ECHO PLANAR DIFFUSION-WEIGHTED MRI OF THE ABDOMEN AND PELVIS: COMPARISON OF FREE-BREATHING MONOPOLAR AND BIPOLAR SPIN-ECHO SEQUENCES IN IMAGE QUALITY AND GEOMETRIC DISTORTIONS

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Introduction: Diffusion-weighted magnetic resonance imaging (DWI) exploits the random, thermally induced displacement of water molecules in biological tissue. Most DWI applications in the abdomen and pelvis employ single-shot spin-echo echo-planar imaging (ssEPI) due to its fast acquisition times and resultant robust performance against motion artifacts. Nevertheless EPI-based DWI suffers from increased sensitivity to magnetic field inhomogeneities, which ensue from susceptibility differences at soft tissue interfaces and eddy currents generated by the high-amplitude diffusion-weighting gradients [1-3]. Geometric distortion results when image readout takes place in the presence of eddy currents, whereby the current-associated residual magnetic field is misread as a spatial encoding gradient field. A bipolar double spin-echo sequence with alternating polarity diffusion sensitising gradients has been employed to counteract the effect of eddy currents [4]. The purpose of this study was to compare artifacts, signal-to-noise ratios (SNR), fat suppression and apparent diffusion coefficient values (ADCs) using monopolar (conventional Stejkal and Tanner) and bipolar ssEPI-DWI on abdominal and pelvic images.

Method: Seven healthy female volunteers underwent abdominal and pelvic DWI imaging on a 1.5T scanner (Siemens Medical Solutions, Erlangen, Germany). Diffusion-weighted imaging was performed with a bipolar EPI sequence with SPAIR fat suppression (TR/TE=6300/69, 40 slices, 5mm thickness, 5 averages, 128x128 matrix interpolated to 256x256, 380mm FOV, Grappa = 2, 30 reference lines, three scan trace with b-values 0,600,900,1050 s/mm^2) followed by a monopolar EPI sequence with identical parameters. In the pelvis, an additional monopolar ssEPI with the minimum feasible TE (TR/TE=6300/58) was used. ADC maps were generated with all b-values using scanner software. Artifacts were assessed in consensus by two radiologists using multi-planar reformating on a 5 point-scale, ranging from 1 (excessive artifact) to 5 (no artifact). ADCs were determined by positioning five circular regions of interest (ROIs, area 0.97 cm^2) over the enquired tissue on the ADC map by visual matching with the T2-W image and calculating a mean. SNR of the liver, spleen, kidneys, pancreas, psoas muscle, sacral bone and uterus were calculated on each DWI series from $SNR_{Tissue} = SI_{Tissue} / SD_{Noise}$. Tissue signal intensity (SI) was the mean of five measurements employing the same ROIs. Standard deviation (SD) of noise was derived from ROIs in an area of air devoid of spurious signal. Efficiency of fat saturation was assessed by calculating fat to muscle signal intensity ratios (FMR) between ischiorectal fossa fat and adjacent internal obturator muscle for each DWI acquisition. A paired Student *t* test was used to assess differences in SNR and ADC between mono- and bipolar ssEPI-DWI for individual b values in abdominal and pelvic organs.

Results: Both radiologists agreed that monopolar sequences (including the minimum TE technique) suffered from distortion, with a zipper-like artefact along the phase-encoding direction (Figure 1). SNR was significantly higher in monopolar compared to bipolar sequences in all tissues irrespective of b value (Tables 1-2, except kidney at b=600 s/mm^2). With the reduced TE in the pelvis, SNR of the monopolar sequence continued to be better than in the corresponding bipolar sequence. FMR did not change significantly between mono- and bipolar acquisitions (for b=600, 0.87±0.08 monopolar, 0.92±0.15 bipolar; b=900, 1.17±0.11 monopolar, 1.05±0.13 bipolar; b=1050, 1.3±0.11, monopolar, 1.02±0.22 bipolar). Except for psoas muscle, ADCs were significantly higher in the bipolar dataset (Tables 1 and 2).

Discussion & Conclusion: Although the bipolar EPI-DWI exhibits a worse SNR than the monopolar technique, its relative insensitivity to geometric distortion enhances the overall image quality. Fat suppression appears to be equally effective in both techniques. ADC values demonstrate a non-coherent behaviour in relationship to different tissues, indicating that ADC measurements are particularly susceptible to local motion influences in combination with the low SNR of tissues with an inherent low TS, such as muscle.

Para-meter	Liver			Spleen			Kidney			Pancreas			Psoas		
	Mono	**Bi**	***p***	**Mono**	**Bi**	***p***	**Mono**	**Bi**	***p***	**Mono**	**Bi**	***p***	**Mono**	**Bi**	***p***
SNR b=600	46.67 ±13.03	35.46 ± 9.75	**0.042**	177.54 ±42.73	134.57 ±34.22	**0.013**	131.52 ±65.57	79.63 ±6.40	0.075	55.07 ±23.27	39.23 ±12.30	**0.028**	21.16 ±7.09	15.33 ±2.65	**0.040**
SNR b=900	36.05 ±8.01	26.54 ±5..91	**<0.001**	156.06 ±57.35	106.08 ±28.92	**0.009**	67.49 ±7.22	50.65 ±3.93	**0.004**	40.52 ±16.88	28.04 ±12.59	**0.004**	14.78 ±1.38	11.90 ±1.83	**0.001**
SNR B=1050	29.73 ±4.83	21.90 ±5.17	**<0.001**	129.07 ±51.26	85.87 ±20.09	**0.030**	50.84 ±7.55	40.01 ±5.07	**0.017**	30.79 ±14.63	24.16 ±10.62	**0.038**	12.74 ±1.72	11.05 ±1.48	**0.003**
ADC (mm^2/s)	1155 ±77	1219 ±114	**0.014**	940 ±208	925 ±153	0.558	1846 ±74	1896 ±57	**0.012**	1686 ±291	1680 ±309	0.882	1160 ±163	1081 ±172	**0.003**

Table 1. *Parameters (mean ± sd) for monopolar and bipolar EPI-DWI with identical TR and TE (TR/TE=6300/69) and different b values (in s/ mm^2). Statistical significance (p<0.05) is indicated by bold typeface.*

Para-meter	Uterus			Sacrum		
	Mono TE=58	**Bi TE=69**	**p**	**Mono TE=58**	**Bi TE=69**	**p**
SNR b=600	83.95 ±31.76	56.84 ±22.03	**0.010**	91.27 ±35.62	57.29 ±24.52	**0.004**
SNR b=900	64.41 ±27.20	40.53 ±13.08	**0.022**	77.83 ±25.81	48.97 ±17.28	**0.003**
SNR b=1050	61.08 ±31.92	36.29 ±14.37	**0.039**	78.26 ±30.71	48.55 ±16.60	**0.008**
ADC (mm^2/s)	1323 ±185	1435 ±264	0.068	420 ±71	504 ±89	**<0.001**

Table 2. *Comparison of bipolar vs. monopolar with minimum TE techniques in the pelvis*

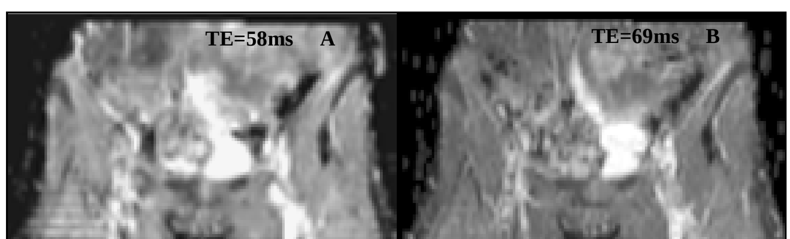

Fig. 1. *Coronally reformated ADC maps in monopolar (TE=58ms)(A) and bipolar (B) acquisitions. Note the geometric distortion artifact manifested as zipper lines in (A).*

References: [1] Bastin ME et al. *Magn Reson Med* 2002;48:6-14, [2] Bammer R. *Eur Radiol* 2003;45:169–84, [3] Truong T et al. *Neuroimage* 2008;40:53-58, [4] Reese TG et al. *Magn Reson Med* 2003;49:177-182

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