Reduced-FOV Lumbar Spine $T_{1\rho}$ MR Imaging Using High-Low EP-2DRF Excitation Pulse

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Introduction: Quantitative $T_{1\rho}$ mapping has been used to assess lumbar disc degeneration by detecting the proteoglycan loss in the discs [1, 2]. However, $T_{1\rho}$ imaging is time consuming in particular for high spatial resolution images obtained with high spin-lock frequency (FSL) though fast acquisition techniques could be employed. In addition, spine $T_{1\rho}$ imaging is vulnerable to the artifact induced by respiration and fat-water chemical shift. Reduced field of view (rFOV) in phase encoding (PE) direction helps to shorten the acquisition time, while preserving the signal to noise ratio (SNR) and resolution [3, 4]. The respiration artifact can be eliminated as no spin in chest or abdomen is excited. In this study we propose a 2DRF pulse with novel high-low echo planner (EP) excitation trajectory for rFOV $T_{1\rho}$ imaging in lumbar spine to shorten scan time and minimize respiration artifacts.

Method: The 2DRF pulse was designed with high-low EP excitation K-space trajectory as shown in Fig.1a. Two gradients in both PE direction and slice selection (SS) direction were applied simultaneously with RF pulse transmission to realize the desired excitation trajectory (Fig.1b). Nineteen Sinc type sub-pulses (TBW=8) with Sinc-Hanning envelope were used to generate smooth slice profiles. Gradient strength slew rate were maximized within the hardware restriction and patient safety regulations. The areas of blip gradients and trapezoid gradients were set based on the desired excitation lobe width and slice thickness. Total duration of this 2DRF pulse was 21.6ms. In vivo MR experiment was conducted on a 3T clinical scanner (Achieva, Philips, Best, The Netherlands). A 15-channel spine coil was used as the signal receiver and the body coil was used for excitation. Pencil beam volume shimming was employed to compensate B_0 inhomogeneity. For $T_{1\rho}$ preparation, a rotary echo spin-lock pulse was implemented before excitation pulse. FSL was set as 500 Hz and the TSLs of 1, 20, 40, 60 and 80ms were used. TFE sequence was used for acquisition with TE/TR=2.4/5000ms, TFE factor=12 and voxel size=1.05×0.95×4mm^3. A slice located at the mid-sagittal section of lumbar spine was scanned. Full FOV obtained by the normal RF pulse and rFOV obtained by the proposed 2DRF pulse were 200×200mm^2 and 100×200mm^2 respectively. $T_{1\rho}$ maps were generated by fitting the $T_{1\rho}$–weighted images to an exponential decay function using a homemade MATLAB (The MathWoks, Natick, MA) program. Coefficient of definition (R^2) maps were also generated.

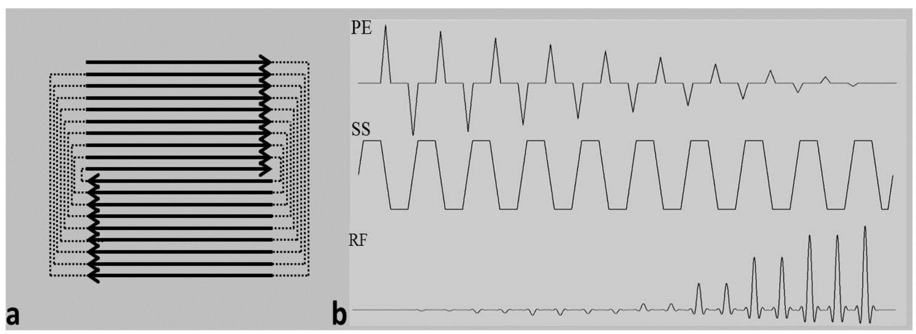

Fig.1. 2DRF pulse excitation trajectory in K-space (**a**) and its pulse profile (**b**).

Results: The scan time of rFOV $T_1\rho$ scan was shortened to half by using the 2DRF pulse. Fig.2 depicts the results of $T_1\rho$ mapping of lumbar discs with and without 2DRF excitation overlaid on baseline images. rFOV $T_{1\rho}$ map (Fig.2a) is consistent with full FOV $T_{1\rho}$ map shown in Fig. 2b with less noise and artifact. No that some pixels in nucleus pulposus of L3/L4 and L4/L5 discs are excluded due to the low R^2 in the rFOV $T_{1\rho}$ map.

Discussion: In this study, high-resolution rFOV $T_{1\rho}$ imaging was achieved with less motion artifact and half scan time by using a high-low EP excitation trajectory 2DRF pulse. Good consistency with full FOV $T_1\rho$ imaging was observed. The scan time could be further reduced to less than one third without losing SNR or resolution by adjusting the 2DRF setting. The high-low EP 2DRF excites central K-space lines last, which ensures a long acquisition window required in TFE sequence. Furthermore, PE blip gradient area decreases with the increase of the sub-pulse amplitude which makes RF transmission at central K-space less affected by eddy current. Compared to traditional EP 2DRF, the rewinding gradient in PE direction is also removed, which may reduce the eddy current during acquisition and benefit the image quality. Simulation study has shown that this 2DRF pulse is less susceptible to gradient-RF delay artifact due to its special excitation profile. This 2DRF has potentials to be used for high-resolution spine $T_{1\rho}$ imaging in routine clinical scan. Grant support: Hong Kong RGC grant SEG_CUHK02, CUHK418811, China NSFC grant 81201076.

References: [1]W. Johannessen, *et al.*, *Spine,* vol. 31, pp. 1253-1257, May 15 2006.[2]Y. X. Wang, *et al.*, *Eur Radiol,* vol. 23, pp. 228-34, Jan 2013. [3]J. Yuan,*et al.*, *Journal of Magnetic Resonance Imaging,* vol. 32, pp. 242-248, 2010. [4] S. Rieseberg, *et al.*, *Magn Reson Med,* vol. 47, pp. 1186-93, Jun 2002.

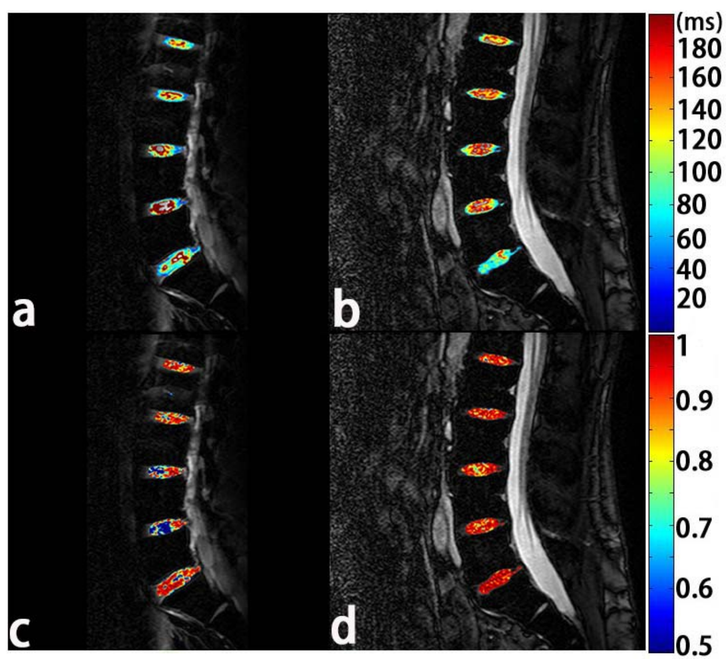

Fig.2. $T_1\rho$ maps and the corresponding R^2 maps with (**a, c**) and without (**b, d**) 2DRF excitation. **a, b** are $T_1\rho$ maps and **c, d** are R^2 maps. Color coded maps are overlaid on T_2w baseline.