Small Field-of-view single-shot EPI-DWI of the prostate: Evaluation of spatially-tailored two-dimensional radiofrequency excitation pulses

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Target audience: Clinicians **Purpose:** The use of spatially tailored, two-dimensional radiofrequency (RF) excitation pulses in single-shot echo-planar imaging (EPI), combined with a decreased FOV in the phase-encoding direction, results in a reduced amount of k-space acquisition lines, which shortens the EPI echo train length (ETL) and reduces susceptibility artifacts without an increase in acquisition time. The purpose of this study was to evaluate the image quality on 3-Tesla clinical MR systems of a zoomed EPI (z-EPI) sequence in diffusion-weighted imaging (DWI) of the prostate in comparison to a conventional single-shot EPI using single-channel (c-EPI1) and multi-channel (c-EPI2) RF excitation, with and without use of an endorectal coil. The improved image quality using z-EPI in evaluation of the pancreas has already been demonstrated in a clinical setting[1].

Methods: Between 10/2012 and 02/2014, images of 33 consecutive patients (mean age: 61 +/- 9 years; mean PSA: 8.67 ± 6.23 ng/ml) who underwent a multiparametric MRI (mp-MRI) study of the prostate on a 3T whole-body (wb) MR system including conventional EPI (c-EPI1 or c-EPI2) were analyzed in this retrospective, IRB-approved study. In 26 of 33 patients, the initial state-of-the-art mp-MRI was performed on a whole-body 3T scanner (Magnetom Trio, Siemens, Erlangen, Germany) using an endorectal coil (c-EPI1). The acquisition protocol consisted of high-resolution T2-weighted sequences, dynamic contrast-enhanced imaging (DCE) and c-EPI1. Z-EPI examinations of these patients and a complete mp-MRI protocol including c-EPI2 of 7 additional patients were carried out on another 3T wb MR scanner with two-channel dynamic parallel transmit capability (Magnetom Skyra with TimTX TrueShape, Siemens). For z-EPI, the one-dimensional spatially selective RF excitation pulse was replaced by a two-dimensional spatially-tailored RF pulse. By applying these innovations, it is now technically feasible to decrease the number of acquisition steps and reduce the ETL without an increase in scan time[2]. Images were evaluated in terms of presence and degree of image blur and susceptibility artifacts (0=not present to 3=impaired diagnostic confidence), maximum image distortion in mm, apparent diffusion coefficient (ADC) values, as well as overall scan preference. Combined ratings of both readers were considered for statistical evaluation of subjective data. Interobserver agreement was assessed. SNR maps were generated to compare c-EPI2 and z-EPI, taking into account the differences in protocol parameters (Figure 1).

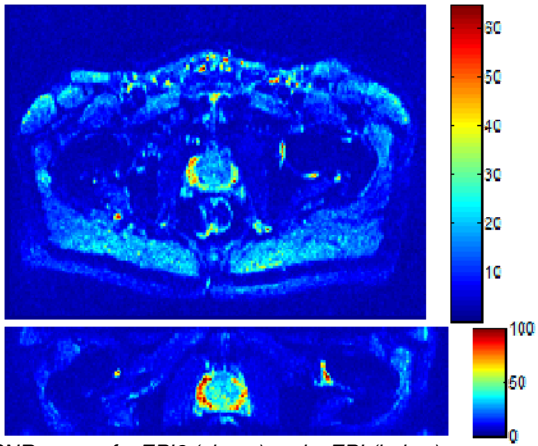

Figure 1: *SNR maps of c-EPI2 (above) and z-EPI (below) sequences. The mean SNR over a ROI in the peripheral zone was 39.5 for c-EPI2 and 75.7 for z-EPI (ratio: 1.92). In the central gland, mean ROI values were 16.8 and 34.3 (ratio: 2.04). The theoretical ratio of the SNRs given the differences in protocols (acquisition matrix, averages) is 1.43, and the color scaling of the SNR maps has been adapted accordingly for better visual comparison.*

	c-EPI1 (n = 26)	c-EPI2 (n = 7)	z-EPI (n = 33)	c-EPI1 vs. z-EPI	cs-EPI2 vs. z-EPI
Mean ADC [x10^{-6} mm^2/s]	1285 ± 299	1253 ± 156	1342 ± 119	p = 0.395	p = 0.150
Mean susceptibility [0 – 3]	2.346 ± 0.596	1.786 ± 0.81	0.697 ± 0.64	p < 0.001	P < 0.001
Mean blur [0 – 3]	1.981 ± 0.64	1.714 ± 0.7	0.697 ± 0.62	p < 0.001	p < 0.001
Mean distortion [mm]	8.23 ± 9.26	6.14 ± 4.6	4.13 ± 5.63	p= 0.12	p = 0.42

Table 1: *Mean ADC values, ratings of susceptibility and image blur from both observers, and measures of maximum image distortion (in mm) are presented. Susceptibility artifacts and image blur were rated significantly lower for z-EPI compared to the other methods. No statistically significantly differences were found with respect to mean ADC values and image distortion.*

Results: Overall image quality of z-EPI was preferred by both readers in all examinations with a single exception (both readers preferred one c-EPI1 sequence due to subjectively less image blur). Susceptibility artifacts were rated significantly lower on z-EPI compared to both other methods as well as image blur. Image distortion was not statistically significantly reduced with z-EPI but showed a trend to better results compared to the other methods (Table 1). Inter-observer agreement for ratings of susceptibility artifacts, image blur and overall scan preference was excellent. SNR was somewhat higher for z-EPI than for c-EPI2 (n=1), even when taking protocol differences into account.

Discussion: Z-EPI leads to significant improvements in image quality and artifacts as well as image blur reduction improving prostate DWI and enabling accurate fusion with conventional sequences (Figure 2). Z-EPI improves image quality of prostatic DWI, potentially resulting in higher detection rates, particularly with small cancers.

Conclusion: In summary, image quality improvements with the z-EPI acquisition are promising and could potentially constitute a new reference standard for DWI of the prostate. Additional evaluation of the z-EPI sequence is desirable in larger patient cohorts with histologically confirmed prostate pathologies to ultimately confirm clinical relevance of the sequence.

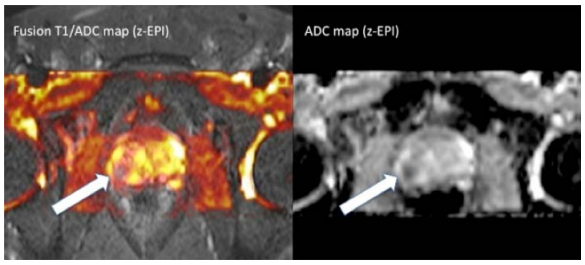

Figure 2: *A system-generated ADC map (right image) obtained with z-EPI enables nearly perfect delineation of the prostate allowing for accurate fusion with morphologic sequences (left image). Anatomic details of the surrounding structures within the FOV are well-depicted.*

Reference: 1. Riffel P et al., Zoomed EPI-DWI of the pancreas using two-dimensional spatially-selective radiofrequency excitation pulses. PLoS One. 2014 Mar 3;9(3):e89468

2. Rieseberg S et al., Two-dimensional spatially-selective RF excitation pulses in echo-planar imaging. Magn Reson Med. 2002Jun;47(6):1186-93