3D TWIRL: a novel k-space trajectory for imaging of fast relaxing nuclei

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Introduction

Magnetic Resonance Imaging of fast relaxing nuclei such as 23Na, 17O, and 31P, requires the use of sequences with ultra-short echo times and high signal-to-noise (SNR) efficiency. To meet these conditions, a number of pulse sequences have been developed in the past. Among these, the Twisted Projection Imaging (TPI) technique has been shown to be the most favourable[1]. TPI combines the ultra-short echo time capability of projection imaging (PI) with a constant sampling density of k-space. This is achieved by twisting k-space trajectories such that the sample density is preserved (Fig.1). In this work we present a novel centric 3D sequence called 3DTWIRL. Trajectories of this new sequence share the same mathematical framework of TPI [2]. This method is requires only the calculation of the innermost TPI cone. The k-space is then sampled by rotating this cone by the appropriate polar and azimuthal angles (Fig.2).

Methods

TPI and 3DTWIRL sequences were implemented on a 9.4T human, whole-body scanner (Siemens Medical Solutions, Erlangen, Germany). All experiments were carried out with a 16-rung birdcage coil (Affinity Imaging GmbH, Jülich, Germany) tuned at the sodium frequency. Phantom measurements were performed on a cylinder (outer height 11.5 cm and outer diameter 20 cm) comprising six compartments filled with 2% and 6% w/v agarose gels containing 30, 100, and 150mmol/l of sodium. In vivo measurements of the brain of an informed healthy volunteer were carried out under a clinical trial protocol (clinical trial DE/0000043490). Except for the k-space distribution of trajectories, both TPI and 3DTWIRL measurements of the phantoms were carried out using the same protocol: FOV=240 mm, resolution = 3 mm, TR/TE = 50/0.27 ms, flip angle = 50º, readout length = 10 ms, p=0.65, number of projections = 3300, total acquisition time = 161 s. The protocol for in vivo measurements was: FOV=220 mm, resolution = 2.5 mm, TR/TE = 120/0.4 ms, flip angle = 90º, readout length = 18 ms, p=0.45, projections=5500, total acquisition time=660 s. A non uniform FFT algorithm was used for image reconstruction[3].

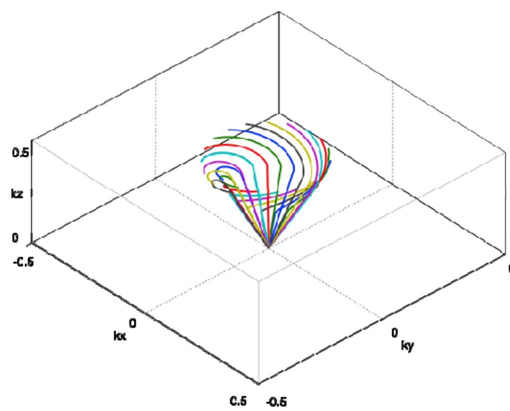

Figure 1- TPI k-space trajectories

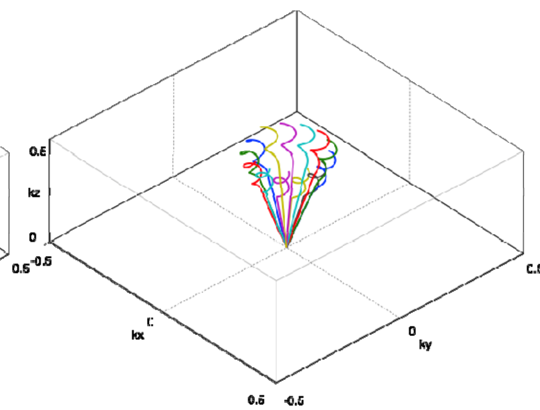

Figure 2 3DTWIRL trajectories

Results

Figure 3 shows transversal images phantom acquired with TPI and 3DTWIRL. The quality of 3DTWIRL images is generally better than of TPI, in particular at the interfaces between air and gels, where the susceptibility gradients are changing very rapidly. Figure 4 shows images obtained in vivo. These images show similar characteristics. However, a better delineation of the posterior limit of the cerebellum was obtained with 3DTWIRL.

Discussion and Conclusions

The initial results that we present in this work indicate that the 3DTWIRL sequence has some advantages with respect to the original TPI sequence; specifically, easy implementation and reduced sensitivity to off-resonances. The main disadvantage of the new method is represented by its limited choice of p.

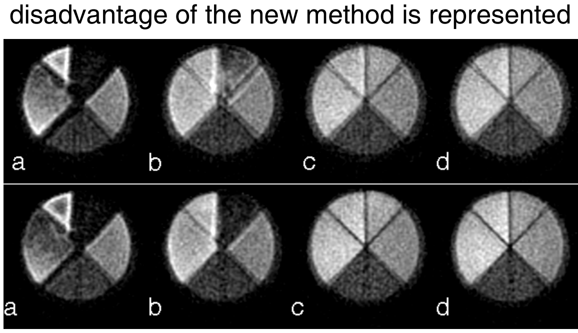

Figure 3 Phantom measurement. Top row TPI images. Bottom row 3DTWIRL

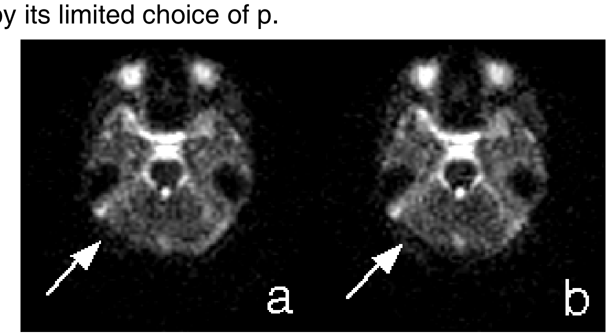

Figure 4 in vivo measurements. a) TPI ;b) 3DTWIRL

References

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