Diffusion-Weighted Imaging of the Abdomen with Readout-Segmented (RS)-EPI

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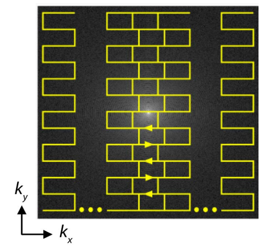
Introduction:

Diffusion-weighted imaging (DWI) in the abdomen has proven useful for various pathologies, including liver lesion characterization [1-4] and simple vessel suppression, diagnosis of diffuse renal disease [5-8], and detection of metastatic spread to lymph nodes [9,10]. However, image distortions arising from the use of EPI has shown to be problematic. We have recently applied DW 'Short-Axis Propeller' (SAP)-EPI to the abdomen on adults to reduce geometric distortions via its faster *k*-space traversal [11]. In this work we explore the use of another short-axis readout technique, Readout-Segmented (RS)-EPI [12], for imaging the abdomen. As shown in Figure 1, the use of several adjacent segments in RS-EPI results in reduced distortion compared with EPI.

Figure 1: *K*-space traversal of RS-EPI [12]. *K*-space is acquired with a series of adjacent EPI segments or 'blinds'. Note that each blind is accompanied by an extra central segment (or navigator blind) in order to perform phase correction on the DW blinds.



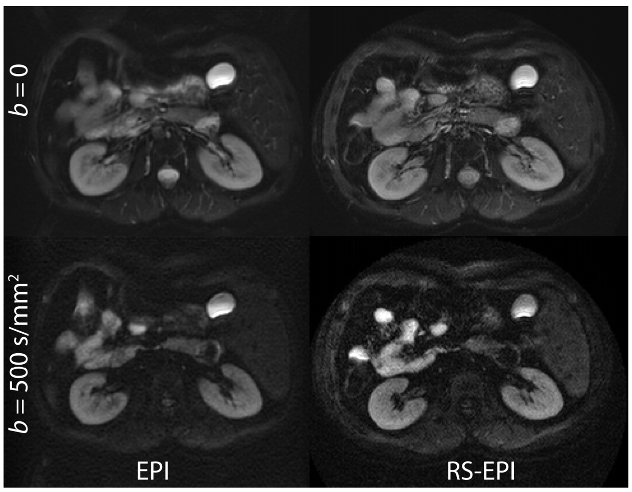


Figure 2: Comparison between ss-EPI and ss-RS-EPI DWI 30sec breath-hold images on a volunteer acquired at 3T. Imaging parameters were: FOV = 34cm, Δz = 8mm, matrix-size = 192 x 192, TR = 2s, one *b* = 500s/mm^2 (S/I direction), TE$_{min}$ = 72ms/56ms (EPI/RS-EPI), 7 blinds of width 64 (RS-EPI), and 7 NEX (EPI).

Materials & Methods:

Breath-hold single-shot (ss)-EPI and ss-RS-EPI diffusion-weighted images were acquired on an adult volunteer using a 3T whole-body GE DVMR750 system using an 8-channel cardiac-array coil. Both sequences used a matrix size of 192 x 192, FOV = 34cm, TE = minimum (RS-EPI: 56 ms, EPI: 72 ms), partial Fourier imaging (24 overscans), slthck/gap = 8 mm/1.5mm, TR = 2s, one *b* = 500 s/mm^2 (S/I direction), in a scan time of 30sec. Seven blinds of size 64 x 192 (freq.×phase) were used for RS-EPI, and 7 NEX were used for EPI to keep the scan time equivalent. By using RS-EPI over EPI, the distortion was reduced by 50% (due to the bandwidth increase in the phase-encode direction). Both sequences were then also acquired on a 6-month old pediatric patient under general aesthesia, after obtaining IRB approval and consent from the patient's parent. Imaging parameters (as different from above) were as follows: matrix size of 128 x 128, FOV = 28cm, slthck/gap = 5 mm/0mm, *b* = 500 s/mm^2 (A/P direction, applied twice), 7 blinds of size 32 x 128 (RS-EPI), and a total scan time of 1 min. In this case, the distortion reduction was 45%. The reconstruction of the RS-EPI data was performed as in Ref. [13], with one exception: the triangular window used for phase correction [14] was increased to the full *k*-space radius in order to reduce phase errors (and address the larger extent of motion that occurs in body imaging).

Results:

A comparison between the *b* = 0 s/mm^2 and isotropic *b* = 500 s/mm^2 EPI and RS-EPI images of the abdomen for the volunteer and patient is shown in Figs. 2 and 3. At an equivalent matrix size and scan time, RS-EPI appears sharper and less distorted, at the expense of a lower SNR.

Discussion & Conclusion:

While EPI-based DWI of the abdomen has proven useful for the diagnosis of various pathologies, image distortions arising from off-resonance effects (especially in the presence of bowel gas) and large FOVs can significantly hamper the image quality. This work shows that RS-EPI can be useful for DWI of the abdomen by reducing geometric distortion and blurring (as shown in Figs. 2-3). Disadvantages of RS-EPI are the increased scan time compared with EPI – which is tied to the extra number of blinds required to cover *k*-space – as well as the increased risk of phase-artifacts that can occur between blinds. Further experiments will explore these effects under free-breathing and respiratory triggering.

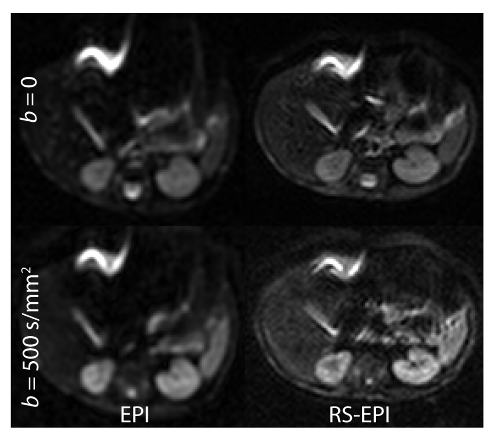


Figure 3: Comparison between the ss-EPI DWI and ss-RS-EPI DWI 1min sequence acquired at 3T on a pediatric patient under suspended respiration. Imaging parameters were: FOV = 28cm, Δz = 5mm, matrix-size = 128x128, TR = 2s, two *b* = 500s/mm^2 (A/P direction), 7 blinds of width 32 (RS-EPI), and 7 NEX (EPI).

References:

[1] Namimoto T, Radiology 1997;204:739. [2] Kim T, AJR Am J Roentgenol 1999;173:393. [3] Ichikawa T, Abdom Imaging 1999;24:456. [4] Taouli B, Radiology 2003;226:71. [5] Ries M, JMRI 2001;14:42. [6] Chan JH, Clin Imaging 2001;25:110. [7] Namimoto T, JMRI 1999;9:832. [8] Fukuda Y, JMRI 2000;11:156. [9] Takahara T, Radiat Med 2004;22:275. [10] Koh D, AJR Am J Roentgenol 2007;188:1622. [11] Skare S, ESMRMB 2009:49. [12] Porter D. ISMRM 2004;442. [13] Holdsworth S, MRM 2009:62 *Early view*. [14] Pipe J. MRM 1999;42(5):963.

Acknowledgements:

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