Dual Navigator Gated FAIR True-FISP Pulse Sequence for Renal Perfusion Imaging

R. Song[1], R. B. Loeffler[1], and C. M. Hillenbrand[1]

[1]Radiological Sciences, St. Jude Children's Research Hospital, Memphis, TN, United States

Introduction:

The accurate quantification of the renal perfusion is great interest in clinical application, as the perfusion rate could be changed in some diseases such as atherosclerosis, hypertension, diabetes, and autoimmune disease. Arterial Spin Labeling (ASL) can be applied to measure the renal perfusion rate without gadolinium contrast agents, which could be a notable concern for the patients with impaired renal function and children. Although ASL has mainly been applied to assess tissue perfusion in the brain, there have been increased interest in other organs such as kidney over past several years [1,2]. Compared to the brain, the kidney is affected by the respiratory motion, and thus the quantification accuracy could be severely degraded. The error could be produced by the pixel-mismatch between the control and tagging images due to the motion. Furthermore, the imaging slice could move to the edge or even outside of the tagged region if the tagged slice is not thick enough, which could lead to the fact that some spins are not fully inverted (tagged) or even not inverted (tagged) at all. FAIR (flow-sensitive alternating inversion recovery) tagging [3] must be used to measure the renal perfusion rate as the blood could flow in the imaging slice in any direction. Based on a study performed in this laboratory, the maximum displacements along superior/inferior, medial/lateral, and anterior/posterior due to the respiratory motion could be up to 11, 4 and 2mm, respectively. If an axial slice is desired, the tagging slice should be at least approximately 35mm for an imaging slice thickness of 8mm. However, such a big tagging slice could results in the significant reduction in the perfusion signal [4,5].

Although healthy subjects may be able to tolerate multiple long breath-held scans, the same may not be true for those who cannot hold their breaths for prolonged periods, including young children. It would therefore be desirable to avoid breath-held scans by using a respiratory-gating technique. In this work, a dual navigator gated FAIR TrueFISP method is presented. With this technique, both inversion and imaging slices are gated and followed to the same reference position and then the "non-tagging" artifact as in perfusion imaging mentioned above could be eliminated.

Method:

The dual navigator gated FAIR TrueFISP sequence is illustrated in Fig. 1. The first navigator, NAV1, gates the inversion (tagging) pulse while the second navigator, NAV2, gates the imaging sequence (TrueFISP). For NAV1, a regular gate and follow respiratory control was applied. If a position was achieved within acceptance window, the inversion pulse was accepted and the slice was shifted to a reference position which was obtained by the first successful NAV1. If the inversion passed with NAV1, NAV2 would check the imaging slice position with a new acceptance window which is α times of that of NAV1 (α = 2 in this study). If the position fell in the acceptance window, the imaging slice was shifted to the reference position set by NAV1. This ensures that the imaging slice is appropriately positioned with the inversion slice, and the "non-tagging" artifact in the perfusion images could be effectively eliminated.

The technique was combined with FAIR TrueFISP sequence. An adiabatic RF FOCI (frequency offset corrected inversion) pulse was utilized to achieve a better slice profile of the slice selective inversion [6]. A modification of Q2TIPS (quantitative imaging of perfusion using a single subtraction (QUIPSS II) with thin-slice TI_1 periodic saturation) [7] was applied. The periodic train of thin-slice saturation pulses are *alternatively* applied to each side of the imaging slice, that allows for elimination of the effects of variable transit delay on both side of the imaging slice for accurate quantification of the renal perfusion rate.

The technique was implemented on a 1.5T clinical MR scanner (Magnetom Avanto, Siemens, Erlangen, Germany). One axial slice of through the kidney was acquired with FOV of 35cm. Other parameters are as follows: TE = 1.88ms, acquisition bandwidth = 600Hz/Pixel, flip angle = 70°, matrix = 192 x 184, imaging/tagging slice thickness = 8/20mm, No. of measurement = 40 (20 image pairs), TR = 4s, TI_2 =1.2s, TI_1 = 0.7s, and TI_{1S} = 0.95s, acceptance window for NAV1 = ±3mm, tracking factor =0.7. A acceptance rate of approximately 60% was achieved during normal breathing. Four preparation scans were applied to reach the steady state, and a centric-reordered k-space acquisition scheme was applied. To minimize artifacts from the transient signal oscillations in TrueFISP, a variable flip angles preparation of 20 rf pulses was used [8]. The excitation frequency was carefully chosen to avoid the banding artifacts within the kidney by a few pre-scans before the perfusion measurement. The M_0 image was acquired by turning off the inversion and saturation pulses. Quantitative perfusion maps were computed on a pixel-by-pixel basis from the magnetization ΔM using tissue/blood partition coefficient λ of 0.8, T_1 of 1.2s for the kidney cortex, and inversion efficiency of 0.95.

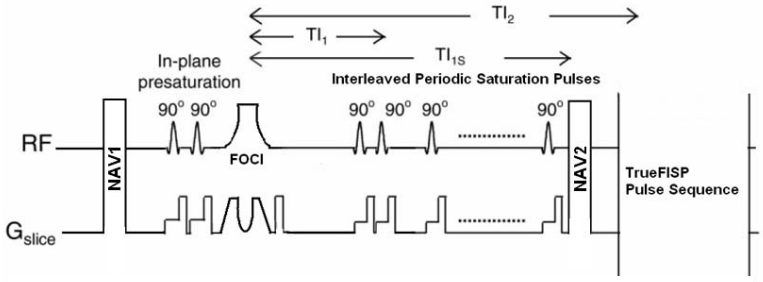

Fig. 1. dual navigator gated FAIR TrueFISP sequence. NAV1 gates the inversion (tagging) pulse while NAV2 gates the imaging sequence (TrueFISP). The same reference position is used for both NAV1 and NAV2.

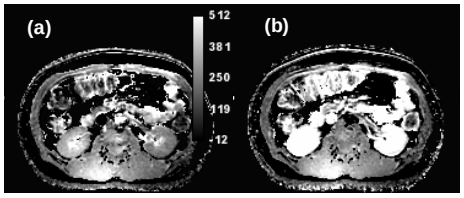

Fig. 2. Axial perfusion rate maps obtained with (a) and without (b) the dual navigator gated technique in the same scale.

Results and Discussion:

Fig. 2 shows axial renal perfusion rate maps obtained with (2a) and without (2b) dual navigator gated FAIR TrueFISP methods in the same scale as indicated for a healthy volunteer. It can be seen from the images that the renal perfusion rates achieved without gating is much higher than that obtained with gating. With the dual navigator gated technique, the measured cortex mean perfusion rate is 298 ml/100g/min, which is in agreement with other studies [1,2]. However, without the navigator gating the value is approximately doubled to 583 ml/100g/min due to the "non-tagging" effects. It shows that the technique is effective to prevent the imaging slice from moving to the edge of or out of the tagged slice, and significantly diminish the "non-tagging" artifact in perfusion images.

At the late stage of this initial study, it has been realized that NAV1 is not necessary for the control acquisition as the inversion is non-selective although the NAV2 is still required. The acceptance rate could be increased by approximately 20% if the NAV1 is removed from the control acquisition. The sequence has been implemented accordingly and will be tested on volunteers.

In conclusion, a dual navigator gated FAIR True FISP pulse sequence has been developed and implemented. Because both inversion and imaging slices are gated to the same reference position, it could prevent the imaging slice from moving to the edge of or out of the inversion slice. Error caused by not or not fully tagged spins could be eliminated, and pixel-mismatch between the tagging and control images could also be improved.

References:

1. Robert et al, Radilogy 1995; 196:281-286. 2.Boss et al, Fortschr Rontgenstr 2005;12:1625-1630. 3. Kim te alMRM, 1995:37:293-301; Kwong, MRM 1995; 34:878-887.4. Yongbi et al, MRM, 1999;42:1098-1105 4. Holm et al, MRI, 2006; 24:1229-1240. 6. Payne et al MRM 1997;38(5):828-833. 7. Luh et al MRM 1999;41(6):1246-125. 8. Vibhas et al MRM 2003;49(1):151-157.