

Renal Perfusion Imaging with Two-Dimensional Navigator Gated Arterial Spin Labeling

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Introduction: Arterial spin labeling (ASL) is a non-invasive technique that uses water in the blood as an endogenous tracer to measure perfusion (1). A major challenge in performing ASL in the kidneys is abdominal motion caused by respiration. Being a subtraction based technique, ASL is inherently prone to motion induced errors and artifacts. Breath-holding is a common strategy to minimize abdominal motion, however, can be difficult to tolerate for patients. Moreover, a single breath-hold often does not allow enough time for sufficient signal averaging, especially in patients. In this study, we implemented a novel two-dimensional (2D) navigator with FAIR-TrueFISP (2) to measure renal perfusion in a free-breathing acquisition. An automated post-processing algorithm was developed for selective averaging based on the navigator images. The purpose was to test the feasibility of a 2D navigator-gated retrospective approach for minimizing respiratory motion for ASL renal perfusion imaging.

Methods: The 2D navigator was applied immediately after the True-FISP acquisition, illustrated in Figure 1. The aim was to acquire a low resolution 2D image to estimate respiratory motion based on the diaphragm position throughout the respiration cycle. The 2D navigator comprised a 2D FLASH sequence with the following parameters: flip angle = 5°, TR/TE = 2.2/1.2 ms, field of view = 400 mm, image matrix size = 96 x 96, receiver bandwidth = 1000 Hz/Pixel, 5/8 partial Fourier encoding along the phase encoding direction, parallel acceleration = 2 with 10 integrated reference lines for calibrating coil sensitivities. The navigator was positioned over the right hemi-diaphragm in either sagittal or coronal plane. The total duration for the 2D navigator was 75 ms. The True-FISP implementation and the perfusion quantification were described previously (2). An inversion time (TI) of 1.5 sec was used for healthy volunteers and a TI = 2 sec was used in patients. A single imaging slice was positioned in an oblique coronal orientation to match the longitudinal axis of both kidneys with the following parameters: flip angle = 60°, echo spacing / TE = 4 / 2.02 ms, TR = 3 sec, receiver bandwidth = 651 Hz/Pixel, image matrix = 128 x 128, field of view = 360 – 400 mm, slice thickness = 8 mm. A linear ramp of radio frequency pulses was used as the catalyzation sequence. Centric ordered phase encoding was used to maximize perfusion sensitivity.

Eleven healthy volunteers and five patients with chronic kidney disease were recruited for the study under the supervision of our institutional revision board. All imaging was performed on a Siemens 3T scanner (MAGNETOM Verio, Siemens Healthcare, Erlangen, Germany). The body coil was used as the transmitter, and the combination of spine and body array coils was used as the receiver. The subjects were instructed to relax and breathe quietly during the free-breathing scans. A total of 50 control/label pairs were acquired in each free-breathing scan with a total scan time of 5 minutes. An 18 sec breath-hold scan was performed at expiration with 3 control/label pairs. Data reconstruction was performed offline.

Results: The FAIR True-FISP sequence with the 2D navigator produced renal perfusion images of excellent quality in volunteers, and greatly improved quality in patients compared to breath-hold. Examples of the ASL maps are illustrated in Figure 2 and 3. The renal cortex and medulla can be clearly depicted in images processed with the retrospective selective averaging. In healthy volunteers, the perfusion rate in the renal cortex ranged from 230 to 311 ml/100g/min with the coronal navigator, 226 to 326 ml/100g/min with the sagittal navigator and 226 to 374 ml/100g/min for the breath-hold scans. These values were in good agreement with previous studies (2,3,4). The mean renal blood flow values in our patient study (n = 5) were 155 ml/100g/min for the renal cortex. Overall, the navigator-gated images demonstrated an average of 3-fold increase in SNR compared to the breath-hold images in healthy volunteers.

Conclusion: The presented 2D navigator gated ASL imaging method can quantify renal perfusion without external contrast agent and compromising patient comfort. It provides a potential clinical solution for patients with impaired renal function or those who may not tolerate breath-holding. The 2D navigation scheme used here may be applied to other abdominal MRI techniques adversely affected by respiratory motion.

References: 1) Calamante et al. J Cereb Blood Flow Metab, 1999. 2) Martirosian et. al. Magn Reson Med, 2004. 3) Fenchel et al. Radiology, 2006. 4) Roberts et al. Radiology, 1995.

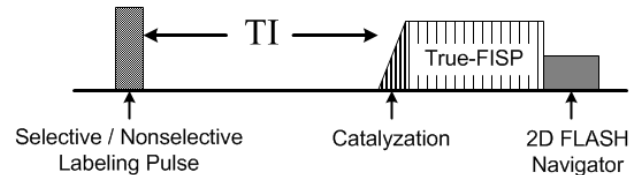


Figure 1. Pulse diagram of the FAIR-TrueFISP sequence with 2D navigator.

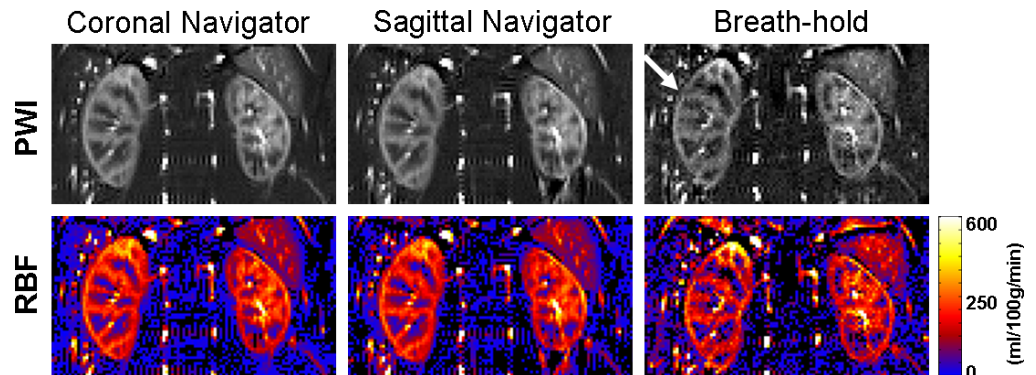


Figure 2. An example of perfusion weighted image (PWI) and renal blood flow map (RBF) of a healthy volunteer.

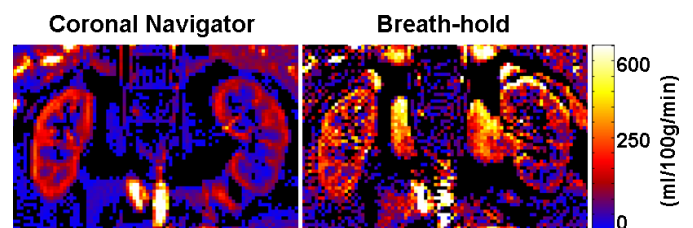


Figure 3. Comparison of breath-hold and 2D navigator-gated ASL scans in a CKD stage 3 patient.