Noninvasive Evaluation of Renal Oxygen Extraction Fraction via Reduced-FOV Asymmetric Spin Echo Approach

Z. Xiao[1], A. Shankaranarayan[2], E. U. Saritas[3], S. Hao[1], and C. Guang[1]

[1]Global Applied Science Laboratory, GE Healthcare, Beijing, Beijing, China, People's Republic of, [2]Global Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States, [3]Department of Bioengineering, University of California, Berkeley, CA, United States

Introduction

Renal oxygen consumption is quite high in relation to the weight of the organ, and this high oxygen consumption is the result of a small oxygen extraction, and a large renal blood flow. Kidney medulla is highly sensitive to variations in blood flow. Consequently, renal ischemia is associated with many common renal injuries, including ureteral obstruction, renal artery stenosis, and contrast material–induced nephropathy. But current tools are limited for assessing deterioration of renal function. So developing a noninvasive technique is of importance to provide regional measurements of relative changes in blood oxygen and its extraction fraction. The BOLD MRI method can measure deoxyhemoglobin and can therefore indirectly estimate renal oxygen content [1], while it has no information about oxygen extraction. The asymmetric spin echo (ASE) technique [2] has been widely used to probe signal alterations induced by susceptibility effects. More recently, a single shot echo planar imaging (EPI) approach was reported by H. An and W. Lin [3] for obtaining quantitative measures of cerebral oxygen extraction. In this study, we developed a respiratory triggered, small FOV ASE EPI sequence for measuring the OEF in the kidney, and performed feasibility study on volunteers. We show that this sequence can dynamically monitor renal function and can be used to study and treat renal disease.

Material and method

The asymmetric spin echo (ASE) single shot echo planar imaging (EPI) sequence was first proposed by H. An and W. Lin [5] for obtaining quantitative measures of cerebral oxygen extraction. It is a variation of a single-shot SE EPI sequence that allows variable time intervals between the $\pi/2$ and π while keeping the TE constant. The acquired images will have different susceptibility weighting. In order to match Yablonskiy and Haacke's theoretical model [4], weak diffusion gradients are applied to suppress intravascular flow signal. Subsequently, R2' and Oxygen Extraction Fraction (OEF) were estimated from the acquired images using the two-compartment model[4].

In this study, for higher resolution and reduced artifact of renal diffusion imaging, we use the reduced-FOV method in [5] with 2D-RF excitation to reduce the FOV in the PE direction. This shortens the echo train and reduces distortion. Respiratory triggering was used to make the sequence motion insensitive. The sequence diagram is shown in figure 1.

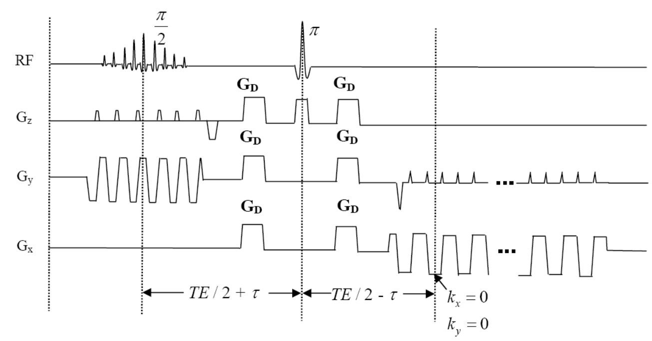

Figure 1. Sequence diagram of the 2D-RF ASE EPI pulse sequence. G_D represents diffusion gradients. Two identical diffusion gradients were placed symmetrically right before and after the π pulse in all three orthogonal directions. τ is the time interval between the center of π pulse and TE/2.

Five healthy volunteer's axial renal images after informed consent were acquired on a clinical GE Signa HDxt 3.0T scanner equipped with the standard 8 channel Torso array coil (GE Medical Systems, Milwaukee, WI, USA). Scan parameters with respiratory triggered acquisition were as follows: TR/TE = 2500/63ms, b = 40 s/mm^2, FOV = 240×60mm^2, receiver bandwidth = 160 kHz, image size = 64×64, number of excitations (NEX) = 1, acquisition time = 1min. The 2D-RF ASE EPI sequence was repeated 19 times to acquire19 images for each slice position, of which 19 asymmetric spin echoes were acquired with τ (ms) corresponding to {13,14,15,15.5,16,16.5,17,18,19,20,21,22,23,24,25, 26,27,28,29} .

Results and Discussion

Figure. 2 shows representative ASE EPI anatomic image and estimation of R2' and OEF maps. As anticipated, Cortex has lower OEF than medulla. Results are in good agreement with the physiological anticipations. Although these results need to be validated in a larger series, 2D-RF ASE EPI may become an important tool for monitoring renal oxygenation in various clinical scenarios which could potentially provide insights into early derangements of renal physiology and function.

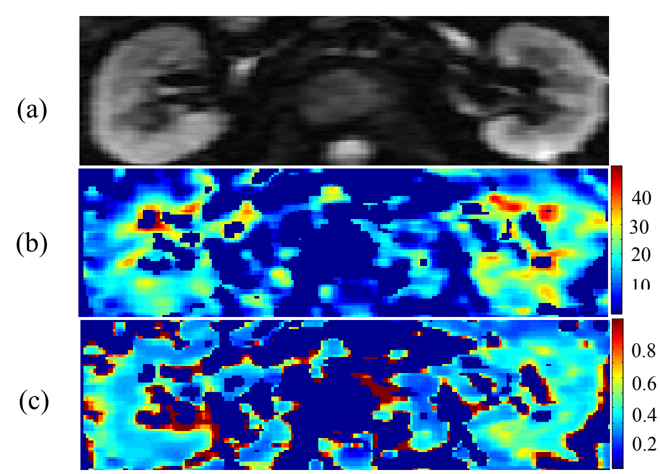

Figure 2. (a) Axial 2D-RF ASE EPI image and corresponding calculated R2' (b) and OEF (c) maps obtained from images acquired with b = 40s/mm^2.

References

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