

High-Resolution Diffusion-Weighted Imaging of the Orbits Using Readout-Segmented EPI

R. Bammer¹, K. W. Yeom¹, S. J. Holdsworth¹, and S. T. Skare¹

¹Radiology, Stanford University, Stanford, CA, United States

Introduction: Diffusion-weighted MRI (DWI) has demonstrated great value for the diagnostic workup of acute ischemic stroke and other abnormalities of the neurocranium, such as abscesses, CJD, *etc.* Similar diagnostic benefits could be anticipated from using DWI on orbital pathologies. High on the list of interesting pathologies are certainly periorbital dermoids/epidermois, fungal and pyogenic infections, and ischemic changes to the optic nerve. Moreover, DWI might be of value for evaluating cellular orbital and periorbital tumors (e.g. lymphomas, PNET, leukemic chloromas, and neuroblastoma mets) as well as other orbital tumors (e.g. optical gliomas, melanomas of the globe, mets, meningiomas, and lacrimal gland tumors). Sadly, anatomic structures within and adjacent to the orbits, such as the nasal cavities, perturb the magnetic field homogeneity, and lead to profound signal loss and distortions on conventional single-shot EPI-based DWI scans. This in turn often renders DWI of these regions meaningless. Recently, readout-segmented (RS)-EPI [1,2] has been suggested as a promising variant of EPI that can significantly reduce EPI-distortions and increase spatial resolution. In a prospectively designed study, a comparative evaluation was performed between standard accelerated (ASSET) EPI DWI and GRAPPA-accelerated RS-EPI DWI on a cohort of 35 pediatric patients at 3T. Incidentally, we found that diffusion-weighted RS-EPI of the orbits was of remarkable diagnostic quality. These findings will be reported here.

Methods: RS-EPI and EPI images were acquired on 35 pediatric patients using a 3T whole-body system (GE DVMR750) and an 8-channel head coil. The following parameters were used: FOV=20cm, Δz =4mm, TR=3s, one $b=0$ and three orthogonal diffusion-encoding directions with $b=1000$ s/mm² (xyz encoding). RS-EPI used a twice-refocused diffusion preparation with a matrix size = 192^2 , 7 segments (width=64, overlap factor=57%), acceleration factor $R=3$, NEX=3, and a scan time of 4:12min. GRAPPA and ghost calibration were performed on the multi-shot data, thus no separate calibration scan was acquired. Data were reconstructed as described elsewhere [2]. The routine ASSET-accelerated EPI sequence used was: matrix size= 128^2 , $R=2$, one $b=0$ and three diffusion directions @ $b=1000$ s/mm² (xyz encoding), and a scan time of 50s. RS-EPI DTI data were then acquired on three pediatric patients using a matrix of 192^2 with 7 64×192 blinds, FOV=20cm, $\Delta z=5$ mm, TR/TE=3000/76ms, $R=3$, NEX=3, 24 overscans, twice refocusing, 1 $b=0$, 7 diffusion directions @ $b=1000$ s/mm², scan time = 7:36min).

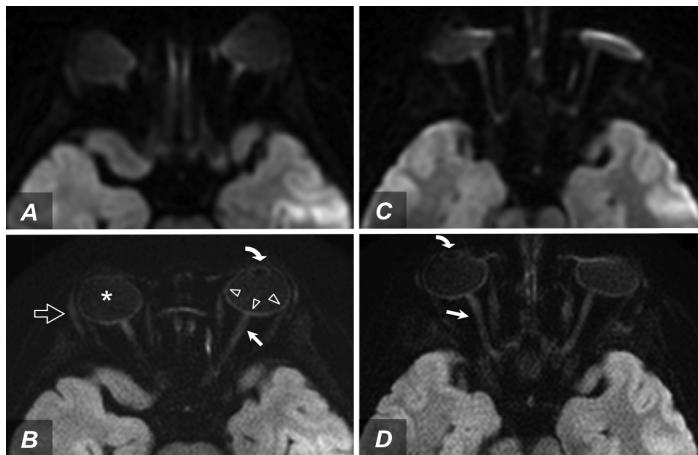


Fig. 1 – ASSET-accelerated (2x) diffusion weighted single-shot EPI (A, C) in two different subjects and their corresponding diffusion-weighted RS-EPI scans (B, D). Single-shot scans have a better SNR but orbital anatomy, such as the lens (curved arrows), optic nerve (arrows), sclera (arrow heads), vitreous humor (asterisk), and lacrimal glands (open arrow) are clearly better depicted on RS-EPI than on conventional ASSET-accelerated EPI scans.

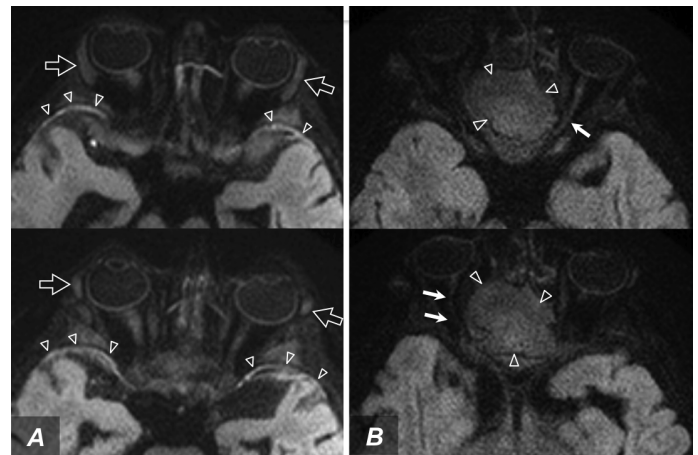


Fig. 2 – (A) Two diffusion-weighted RS-EPI sections in a patient suffering from a subdural empyema. The normal orbital anatomy is well delineated. Subdural pus collection can be seen as a rim-enhancing structure (open arrows). (B) Two diffusion-weighted RS-EPI sections in a patient suffering from a metastatic neuroblastoma (arrow heads). The mass effect of the lesion is displacing the optic nerves bilaterally (arrows). This scan has lower SNR because a neurovascular array coil was used.

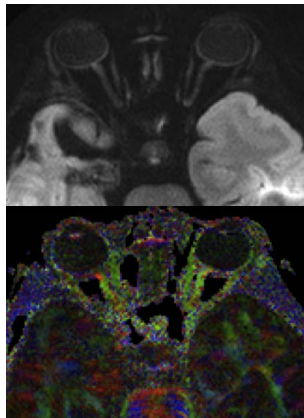


Fig. 3 – RS-EPI DTI scan (top – isoDWI) in a patient with right temporal lobe surgical changes related to prior ganglio glioma. The colorFA shows WM disruption at this level.

Results: Overall image quality was considerable better on RS-EPI than on ASSET EPI for all 35 cases. Although ASSET EPI scans had better SNR, higher spatial resolution as well as reduced blurring and distortions on RS-EPI scans helped to better reveal important anatomical details on exams of the orbits. In fact, orbital structures could be well delineated in all 35 RS-EPI scans. Figure 1 shows side-by-side comparisons between ASSET EPI (top) and RS-EPI (bottom) DWIs in two patients and highlights these findings. Figure 2A shows a patient with a small subdural empyema, which was equivocal on conventional ASSET EPI mostly because of poor resolution and profound signal loss in the area around the orbits. Figure 2B demonstrates bilateral optic nerve displacement in a patient with a metastatic neuroblastoma. Although the lesion could be seen also on ASSET EPI scans, the optic nerve displacement is better appreciated on the high-resolution RS-EPI scans. Lastly, Figure 3 shows isoDWI and colorFA maps from a DTI study in a patient suffering from a ganglio glioma. Due to the improved SNR from the use of more diffusion directions used for DTI, orbital details are even more apparent.

Discussion & Conclusion: Despite its obvious diagnostic benefits, reports on the use of DWI to diagnose orbital pathology have been relatively scarce. This can mostly be attributed to the mediocre image quality of regular DWI as can be seen in DWI studies of orbital inflammatory syndrome, orbital cellulitis, orbital abscesses, and orbital lymphoid lesions [3,4]. With optical neuritis being one of the early hallmarks of MS, DWI and DTI of the optic nerve has been also attempted [5,6]. To mitigate distortions, the authors used reduced FOV technique that leveraged on Zoom EPI. Another study that also looked at the optic nerve used a localized volume 3D single-shot STEAM-EPI approach [7]. Unfortunately, both techniques require rather complicated pulse preparation schemes. Alternatively, RF-refocused readout methods, such as PROPELLER or SPLICE, could potentially provide high quality images as well, but can suffer from prohibitively long scan times for clinically useful resolutions. In summary, we could demonstrate that RS-EPI can provide high-resolution DWI/DTI scans of orbital structures with very little distortions or signal loss. The longer scan time of RS-EPI over ASSET EPI is therefore well invested for the diagnostic work up of orbital abnormalities.

References: [1] Porter D. *ISMRM* 2008;3262; [2] Holdsworth S. *MRM* in press; [3] Kapur R. *AJNR* 30:64-70, 2009; [4] Sepahdari AR. *AJR* 193: W244-50; [5] Wheeler C. *MRM* 47:24-31, 2002; [6] Wheeler C. *MRM* 56:446-51, 2006; [7] Jeong EK. *MRM* 56:1173-81, 2006; **Acknowledgements:** This work was supported in part by the NIH (1R01 EB008706+S1, 5R01 EB002711, 1R01 EB006526, 1R21 EB006860, P41RR09784), Lucas Foundation, Oak Foundation, and the Swedish Research Council (K2007-53P-20322-01-4).