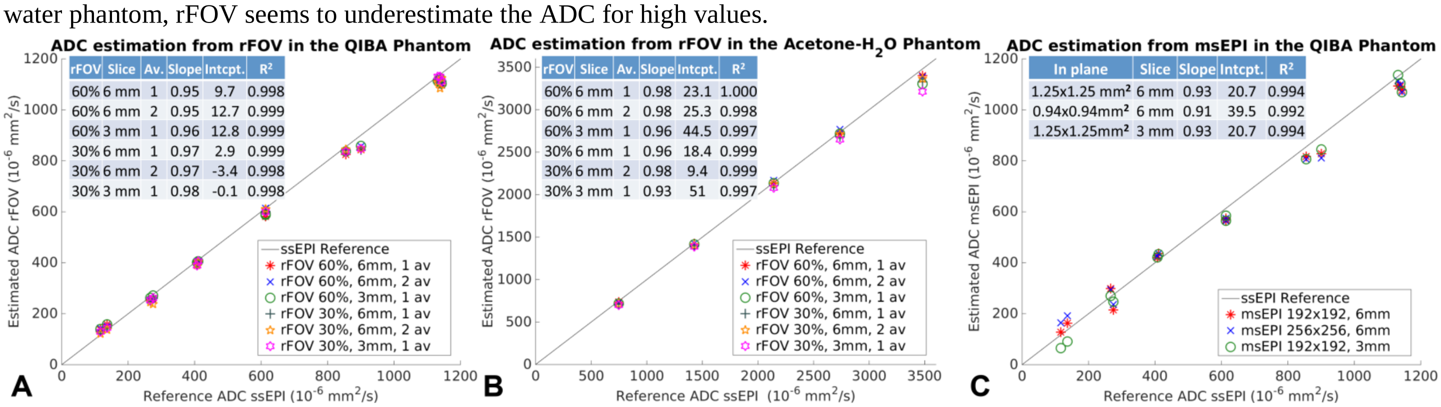

***Figure 1**. ADC measures for rFOV (A) and msEPI (B) in the QIBA phantom, as well as for rFOV in the acetone-water phantom (C) were compared to ADC measures from ssEPI. The slope, intercept and R^2 parameters obtained from a linear regression analysis are also shown for all the cases.*

Discussion: As expected, rFOV and msEPI provided images with lower distortion than ssEPI (not shown). Importantly, both techniques are able to provide accurate ADC maps. However, rFOV seems to underestimate the ADC for cases of low SNR in the presence of high ADC, likely due to noise floor effects on the fitting. Multi-shot EPI appears to have higher variability in ADC measurement, which may be due to residual ghosting artifacts.

Conclusion: Both rFOV and msEPI may enable accurate ADC measurement with reduced distortions relative to ssEPI. However, further validation exploring additional confounding factors (eg: motion, perfusion), as well as in-vivo studies are required.

References: [1] Saritas E, et al, MRM 2008; 60:468-7. [2] Mannelli L, et al, ISMRM 2015 p.142. [3] Chen N, et al, Neuroimage 2013;72:41-47. [4] Banerjee S, et al, ISMRM 2016 p.3428. [5] Pierpaoli C, et al, ISMRM 2009 p.1414. [6] Wang X, et al, ISMRM 2016 p.921.

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