Diffusion-Weighted 3D Multi-Slab EPI for Clinical Imaging

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Purpose

A Diffusion-Weighted 3D Multi-Slab EPI (DW-3D-MS-EPI) protocol suitable for clinical imaging.

Introduction

DW-3D-MS-EPI (1) has previously been presented as a promising technique for isotropic, high-resolution, diffusion-weighted imaging. With multiple 3D encoded slabs, rather than 2D slices, the voxel definition is more precise and an increased Signal-to-Noise ratio (SNR) has been reported (1). Although multiple groups have shown good results, the scan times have been too long for clinical routine scans. The long scan times stemmed primarily from the small voxel sizes used. Also no 'online'-reconstruction has been presented, to our knowledge. In this work we have adapted the DW-3D-MS-EPI sequence, using 'online'-reconstruction and a feasible scan time. Scan parameters were carefully chosen to avoid T1-dependent weighting of slabs at the overlapping regions.

	DW-ssEPI	DW-3D-MS-EPI
TE (ms)	82	82
TR (ms)	11100	4000
FOV (cm)	22	22
Matrix	112x112	112x112x8
Slice/slab-thick. (mm)	2.0	16.0
Slice/slab	87	20
#T2w	4	2
#DW	24	8
Resolution (mm³)	2x2x2	2x2x2
Tot. Scan time	05:22	05:24

Table 1. Relevant scan parameters for the four acquired data sets. All scans were performed with b = 1000 s/mm².

Methods

A healthy volunteer was scanned on two clinical MRI systems; one 3T (GE DVMR750, GE Healthcare, Milwaukee) and one 1.5T (GE DVMR450, GE Healthcare, Milwaukee). Relevant scan parameters can be found in Table 1. For the 1.5 T and the 3.0 T scans the prescribed nominal image resolution was 2.0 mm³. The vendor's excitation and refocusing pulse was replaced with in-house designed, SLR-optimized, pulses having a common time-bandwidth-product of 12. The pre-scan was adjusted to optimize slice uniformity, rather than the global signal, improving slab combination and minimizing slab-bounding artifacts. The EPI raw data was streamed from the scanner to a separate server via the vendor's raw data server interface and stored in HDF5 format (The HDF Group, Hierarchical data format version 5, 2000-2010) for image reconstruction. Data reconstruction was started as the scan started and reconstructed during scanning as volumes were acquired. After the first b=0 volume, Nyquist ghost and GRAPPA-weight estimation was performed. A scan time and parameter matched 2D Diffusion-Weighted Single-Shot EPI (DW-ssEPI) was acquired for reference. Both the DW-ssEPI and the DW-3D-MS-EPI were retrospectively motion corrected as a part of the image reconstruction (2). The DW-3D-MS-EPI data were corrected for both intra- and interslab motion to avoid slab alignment mismatch.

Results

In Figure 1, the four reconstructed datasets are shown. The left panels, Fig. $1_{a,c,e,g}$, show data from the DW-ssEPI scans, while the right panels, Fig. $1_{b,d,f,h}$, show data from the DW-3D-MS-EPI scans. Comparing the left and right panels, an overall increased SNR can be seen, most apparent in the central regions of the brain.

Discussion

With a steadily increasing clinical interest in, and demand for, 3D imaging and isotropic image resolution, we consider DW-3D-MS-EPI a favorable alternative to conventional 2D approaches. The improved SNR seen in DW-3D-MS-EPI, due to an increased scan efficiency, reduces the noise propagation in the ADC - calculations (1). In this abstract the DW-ssEPI scans were acquired with the same, sharp, RF-pulses as for the DW-3D-MS-EPI scan to guarantee well-defined voxels in the slice direction. The apparent compromise that comes with the DW-3D-MS-EPI sequence is the reduced number of diffusion encoding directions, 24 against 8 in our case, which could influence diffusion tensor estimation. However, the improved quality in the isoDWI and the ADC we believe should be advantageous for a vast bulk of radiological assessment. Although DW-3D-MS-EPI could be acquired with shorter TR, we would like to advise caution, as T1-dependent tissue saturation will start to manifest itself in the overlapping zone between adjacent slabs.

Conclusion

DW-3D-MS-EPI is possible at clinically practical scan times and could be considered when high-resolution, high SNR diffusion weighted imaging is requested with a moderate number of diffusion directions.

References

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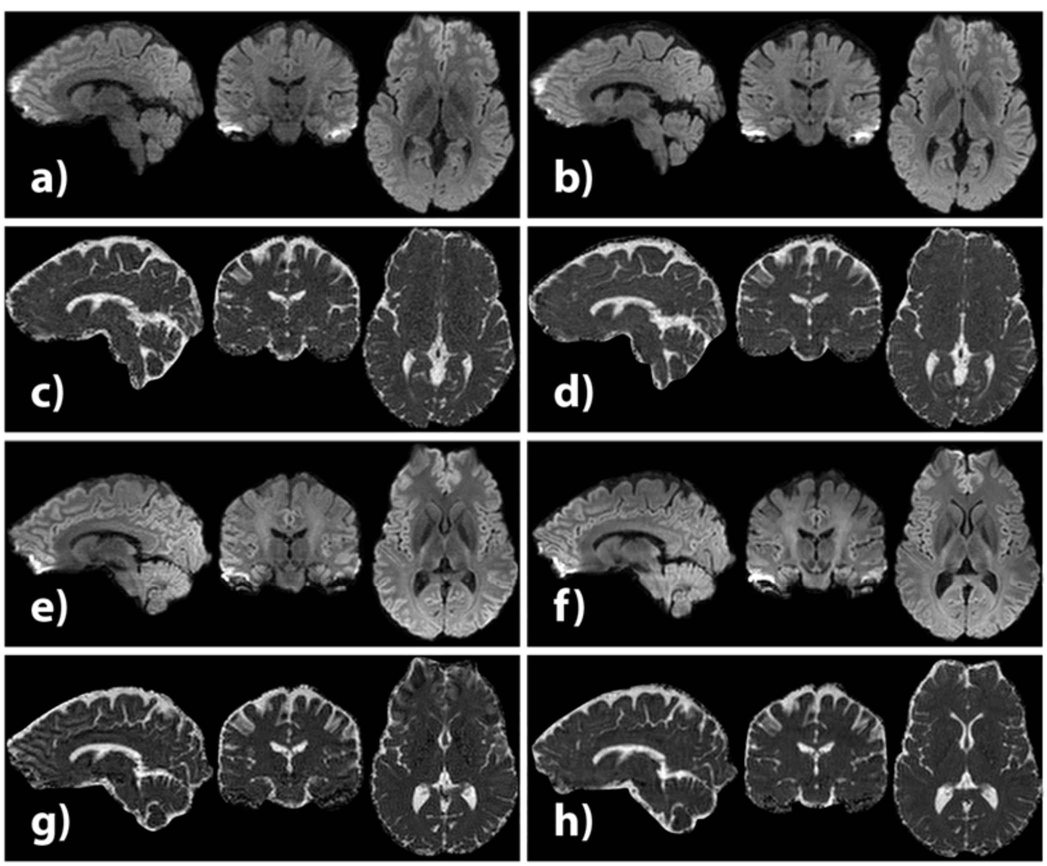

Figure 1 Reconstructed volumes from the four acquired datasets. 1.5 T isoDWI data is shown in a) for DW-ssEPI, b) DW-3D-MS-EPI. 1.5 T ADC maps are shown in c) for DW-ssEPI, and d) for DW-3D-MS-EPI. 3.0 T isoDWI data is shown in e) for DW-ssEPI, f) DW-3D-MS-EPI. 3.0 T ADC maps are shown in g) for DW-ssEPI, and h) for DW-3D-MS-EPI