T1-weighted 3D SAP-EPI for use in pediatric imaging without general anesthesia

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Introduction: 3D Short-Axis readout Propeller EPI (SAP-EPI) was recently introduced as an alternative to the 3D T1-w Spoiled Gradient Echo (SPGR) technique commonly used for routine clinical studies [1]. In the presence of motion, the data consistency for encoding in 3D-SPGR is violated and gives rise to ghosting artifacts. In 3D SAP-EPI, the acquisition of 'bricks' (each consisting of an EPI blade that goes through the center of *k*-space) gives full brain coverage with a frame rate of ~3s (Fig. 1). Since each brick can be acquired at full FOV, the option of performing 3D motion and distortion correction between bricks is available. 3D SAP-EPI can have particular impact on pediatric imaging, since gross patient motion is difficult to avoid, and as a consequence, many patients are sedated or anesthetized. Whilst motion-compensated methods are available for T2w/FLAIR/DWI, a T1w method is not currently available and would be tremendously useful. In this abstract, we demonstrate the utility of 3D SAP-EPI applied to a moving pediatric patient.

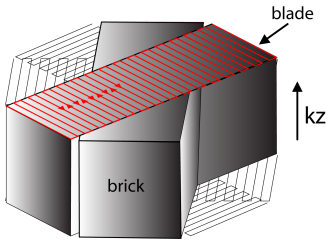

Figure 1. *Traversal of k-space in 3D SAP-EPI [1]. Bricks are swept by 180º in the x-y plane.*

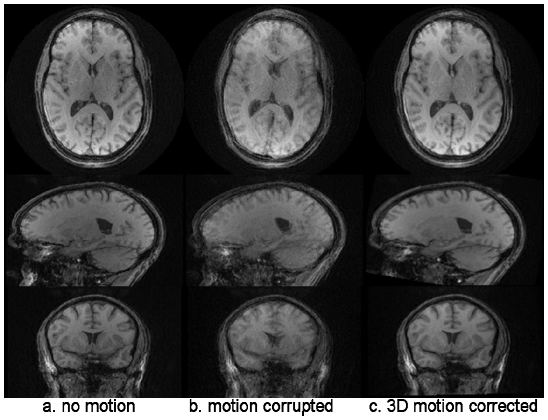

Figure 2. *Human brain scans from a controlled motion 3D SAP-EPI experiment.*

Methods: The 3D SAP-EPI *k*-space trajectory is shown in Fig. 1. Images were acquired on a 1.5T GE Excite (Waukesha, WI, USA: 50mT/m, 150mT/m/s) and an 8-channel head coil. First of all, to verify the utility of the sequence controlled motion experiments were performed on a healthy adult volunteer. 3D SAP-EPI data were acquired with the following scan parameters: FOV = 25 cm^3; a matrix size of 192 x 192 x 128; a voxel size of 1.3 x 1.3 x 2.0 mm^3, 8 blades of size 48(k_{RO}) x 192(k_{PE}) x 128(k_{PEz}), a GRAPPA-acceleration factor R = 3; NEX = 3; full Fourier; TR/TE/FA = 55ms/17ms/60º; a brick frame rate of 7 s. The scan time was 2:48mins (one would expect a ~3mins for a conventional 3D fast SPGR of a similar scan prescription). The volunteer was asked to move in the through- and in-plane direction and the scan was then repeated. Blades from the first and second dataset were then mixed. After obtaining IRB approval and consent from the patient's parents, 3D SAP-EPI were acquired on a 6yr old male with an optic glioma. Imaging parameters were: FOV = 24 x 24 x 12.8 cm^3; a matrix size of 192 x 192 x 64; and a voxel size of 1.3 x 1.3 x 2 mm^3. Four blades of size 64 x 192 x 64 were acquired with a 180º sweep (thus the edges of *k*-space were slightly undersampled); a brick frame rate of 3.5s; and a total scan time of 2:07mins. Three repetitions of each blade angle were made, in order to increase the chance of acquiring a brick without inter-brick motion. The brick with the best GRAPPA fit and Nyquist ghost parameters was used in the final reconstruction. For the post-processing stage, the blades underwent referenceless Nyquist-ghost correction [2], and GRAPPA weights [3-5] estimation and application on a per brick basis. 3D motion and distortion correction was then applied using the combination of all blades for estimating the ΔB0 field [6], followed by gridding of the blades together [7].

Results: Data obtained from the mixed-blade dataset is shown in Fig. 2. The 3D motion- and distortion-corrected image shown in Fig. 2c shows the successful correction of the motion-corrupted data in Fig. 2b. Patient data are shown in Fig. 3. The top row shows the routine T1-w fast SPGR image corrupted by motion. The rows below this show motion corrupted 3D SAP-EPI data which also have been corrected for motion, as well as combined motion and distortion correction. As indicated by the white arrow, a double image is evident in the posterior region of the motion corrected image, due to residual distortion. A marked improvement can be observed in this area for the combined 3D distortion and motion corrected images.

Discussion & Conclusion: In our experience, approximately 20% of pediatric patients must either be rescanned or sedated, due to severely motion corrupted images. 3D SAP-EPI has yielded images with high grey-white matter contrast and data can be acquired in a similar scan time than fast 3D SPGR. Together with its motion correction capability, 3D SAP-EPI could be a useful alternative to fast 2D and 3D SPGR routinely used for pediatric brain imaging. Fig. 3 is an example of a successfully corrected dataset acquired on a 6yr old moving patient. By collecting several bricks per blade angle, one can discard the corrupted bricks in the event of substantial intra-volume motion – and 3D motion correction can then be performed using the remaining bricks. While the brick frame rate of 3.5s cannot rule out intra-volume motion, the use of 4 blades and 3 repetitions of the acquisition enabled two of the bricks that were corrupted by inter-brick motion to be discarded. To increase the brick frame rate, future work would be to implement GRAPPA in the *z*-direction also, or to use a multi-slab approach. Deciding which bricks to discard in a non-supervised manner could be investigated with the use of *k*-space entropy or by the GRAPPA fit error. Here, the use of thin SAP-EPI blades combined with parallel imaging has allowed reduced distortions. Any residual distortion can be partly corrected for, using 3D distortion correction with the combination of all blades/bricks, without the penalty of extra calibration time. Future work would be to acquire images at higher field strengths to test the distortion correction method, and to put forward a good method for automatic brick elimination based on motion.

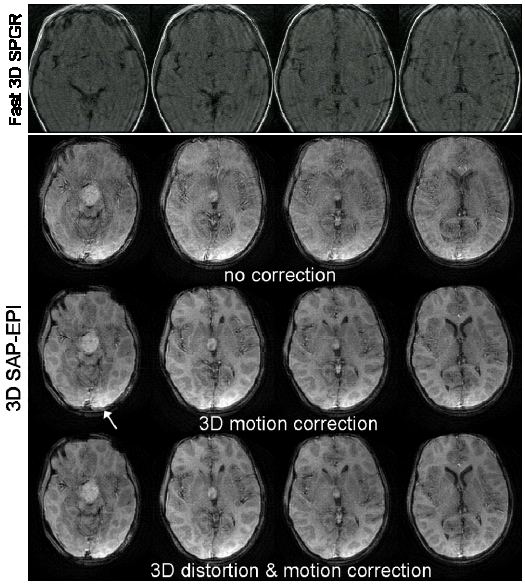

Figure 3. *Human brain scans acquired with fast 3D SPGR (top row) and 3D SAP-EPI (remaining rows). Parameters were: a matrix size of 192 x 192, blade width = 64, 4 blades selected from 3 repetitions, R = NEX = 3, TR/TE = 56 ms/17ms, a FOV = 24 x 24 x 12.8 cm^3, 64 partitions, a voxel size of 1.3 x 1.3 x 2 mm, and scan time = 2:07mins.*

References: [1] Holdsworth SJ et al. ISMRM 2008:1352. [2] Nordell A et al. ISMRM 2007:1833. [3] Griswold MA et al. MRM 2002;47:1202-1210. [4] Qu P et al. JMR 2005;174(1):60-67. [5] Skare S et al. MRM 2007;57:881–890. [6] Skare S et al. ISMRM 2008:417. [7] Jackson JI. IEEE Trans Med Imag 1991;10:473-478. **Acknowledgements:** This work was supported in part by the NIH (2R01EB002711, 1R01EB008706, 1R21EB006860), the Center of Advanced MR Technology at Stanford (P41RR09784), Lucas Foundation, and the Swedish Research Council (K2007-53P-20322-01-4). We would like to thank Bronwen Holdsworth, Tom Brosnan, Allan White, Serman Lim, Michael Beers, Alfred Barikdar, Young Chang, and Liz Ellison for their assistance.