Diffusion-Weighted, Readout-Segmented EPI with Synthesized T2- and T2*-Weighted Images

David Andrew Porter1

1Healthcare Sector, Siemens AG, Erlangen, Germany

Target Audience: Sequence programmers and radiologists.

Purpose: Diffusion-weighted Imaging (DWI) using readout-segmented EPI (rs-EPI) with 2D navigator correction [1] is an alternative to standard single-shot EPI (ss-EPI) that improves image quality by reducing susceptibility artifacts and allowing a higher spatial resolution. This improved image quality raises the possibility that the low b-value image could be used to replace a separate T2-weighted acquisition and reduce the overall examination time. The acquired images are more than 100 times more efficient than single-shot EPI images, making it potentially useful for identifying hemorrhage.

Methods: Pulse Sequence: In the standard rs-EPI sequence (Fig. 1), data are acquired from two spin echoes. The first is used to acquire imaging data from multiple excitations by sampling a different readout segment at each shot. The second is used to sample a 2D navigator region at the centre of k-space to correct the shot-to-shot, motion-induced phase variation. The same acquisition is performed for both low- and high-b-value images, even though navigator correction is only required in the high-b-value case. The new technique replaces the navigator acquisition at low-b-value with a second imaging echo, so that an image is now generated for two echo times. For the high-b-value scans, a 2D navigator is acquired as in the original sequence. A variant of the new technique is to omit the second RF refocusing pulse for the low-b-value scans, so that the image from the second echo has T2*-weighting.

Image Calculation: For typical diffusion-weighted, rs-EPI protocols, the first echo time tends to be below the preferred value for clinical T2-weighted imaging and the second echo time tends to be above this preferred value. An image corresponding to the preferred echo time can be generated by combining the data from the two echoes to generate a synthesized image for an intermediate echo time [2]. A synthesized image with signal S is defined in this study using a weighted geometric mean of the two acquired images given by the following expression:

\[ S_w = \sqrt[2]{S_1 S_2}, \quad \text{with} \quad \frac{TE_2 - TE_S}{TE_S - TE_1} \]

Results: Figs. 2 and 3 show images acquired from a healthy subject using the prototype sequence at 3T and 1.5T respectively. The first two images in the top row of Fig. 2 are the standard trace-weighted and low-b-value images. The third image is the additional late-echo image generated by the modified sequence. Synthesized low-b-value images for a range of intermediate echo times are shown in the second row. Fig. 3 shows images acquired with the second RF refocusing pulse omitted to give the late echo a T2*-weighted contribution, the level of which can be controlled by the echo time selected for the synthesized image.

Discussion: The technique introduced in this paper promises to extend the clinical utility of diffusion-weighted rs-EPI by providing additional T2- or T2*-weighted images for a user-specified echo time. This is achieved with almost no increase in scan time and without compromising the short echo time requirement for optimal SNR in the diffusion-weighted scans. The combination of high-quality DWI and T2*-weighted images is likely to be of particular benefit in acute stroke [3].


Fig. 1: Pulse diagram for readout-segmented EPI with 2D navigator correction. For b=0 scans in the modified sequence the fixed readout pre-phase gradient (●) is replaced by the variable encoding gradient (■) as for the imaging echo.

Fig. 2: Data from a modified rs-EPI sequence with two spin echo images at b=0, FOV 220mm, matrix 256x256, TR 5600ms, slice thickness 4mm, 11 readout segments.

Fig. 3: rs-EPI with a spin echo and a gradient echo image at b=0. Matrix 214x214, TR 3000, 9 readout segments.