High resolution distortion-free diffusion-tensor imaging of craniovertebral junction

M. Iima[1], A. Yamamoto[1], T. Okada[1], M. Kanagaki[1], D. L. Bihan[2,3], S. Kasahara[1], E. Morimoto[1], S. Nakajima[1], R. Sakamoto[1], T. M. Mehemed[1], and K. Togashi[1]

[1]Department of Diagnostic Imaging and Nuclear Medicine, Kyoto University Graduate School of Medicine, Kyoto, Japan, [2]Human Brain Research Center, Kyoto University Graduate School of Medicine, Kyoto, Japan, [3]Neurospin, CEA-Saclay Center, Gif-sur-Yvette, France

Background and Purpose

Diffusion-weighted imaging (DWI) using single-shot echo-planar imaging (SS-EPI) has been used widely for clinical applications, especially in the acute brain ischemia. However this method suffers from a high sensitivity to susceptibility and distortion artifacts, low signal-to-noise ratio (SNR) and limited spatial resolution. Multi-shot EPI (MS-EPI) has also been proposed as an improvement over SS-EPI, but correction of movement between multiple shots remains problematic. Read-out segmented EPI (RS-EPI) combined with GRAPPA parallel acquisition and 2D-navigator-based reacquisition has been recently introduced to obtain distortion-free images with high resolution and reduced blurring from T2* signal decay compared to SS-EPI [1,2], of particular interest for diffusion-weighted (DWI) imaging and DTI. We have evaluated the potential of this new distortion-free approach compared to SS-EPI to the examination of the craniovertebral junction(CVJ) which poses significant challenges to clinicians due to its complicated anatomic structure.

Materials and Methods

RS-EPI (work in progress, provided by Siemens) and SS-EPI DTI images were acquired from 6 healthy volunteers using a 3T MR scanner (MAGNETOM Trio, A Tim System, Siemens Healthcare, Erlangen, Germany) with a 32-channel head coil. For RS-EPI DTI, the following parameters were used: matrix size=194 x 194; FOV=160mm; voxel size=0.8mm x 0.8mm x 3.0mm; slices=20; readout segments=15; GRAPPA R=2; TR=5000ms; TE1/TE2=64ms/102ms; echo spacing=0.32ms. scan time: 10.47mins. SS-EPI DTI sequence was used as comparison to RS-EPI: matrix size=128 x128, FOV=220mm, GRAPPA R=2,voxel size=1.7mm x 1.7mm x 3.0mm, and a scan time of 1.05 min. For both approaches the DTI protocol consisted in 1 acquisition at b=0 and 6 directions at b=1000s/mm^2 ; Diffusion tensor calculation and image analysis were performed using DTI studio software version 3.0 (H.Jiang, S. Mori; Department of Radiology, Johns Hopkins University). Trace, color map and fractional anisotropy images were evaluated by 2 independent readers. for the following criteria: resolution, distortion, image noise, resolution using a semi-quantitative scale [0,5].

Results

Typical images for SS-EPI and RS-EPI are shown in Fig.1. White matter tracts could be better delineated in the brainstem and distortion artifacts around the mastoids were clearly reduced with the RS-EPI sequence. More fine structures were also visible in the spine and cerebellum. Overall, the average scores calculated from the data of the 6 volunteers (Fig.2) clearly shows that RS-EPI ranked higher than SS-EPI for the 4 criteria, especially distortion level.

Discussion and Conclusion

It is considered difficult to make a precise assessment of CVJ using the standard SS-EPI method, because of unavoidable distortion and susceptibility artifact. However, the images obtained in all sections with the RS-EPI DTI method were free of distortion and allowed a better delineation of CVJ internal structure of CVJ because of the higher spatial resolution. The image noise was also better, but the acquisition time was relatively long compared to SS-EPI. Indeed, a current limitation of RS-EPI is its relatively long acquisition time which makes it sensitive to patient motion [3]. Further advances will be necessary to reduce scan time and make RS-EPI compatible with even clinically acceptable scan times. With those advances RS-EPI appears as an attractive alternative to SS-EPI DTI for evaluating CVJ lesions, such as demyelinating and neurodegenerative diseases, brain and skull base tumors, or inflammation.

References

[1] Porter et al. MRM 62:468-75(2009)

[2] Heidemann et al. MRM 64:9-14(2010)

[3] Mukherjee et al. AJNR 29:843-52(2008)

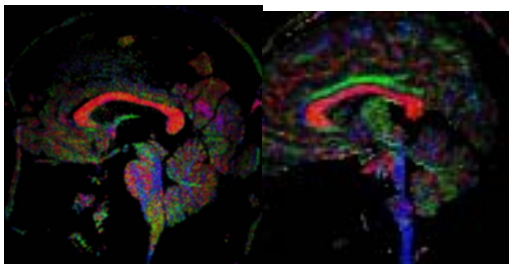

Fig.1a Sagittal DTI color map of CVJ (left: RS-EPI; right: SS-EPI). The lateral cerebrospinal fasciculi are clearly identified as clear blue line penetrating the pons and the anterior medulla on the RS-EPI image.

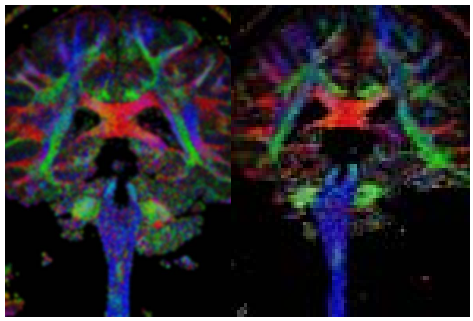

Fig.1b Coronal DTI color map of CVJ (left: RS-EPI; right: SS-EPI). The amount of distortion is clearly larger for the SS-EPI image. The pyramidal decussation is seen as green line at the medulla level on both RS and SS-EPI.

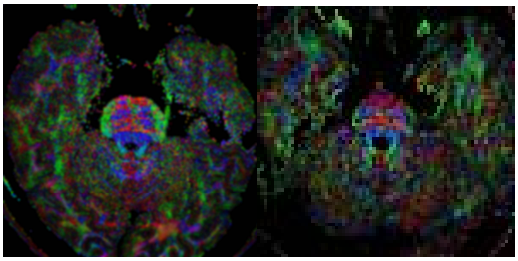

Fig.1c. Axial DTI color map of CVJ (left: RS-EPI; right: SS-EPI). Higher SNR in the RS-EPI image allows delineation of fine structures (transverse fiber of the pons) which could not be identified with the SS-EPI sequence.

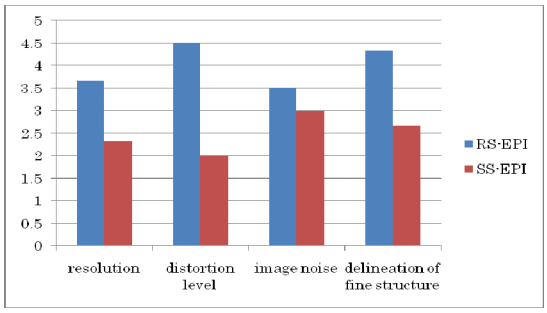

Fig.2

The graph shows comparison between SS-EPI and RS-EPI with 4 categories.